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DEPARTMENT OF DEFENSE HANDBOOK

ELECTRONIC PARTS, MATERIALS, AND PROCESSES FOR SPACE AND LAUNCH VEHICLES

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AMSC N/A **FSC 1820**

FOREWORD

1. This military handbook is approved for use by all Departments and Agencies of the Department of Defense (DoD).
2. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.
3. This Handbook was developed to aid Designers and Parts, Materials, and Processes (PMP) specialists with the design, development, and fabrication of electronic systems required to have long life and/or high reliability while operating under extreme conditions/ environments of Space and Launch Vehicles. The term "electronic" is used in a broad sense in this handbook and includes electrical, electromechanical, electromagnetic, and electro-optical parts associated with electronic assemblies such as computers, communication equipment, electrical power, guidance, instrumentation, and space vehicles.
4. Analysis of space mission failures and on orbit anomalies by the USAF Space Systems Division revealed that the non-availability of reliable space quality electronic piece parts was a serious deterrent to achieving space mission success. In responding to this problem, the USAF Space Systems Division had initiated a program, documented in MIL-STD-1546, with the objective of establishing a "space quality baseline" of parts, materials, and processes that have a proven track record of high reliability. In addition, a standard was developed (MIL-STD-1547) to document the technical requirements for parts, materials, and processes for space and launch vehicles.
5. The objective of MIL-STD-1547 as parts, materials, and processes control program standard was to ensure a technical baseline in the selection, application, procurement, control and standardization of parts (electrical and mechanical), materials, and processes for space and launch vehicles, to reduce overall program costs, and improve the reliability of space and launch vehicles.
6. This Handbook was derived from the MIL-STD-1547 and individual piece part specifications in an effort to preserve the known reliability characteristics of space level qualified and flown PMP items which make-up the "space quality baseline". These characteristics are the basis for reliability predictions and part failure prediction models used in MIL-HDBK-217 may be used as basis for evaluation of new technologies and product improvements. In addition, the individual component Military Specification criteria previously called out in MIL-STD-1547 for individual items, will no longer be available since most of these Military Specifications are either changed to Performance Specifications, Test Standards, or canceled.
7. This handbook information is based on the lessons learned from over 30 years of space flight history and provides the basis for estimating of PMP element Application Information, Design and Construction Considerations, and Quality Assurance Provisions for the proposed Design Application.
8. Space and Launch Vehicles are mostly single string without redundant systems, except for the most critical components, due to weight and size considerations, and are required to perform to designed specifications every time and cannot be replaced in flight. Any failures could cause performance

degradation and even mission failure. In today's environment of "faster, better, cheaper", high rate of technological turn-over and obsolescence, and push towards the use of "Best Industry Practices" the system designers and PMP specialists are faced with a real challenge.

9. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving the document should be addressed to SMC/AXMP, 160 Skynet Street Suite 2315, Los Angeles AFB, El Segundo, CA 90245-4683 by using a Standardization Document Improvement Proposal (DoD Form 1426).

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1. SCOPE

This Handbook was developed to aid Designers and Parts, Materials, and Processes (PMP) specialists with the design, development, and fabrication of electronic systems required to have long life and/or high reliability while operating under extreme conditions/ environments of Space and Launch Vehicles.

1.1 Purpose

The purpose of this handbook is to establish and maintain consistent and uniform methods for development of technical requirements for electronic parts, materials, and processes used in the design, development, and fabrication of space and launch vehicles. It provides a common basis for estimating of Application Information, Design and Construction Considerations, and Quality Assurance Provisions for the proposed Design Application. It also establishes a common basis for comparing and evaluating of industry practices for related or competitive designs. This handbook is intended to be used as a tool to increase the performance and reliability of the system under design.

1.2 Organization of the Handbook

This Handbook is organized in two (2) major parts: First part is a general section from par. 1.0 through 5.0 detailing general information about and how to use the handbook, applicable documents that are referenced and are an integral part of this handbook, definitions, and general good practices to be considered whenever dealing with PMP; 2nd Part is the EEE Parts Section comprised of all the specific parts sections. (i.e. Capacitors, Fuses, etc.); Each of the individual Parts Section is further organized into two (2) areas: 1st a General Section detailing all the technologies covered, recommended application and application information for each technology, Design and Construction information for each, and general Quality Assurance provisions for the individual Part Section; 2nd is each individual detail sections for each major technology covered by the individual Part Section.

1.3 Application of the Handbook

This handbook is a guide and reference document intended to aid designers and parts engineers in the Parts Design Application Selection, Specification, and Verification for systems intended to be used in Space Flight and Launch Vehicles**.**

2.0 APPLICABLE DOCUMENTS

2.1 General The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this book.

2.2 Government Documents

2.2.1 Specifications, Standards, and Handbooks The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplements thereto, cited in the solicitation. When this handbook is used by acquisition, the applicable issue of the DoDISS must be cited in the solicitation.

MIL-C-17	Cables, Radio Frequency, Flexible and Semirigid, General Specification for
MIL-T-27	Transformer and Inductor (Audio, Power, and High Power Pulse), General Specification for
MIL-C-123	Capacitors, Fixed, Ceramic Dielectric, (Temperature Stable and General Purpose), High Reliability, General Specification for
MIL-R-874	Resistor Networks, Fixed Film, Established Reliability, General Specification for
MIL-S-3786	Switches, Rotary (Circuit Selector, Low Current Capacity), General Specification for
MIL-S-3950	Switch, Toggle, Environmentally Sealed, General Specification for
MIL-C-5015	Connector, Electrical, Circular Threaded, AN Type, General Specification for
MIL-W-5088	Wiring, Aerospace Vehicle
MIL-S-5594	Switches, Toggle, Electrically Held, Sealed
MIL-R-6106	Relay, Electromagnetic (Including Established Reliability (ER) Types), General Specification for
MIL-S-6807	Switch, Rotary, Selector, General Specification for
MIL-W-6858	Welding, Resistance, Spot and Seam
MIL-I-6870	Inspection Program Requirements, Non-destructive testing for Aircraft and Missile Materials and Parts
MIL-W-6873	Welding, Flash, Carbon and Alloy Steel

MIL-H-6875	Heat Treatment of Steels (Aircraft Practice), Process for
MIL-F-7190	Forging, Steel, For Aircraft and Special Ordnance Applications
MIL-C-7438	Core Material, Aluminum, For Sandwich Construction
MIL-B-7883	Brazing of Steels, Copper, Copper Alloys, Nickel Alloys, Aluminum and Aluminum Alloys
MIL-S-8802	Sealing Compound, Temperature-Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High-Adhesion
MIL-S-8805	Switches and Switch Assemblies, Sensitive and Push (Snap Action), General Specification for
MIL-S-8834	Switches, Toggle, Positive Break, Aircraft, General Specification for
MIL-W-8939	Welding, Resistance, Electronic Circuit Modules
MIL-I-8950	Inspection, Ultrasonic, Wrought Metals, Process for
DOD-E-8983	Electronic Equipment, Aerospace, Extended Space Environment, General Specification for
MIL-T-9046	Titanium and Titanium Alloy, Sheet, Strip and Plate
MIL-T-9047	Titanium and Titanium Alloy Bars, Forging Stock
MIL-A-9117	Adhesive: Sealing, for Aromatic Fuel Cells and General Repair
MIL-S-9395	Switches, Pressure, (Absolute, Gage and Differential), General Specification for
MIL-S-13165	Shot Peening of Metal Parts
MIL-S-15291	Switches, Rotary, Snap Action
MIL-C-15305	Coil, Fixed and Variable, Radio Frequency, General Specification for
MIL-S-19500	Semiconductor Device, General Specification for
MIL-T-21038	Transformer, Pulse, Low Power, General Specification for
MIL-A-21180	Aluminum Castings, High Strength
MIL-S-22710	Switch Code, Indicating Wheel (Printed Circuit) (Thumb Wheel and Push-Button), General Specification for
MIL-W-22759	Wire, Electric, Fluoropolymer-Insulated, Copper or Copper Alloy
MIL-A-22771	Aluminum Alloy Forgings, Heat Treated

MIL-S-22885	Switch, Push Button, Illuminated, General Specification for
MIL-C-23269	Capacitors, Fixed, Glass Dielectric, Established Reliability, General Specification for
MIL-F-23419	Fuse, Instrument Type, General Specification for
MIL-T-23648	Thermistor (Thermally Sensitive Resistor), Insulated, General Specification for
MIL-S-24236	Switches, Thermostatic, (Metallic And Bimetallic), General Specification for
MIL-C-24308	Connector, Electric, Rectangular, Miniature Polarized Shell, Rack and Panel, General Specification for
MIL-S-24317	Switches, Multistation, Pushbutton (Illuminated and Non-Illuminated), General Specification for
MIL-C-26482	Connector, Electrical, (Circular, Miniature, Quick Disconnect, Environment Resisting) Receptacles and Plugs, General Specification for
MIL-C-27500	Cable, Electrical Shielded and Unshielded, Aerospace
MIL-F-28861	Filters and Capacitors, Radio Frequency/Electromagnetic Interference Suppression, General Specification for
MIL-M-38510	Microcircuit, General Specification for
MIL-H-38534	Hybrid Microcircuits, General Specification for
MIL-I-38535	Integrated Circuits (Microcircuits) Manufacturing, General Specification for
MIL-M-38780	Manual, Technical Non-destructive Inspection
MIL-C-38999	Connector, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded, and Breach Coupling), Environment Resistant, Removable Crimp and Hermetic Solder Contacts, General Specification for
MIL-C-39003	Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Established Reliability, General Specification for
MIL-R-39005	Resistor, Fixed, Wirewound, (Accurate), Established Reliability, General Specification for
MIL-C-39006	Capacitors, Fixed Electrolytic (Nonsolid Electrolyte), Tantalum, Established Reliability, General Specification for
MIL-R-39007	Resistor, Fixed, Wirewound (Power Type), Established Reliability, General Specification for
MIL-R-39008	Resistor, Fixed, Composition (Insulated), Established Reliability, General Specification for

MIL-R-39009	Resistor, Fixed, Wirewound (Power Type, Chassis Mounted), Established Reliability, General Specification for
MIL-C-39010	Coil, Fixed, Radio Frequency, Molded, Established Reliability, General Specification for
MIL-C-39012	Connector, Coaxial, Radio Frequency, General Specification for
MIL-R-39015	Resistor, Variable, Wirewound (Lead Screw Actuated), Established Reliability, General Specification for
MIL-R-39016	Relay, Electromagnetic, Established Reliability, General Specification for
MIL-R-39017	Resistor, Fixed Film, (Insulated) Established Reliability, General Specification for
MIL-C-39029	Contact, Electrical Connector, General Specification for
MIL-R-39035	Resistor, Variable, Nonwire Wound (Adjustment Type), Established Reliability, General Specification for
MIL-G-45204	Gold Plating, Electrodeposited
MIL-I-46058	Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)
MIL-A-46146	Adhesive Sealants, Silicone, RTV, Non-corrosive (For Use With Sensitive Metals and Equipment)
MIL-C-49467	Capacitors, Fixed, Ceramic, Multilayer, High Voltage, (General Purpose), Established Reliability, General Specification for
MIL-C-49468	Crystal Units, Quartz, Precision, General Specification for
MIL-P-50884	Printed Wiring, Flexible, and Rigid-Flex
MIL-P-55110	Printed Wiring Boards, General Specification for
MIL-R-55182	Resistor, Fixed, Film, Established Reliability, General Specification for
MIL-C-55302	Connector, Printed Circuit Subassembly and Accessories
MIL-R-55342	Resistor, Fixed, Film, Chip, Established Reliability, General Specification for
MIL-C-55365	Capacitor, Chip Fixed Tantalum, Established Reliability
MIL-H-81200	Heat Treatment of Titanium and Titanium Alloys
MIL-W-81381	Wire, Electric, Polyimide - Insulated, Copper or Copper Alloy
MIL-T-81556	Titanium and Titanium Alloys, Bars, Rods and Special Shaped Sections, Extruded

MIL-F-83142	Forging, Titanium Alloys, For Aircraft and Aerospace Applications
MIL-A-83376	Adhesive Bonded Aluminum Sandwich Structures
MIL-A-83377	Adhesive Bonding (Structural) for Aerospace and Other Systems, Requirements For
MIL-C-83421	Capacitors, Fixed, Supermetallized, Plastic Film Dielectric, (DC, AC, or DC and AC). Hermetically Sealed in Metal Cases, ER
MIL-C-83513	Connectors, Electrical, Rectangular, Microminiature, Polarized Shell, General Specification for
MIL-R-83536	Relays, Electromagnetic, Established Reliability, General Specification for
MIL-W-83575	Wiring Harness, Space Vehicle, Design and Testing, General Specification for
MIL-A-83577	Assemblies, Moving Mechanical, for Space and Launch Vehicles, General Specification for
MIL-C-83723	Connector, Electrical, (Circular, Environment Resisting), Receptacle and Plugs, General Specification for
MIL-R-83726	Relay, Hybrid and Solid-state Time Delay, General Specification for
MIL-C-83733	Connector, Electrical, Miniature, Rectangular Type, Rack to Panel, Environment Resisting, 200 deg C Total Continuous Operating Temperature, General Specification for
MIL-C-87164	Capacitors, Fixed, Mica Dielectric, High Reliability, General Specification for
MIL-C-87217	Capacitors, Fixed, Supermetallized Plastic Film Dielectric, Direct Current for Low Energy, High Impedance Applications, Hermetically Sealed in Metal Cases, Established Reliability, General Specification for
MIL-R-87254	Resistors, Fixed Film, High Reliability, General Specification for

2.2.2 FEDERAL STANDARDS

FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
QQ-A-367	Aluminum Alloy Forgings

2.2.3 MILITARY STANDARDS

MIL-STD-129	Marking for Shipping and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-198	Capacitor, Selection and Use of

MIL-STD-199	Resistor, Selection and Use of
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-275	Printed Wiring for Electronic Equipment
MIL-STD-401	Sandwich Constructions and Core Materials; General Test Methods
MIL-STD-403	Preparation for and Installation of Rivets and Screws, Rocket and Missile Structures
MIL-STD-750	Test Methods for Semiconductor Devices
MIL-STD-866	Grinding of Chrome Plated Steel and Steel Parts Heat Treated to 180,000 psi or Over
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-889	Dissimilar Metals
MIL-STD-976	Certification Requirements for JAN Microcircuits
MIL-STD-981	Design, Manufacturing, and Quality Standards for Custom Electromagnetic Devices for Space Applications
MIL-STD-1132	Switches and Associated Hardware, Selection and Use of
MIL-STD-1331	Parameters To Be Controlled for the Specification of Microcircuits
MIL-STD-1346	Relays, Selection and Application
MIL-STD-1353	Electrical Connectors and Associated Hardware, Selection and Use of
MIL-STD-1523	Age Controls of Age Sensitive Elastomeric Materials for Aerospace Applications
MIL-STD-1580	Destructive Physical Analysis for Space Quality Parts
MIL-STD-1595	Qualification of Aircraft, Missile and Aerospace Fusion Welders
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (Metric)
MIL-STD-2000	Standard Requirements for Soldered Electrical and Electronic Assemblies
MIL-STD-2118	Flexible and Rigid-Flex Wiring for Electronic Equipment, Design Requirements for
MIL-STD-2175	Castings, Classification and Inspection of
MIL-STD-2219	Fusion Welding for Aerospace Applications

2.2.4 MILITARY HANDBOOKS

MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Plastics for Aerospace Vehicles
MIL-HDBK-23	Structural Sandwich Composites
MIL-HDBK-217	Reliability Prediction of Electronic Equipment
DOD-HDBK-263	Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies, and Equipment.
MIL-HDBK-339	Custom Large Scale Integrated Circuit Development and Acquisition for Space Vehicles

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the contracting office or as directed by the contracting officer.)

2.2.5 AIR FORCE WRIGHT AERONAUTICAL LABORATORIES (AFWAL)

ADD436124L	DOD/NASA Structural Composites Fabrication Guide Vol I
ADD436125L	DOD/NASA Structural Composites Fabrication Guide Vol II
	DOD/NASA Advanced Composite Design Guide, Vol I - IV

2.2.6 NASA MANNED SPACECRAFT CENTER

Standard 125 Cadmium Restriction on Use

2.2.7 NASA PUBLICATIONS

TM X-64755	Part Derating Guidelines; Department of the Air Force, Air Force Systems Command (AFSC) Pamphlet 800-27

Application for copies should be addressed to: Department of the Air Force, Headquarters Air Force Systems Command, Andrews Air Force Base, DC 20334

MSFC-SPEC-250	Protective Finishes for Space Flight Vehicle Structures and Equipment, General Specification for
MSFC-STD-355	Radiographic Inspection of Electronic Parts
MSFC-SPEC-469	Titanium and Titanium Alloys, Heat Treatment of
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
NASA-SP-8063	Lubrication, Friction and Wear
NHB 5300.4(3A-2)	Requirements for Soldered Electrical Connections
NHB 8060.1	Office of Space Transportation Systems Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion
SP-R-0022A	General Specifications, Vacuum Stability Requirements of Polymine Materials for Space Craft Applications

Application for copies should be addressed to: Marshould Space Flight Center, Document Repository (AS24D), Huntsville, AL 35812

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specified acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.3 NON-GOVERNMENT PUBLICATIONS

The following documents form a part of this handbook to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposal may apply.

2.3.1 AMERICAN NATIONAL STANDARD INSTITUTE

CF-152 Composite Metallic Materials Specification for Printed Wiring Boards

Application for copies should be addressed to: American National Standard Institute, 11 West 42nd Street, New York, NY 10036

2.3.2 AMERICAN SOCIETY FOR TESTING MATERIAL

ASTM E 595-84 Standard Test Method for Total Mass Loss and Collected Volatile Condensable Material From Outgassing in a Vacuum Environment

Application for copies should be addressed to: American Society for Testing Materials, 1916 Race Street, Philadelphia, PA 19111

2.3.3 ELECTRONICS INDUSTRIES ASSOCIATION

RS-469 DPA of Ceramic Capacitors

RS-477 Cultured Quartz

IND-STD-557 Statistical Process Control Systems

Application for copies should be addressed to: Electronic Industries Association, 2001 Pennsylvania Ave, N.W., Washington, D.C. 20006

2.3.4 INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 302 Standard Definitions and Methods of Measurement for Pezoelectric Vibrators Operating Over the Frequency Range Up to 30 Megahertz

Application for copies should be addressed to: American National Standards Industries, 1430 Broadway, New York, NY 10018

2.4 Order of precedence In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 DEFINITIONS

Terms are in accordance with the following definitions:

ACQUISITION ACTIVITY The acquisition activity is the Government office or contractor organization acquiring the equipment, system, or subsystem.

CASE TEMPERATURE The Case Temperature (T_C) is the temperature measured (typically the hottest temperature point found on the mounting surface of the device) on the external surface of the device's package. The T_C is determined in accordance with the applicable specification standard.

CHANGE CONTROL BOARD (CCB) Change Control Board (CCB) is an organization established by the Contractor for managing and control of product changes.

CONTRACTING OFFICER A contracting officer is a person with the authority to enter into, administer, or terminate contracts and make related determinations and findings. The term includes authorized representatives of the contracting officer acting within the limits of their authority as delegated by the contracting officer.

DERATING Derating of a part is the intentional reduction of its applied stress, with respect to its rated designed stress capabilities, for the purpose of providing a margin between the applied stress and the demonstrated designed limit of the part's capabilities. Typical derating parameters are: applied Voltage, Current, Power, and Operating Temperature. Derating criteria is part type, technology, and design application dependent and is used by the Arhenius Reliability Prediction Model for in system operating life predictions. Therefore, the higher the derating margin the longer the part is expected to operate in the system.

DESTRUCTIVE PHYSICAL ANALYSIS (DPA) A Destructive Physical Analysis (DPA) is a systematic, logical, detailed examination of parts during various stages of disassembly, conducted on a sample of completed parts from a given lot, to verify part Design and Construction, Workmanship, and Processing controls. The purpose of these analyses is to maintain configuration control and determine those lots of parts, delivered by a vendor, which have anomalies or defects such that they could, at some later date, cause a degradation or catastrophic failure of a system. Anomalies found through DPA, and determined to have an impact to the part design application, are typically segregated into screenable (this means that the entire lot is subjected to a specified screen(s) prior to part stocking) and unscreenable (which will typically cause lot rejection) anomalies

ELECTRONIC PARTS The term "electronic" is used in a broad sense in this handbook and includes electrical, electromagnetic, electromechanical, and electro-optical devices. These parts are associated with electronic assemblies such as computers, communication equipment, electrical power supplies, guidance, instrumentation, and space vehicles. Connectors are also classified as electronic parts.

END-OF-LIFE DESIGN LIMIT The End-of-Life design limits for an item are the expected variations in its electrical parameters over its period of use in its design environment. The parameter variations are expressed as a percentage change beyond the specified minimum and maximum values. Circuit designs should accommodate these variations over the life of the system.

HOT-WELDED CAN A Hot-Welded Can is a cap sealed component utilizing thermocompression attachment of the cap to the base of the device.

INTEGRATED PROGRAM TEAM (IPT) The Integrated Program Team (IPT) is a formal organization consisting of members from the Contracting Officer representatives, Contractor and Subcontractor representatives established to manage and control the program activities.

MANUFACTURING BASELINE The manufacturing baseline is a detailed description of the manufacturing and of the sequence of operations necessary to produce a specific item, part, or material. The manufacturing baseline includes all associated documentation and revisions, that is identified or referenced, such as: that pertaining to the procurement and receiving inspection, storage, and inventory control of parts and materials used; the manufacturing processes; the manufacturing facilities, tooling, and test equipment; the in-process manufacturing controls; the operator training and certification; and the inspection and other quality assurance provisions imposed. Manufacturing Baseline includes a manufacturing process list (identifying each document by title, number, date of issue, applicable revision, and date of revision), the manufacturing sequence, (normally in the form of a flow chart), and the manufacturing processes, (normally in the form of travelers used for part and lot processing).

MATERIAL Material is a metallic or nonmetallic element, alloy, mixture, or compound used in a manufacturing operation which becomes either a temporary or permanent portion of the manufactured item or which can leave a remnant, residue, coating, or other material that becomes or affects a permanent portion of a manufactured item..

MATERIAL LOT A lot for material refers to material produced as a single batch or in a single continuous operation or production cycle and offered for acceptance at any one time.

PART A part is one piece, or two or more pieces joined together, which are not normally subjected to disassembly without destruction or impairment of its designed use.

PARTS, MATERIALS, AND PROCESSES CONTROL BOARD (PMPCB) The PMPCB is a formal contractor organization, formerly established by contract direction to manage and control the selection, application, procurement, and documentation of parts, materials, and processes used in equipment, systems, or subsystems.

PERCENT DEFECTIVE ALLOWABLE (PDA) The Percent Defective Allowable (PDA) of a production lot of parts or materials is a maximum allowable percentage of parts or material specimens that fail to pass one or more tests before the entire production lot is considered to be unacceptable.

PROCESS A process is an operation, treatment, or procedure used during a step in the manufacture of a material, part, or an assembly.

PRODUCTION LOT Unless otherwise specified in the detail specification, a production lot of parts refers to a group of parts of a single part type; defined by a single design and part number; produced in a single production run by means of the same production processes, the same tools and machinery, same raw material, and the same manufacturing and quality controls; and to the same baseline document revisions and tested within the same period of time. All parts in the same lot have the same lot date code, batch number, or equivalent identification.

REGISTERED PART, MATERIAL AND PROCESSES (PMP) A registered PMP is a part, material, or process which is registered with the PMPCB to call attention to special reliability, quality, or other concerns, relating to its procurement or application. Registered PMP includes, but is not limited to, reliability suspect PMP, limited application PMP, and PMP involving restricted or special controlled usage, storage, or handling due to safety or environmental concerns.

RELIABILITY SUSPECT (PMP) A reliability suspect PMP is a part, material, or process that has been determined from past performance data, analysis, and other industry sources to have special reliability and quality concerns that could affect its performance in the intended design application.

SPACE QUALITY PMP A space quality PMP is a part, material, or process, of the same quality and reliability, produced on the same production line, by the same vendor and of the same design and construction, previously qualified and flown under the same or more stringent space applications.

CONTRACTOR The term “contractor” signifies a producer of modules or higher level items of equipment. A contractor that provides items to another contractor can be identified as a “subcontractor”. Some system programs have one major contractor identified as a “prime contractor”, which is responsible directly to the acquisition activity. Other programs may have two or more major contractors, each responsible directly to the acquisition activity (neither one subordinate to the other), which are called “associate contractors”. In the case of programs with associate contractors, the acquisition activity may designate one associate contractor as responsible for managing the program Parts, Materials, and Processes Control Program.

COMMERCIAL - OFF - THE - SHELF (COTS) A commercial off-the-shelf (COTS) item is an item which has been developed and produced to military or commercial standards and specifications, is readily available for delivery from an industrial source, and may be acquired without change to satisfy a military requirement.

ELECTROSTATIC DISCHARGE (ESD) A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by electrostatic field.

SCREENING Screening is defined as a stress test or series of tests, (electrical, environmental, mechanical and or combinations thereof), imposed on 100% of the parts and or materials for the purpose of defect elimination.

QUALITY CONFORMANCE INSPECTION Quality Conformance Inspection is defined as a stress test or series of tests, (electrical, environmental, mechanical and or combinations thereof), imposed on a sample of the parts and or materials from a lot, for the purpose of lot integrity and performance verification.

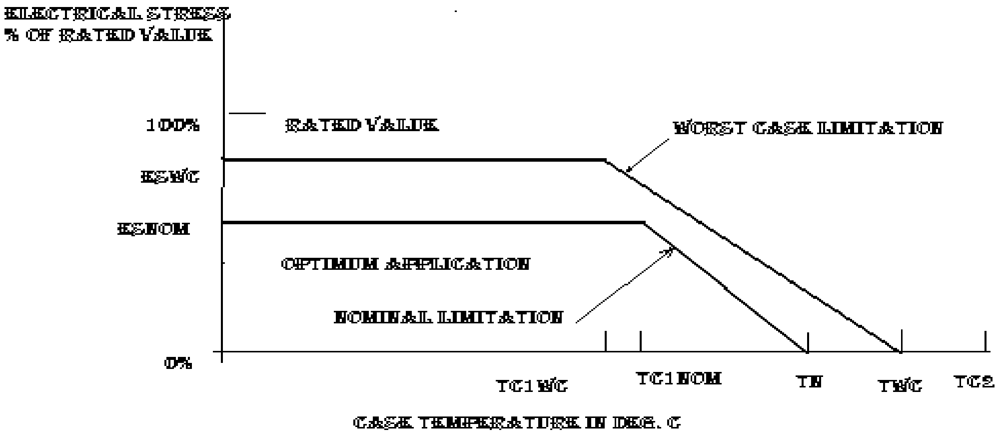
4.0 GENERAL CONSIDERATIONS

4.1 General The information covered by this section on space quality electronic parts, materials, and processes is categorized in four major areas covering the general application, design and construction, and quality conformance considerations that are applicable to all parts, materials, and processes as applicable. This information is based on proven track record of the past specified requirements over 30 years of space applications history and lessons learned. The application area includes derating, end-of-life limitations, mounting recommendations, and other design considerations intended to ensure the high reliability of the parts when used in space and launch vehicle applications. The design and construction, and the quality assurance considerations provide information that supersedes or supplement the referenced general military specifications to ensure their performance and necessary quality for space and launch vehicles applications. These design, construction, and quality assurance considerations have traditionally provided the basis for individual parts specifications and performance requirements developed by the contractors for space quality PMP types when Space Qualified PMP were not available. The Contractor, however, can provide alternative solutions based on specific designs and data which validate the proposed solutions.

4.2 Application Considerations

4.2.1 Electrical derating. Circuits are designed with the parts derated as specified herein. The extent to which electrical stress (e.g., voltage, current, or power) is derated, is dependent upon operating temperature. The general interrelationship between electrical stress and temperature is shown in Figure 4-1. The optimum operating conditions lie within the area below the nominal limitation line (ES_{NOM}). To obtain the specific curve for each part type, numerical values are applied to the general curve based on the specified maximum rated values being 100 percent. The applicable derating curve or derating factor is given in the detailed section for each part type. The derating factor is to be multiplied times the part rating to obtain the allowed nominal limitation value for specific applications.

4.2.2 Mechanical derating. Mechanical designs , much the same as electrical and electromechanical designs, require adequate mechanical stress margins for the intended application to sustain long-life performance in associated equipment over the specified design life. These margins are obtained through derating of parts and materials mechanical design characteristics and properties associated with environments such as shock, vibration, acceleration, and temperature that produce force-function effects on flight hardware. Strength margins, (or derating criteria) are based on mechanical property data from MIL-HDBK-5 where applicable, and delimit susceptibility to mechanical failure modes such as bending, deformation, fracture, rupture, excessive deflection, and fatigue. Functional margins should be calculated based on the recommendation of MIL-A-83577 wherever possible.



Where:

TC_1 = Case Temperature above which applied electrical stress should be reduced. Unless otherwise specified, TC_1 (worst case) is the same as TC_1 (nominal)

TC_2 = Maximum allowable Case Temperature per detailed specification, based on the part design.

T_N = Nominal boundary limitation. Typically $T_N = T_{WC}$-10°C. Other temperature deltas may be given in the detail specification.

T_{WC} = Worst case thermal boundary. Typically $T_{WC} = T_{C2}$-30°C

ES_{NOM} = Maximum steady state or average operating electrical stress

ES_{WC} = Worst case electrical stress, including electrical transient and radiation effects

100% = Maximum rated value per detailed specification

FIGURE 4.1- Typical Electrical Stress vs. Temperature Derating Scheme

4.2.3 End - of - life. Circuits design criteria needs to be robust such that the required functional performance is maintained, even if at the component level, the performance values of the parts used vary within the identified end-of-life design limits. The detail sections of this handbook provide the 10 year end-of-life parametric limits for each product type, based on proven device characteristics, and should be used as a guide whenever specific end - of - life limits are determined. The end - of - life design limits are based on sound engineering for component level performance to provide the required system level performance.

4.2.4 Aging sensitivity. Electrical, Electronic, Electromagnetic, Optical, and Mechanical parts and materials are considered, aging sensitive, when they are subject to gradual shortening of their useful life or degradation of their performance parameters over time. Aging mechanisms include the following: Loss of hermeticity, Stress relaxation, Oxidation and Corrosion, Outgassing, Cold flow and Creep, Loss of adhesion, Embrittlement and Hardening, Loss of Torque, Loss of Spring Tension, Increase in component Current Leakage, Breakdown Voltage and Forward degradation, Annealing etc. Aging sensitivity effects should be taken into account in the design, selection, monitoring procedures, stocking, kitting, and application of parts and materials.

4.2.5 Aging sensitivity monitoring Typical procedures used for monitoring of Aging Sensitive PMP items include the following: Shelf Life Control program, Periodic stock recertification and testing, First In First Out, Lot Date Code limitation at Kitting, Storing environments controls, etc.

4.2.6 Sealed packages. Hermetically sealed parts are preferred for use in space and launch vehicles for their stability and robustness. If non-hermetically sealed parts are selected, careful consideration should be given to the following factors: in-process next assembly and cleaning operations are not detrimental to the parts, the part outgassing, sublimation, moisture penetration, and or moisture absorption are adversely affecting the system and the part in its intended application.

4.2.7 Registered pmp. This is a left over from MIL-STD-1547 and is provided for reference to aid designers and parts engineers with understanding of the traditional space level components requirements. The detailed sections of this handbook identify known registered PMP, their applications and their procurement restrictions. The contractors should identify how various restrictions are mitigated whenever components of this type are used in the design.

4.2.8 Reliability suspect pmp. The detailed sections of this handbook identify known reliability suspect PMP designs, their applications and their procurement restrictions. In addition, all parts containing desiccants and organic materials, dissimilar metals such as Au-Al, Al-Ag, Cadmium plating, Pure or unfused Sn, Teflon, and more than 5000ppm of moisture have been traditionally considered reliability suspect for use in space application.

4.2.9 Handling of electrostatic-sensitive items Protection against electrostatic damage to electrostatic sensitive devices is established through development of Electrostatic discharge (ESD) control program for the protection of electrical and electronic parts, components, assemblies, and equipment in accordance with MIL-STD-1686. DOD-HDBK-263 may be used for guidance in establishing an ESD control plan.

4.2.10 Marking The marking will be in accordance with the applicable military specification and contractor's established control procedures for the use and tracking of individual PMP items in the design.

4.2.11 Installation and mounting Parts and Materials could be damaged during the system manufacturing (assembly and test) by the thermo-mechanical stresses. It is therefore, recommended that these stresses be minimized through design, use of appropriate mounting techniques, and optimum processes. Mechanical stresses due to dissimilar materials joined together should also be compensated for by the design.

4.2.12 Outgassing. Materials and finishes outgassing requirements for space and launch vehicles are documented in NASA specification SP-R-0022. Total mass loss (TML) (due to outgassing) of not more than 1.0 percent and a collected volatile condensable material (CVCM) of not more than 0.1 percent when tested in accordance with ASTM E 595 is recommended. However, if the TML is greater than 1.0 percent, but it can be shown that contributions to the TML in excess of 1.0 percent are due only to absorbed water vapor, the materials are acceptable.

4.2.13 Alternate qci test/sampling plan. Alternate QCI test/sampling plan is documented in appendix C of this Handbook

4.2.14 Space quality part characteristics The characteristics required for specific part types, that allows them to be of space quality, are stated in subsequent detailed part type sections of this handbook. The applicable Military Specification Requirements are identified in the detailed requirements section for each part type. NOTE: The referenced Military Specifications are of the revision in effect in through end of 1995 and their current revisions may not reflect the same requirements. PMP items manufactured may not meet the original qualified levels.

4.2.15 Conformal coatings. The Conformal Coatings and acceptance criteria, used on the printed wiring boards, which were qualified for space application are documented in MIL-STD-275 and below:

a To prevent stressing solder joints, the underside of components spaced off the printed wiring board should not bridge between printed wiring board surface and the part(s) leads.

b Visual criteria for the conformal coating should reject any blisters, cracking, crazing, peeling, wrinkles, mealing, evidence of corrosion. In addition, a pinhole, bubble or combination that bridge more than 50% of nonconnecting conductors can be reworked.

c Only mechanical removal means are recommended, other than Type AR (MIL-I-46058) and solvent removable parylene (paraxylene) coatings, to be used during rework.

4.2.16 Reuse of parts and materials Installed Parts and Materials are not recommended to be reused if they have been completely removed from the assemblies due to high risk of part and or material damage during the disassembly and the subsequent reassembly process. Contractor could, however, qualify the methodology it the high price associated with the qualification process is offset by other factors such as frequency of occurrence, etc.

4.2.17 Rework and repair considerationsAll rework and repair procedures that are used in the assembly manufacturing process should consider and incorporate the allowable practices specified in individual Military Specification for each part and material subjected to rework or repair. Whenever possible, the contractor should actively pursue the elimination of the frequent rework and repair activities through process improvements, in order to minimize the end item performance variations.

4.3 PART DESIGN AND CONSTRUCTION

4.3.1 Design and construction. Traditionally, the Parts Design and Construction was required to be in accordance with the applicable Military Specification requirements for JAN Class S level which was the level of parts established to meet most space applications needs. Therefore, whenever these parts were not available as JAN Class S and the detail Military Specification did not have a JAN Class S criteria, the Military Specification JAN Class S criteria for the nearest part of the same family or technology was followed, and the design activity provided rationale and technical documentation illustrating their capability to meet the program's technical requirements. It is understood that under the current economic environments these types of components may not be available for use. However, under these conditions it is the contractor’s responsibility to ensure through sound engineering that the selected components are of a design and construction suitable and reliable for the intended application.

4.3.2 Material hazards. Reliability and Safety considerations require Mechanical and Electronic parts to be constructed of materials that prevent exposure of either personnel or adjacent components to hazardous conditions. Hazardous conditions include, but are not limited to the following: arc generation, flammability, severe outgassing, toxicity, sublimation, and high vapor pressure. The contractor should take these elements into consideration as well as the long term storage, and storage environments associated with space systems, when selecting PMP items for the application.

4.3.3 Tin-coated surfaces. Mechanical and electronic parts with internal and or external surfaces coated with a pure unfused tin plating have been determined to be “Aging Sensitive” and Reliability Suspect due to high potential of Tin Whisker growth under certain environments which are capable of shorting out electronic circuitry. However, a tin alloy plating containing a minimum of 2 weight percent of a second element (i.e. 98% Sn, 2% Pb) has been determined to inhibit and prevent the formation and growth of tin whiskers. This phenomenon does not apply to drawn wire products, such as cables.

4.3.4 Processes and controls. Performance reliability of parts and materials depend first on their design robustness for the intended application, and second on the manufacturing processes and their controls used in the manufacture of parts and materials. A great emphasis has been put over the years on Statistical Process Controls (SPC), Statistical Experimental Design methodology, Togochy/ Deming methodologies, and other techniques for process development and control that could be effectively employed on high volume and continuous flows production lines. While the utilization of these methods are always encouraged, the part and or material design capabilities need to be reviewed carefully, since all of the above methods will only provide consistence in performance to the part and material design capabilities. Therefore, the process controls cannot be substituted for poor designs nor can the design be substituted for poor processes and controls.

Majority of the Military Specifications that govern each material and part technology type have been or are in the process of being transformed into Performance Specifications which pay close attention and emphasize the use of controls, such a those mentioned above, in an effort of maintaining a continuous product improvement, take advantage of industry practices developed for the High Volume and Continuous Flow Product Lines, and minimize the costs associated with specialty items. The part and material manufacturer should follow all the processes and processing controls that ensure the reliability and quality required, as delineated by the Military Specifications or accepted Industry Specifications which govern the part and material technology. These manufacturing processes and controls should be fully documented in a sufficient detail to provide a controlled manufacturing baseline for the manufacturer which ensures that subsequent production items can be manufactured and are equivalent in performance, quality, dimensions, and reliability to initial production items used for qualification or for flight hardware. This documentation should include the name of each process, each material required, the point each material enters the manufacturing flow, and the controlling specification or drawing. The documentation should indicate required tooling, facilities, and test equipment; the manufacturing check points; the quality assurance verification points; and the verification procedures corresponding to each applicable process or material listed.

4.3.5 Rework during manufacture of materials and parts. All rework performed during the manufacture of materials and parts should follow the acceptable procedures and controls that are documented within the Military Specification and or Industry Specifications governing the individual part and material technology. Except as may be allowed by the detailed requirements section for each specific electronic part, rework during manufacturing is not recommended.

4.3.6 Design and construction limitations It is recommended that the Design and Construction, for the parts proposed for use in space applications, be validated for the intended application and any known limitations (from past history with the same or similarly constructed parts in similar applications) be mitigated either through design and or test methods.

4.4 QUALITY ASSURANCE PROVISIONS

The elements outlined below are characteristics that have to be considered of a space level PMP. Although their implementation is PMP technology and vendor specific, there are some common characteristics that if met the success of the part and or material in the system application is greatly enhanced. The elements outlined are included to establish a baseline for the past requirements imposed by the contract on the PMP items, and to explain their importance and effects on the space level PMP.

4.4.1 Produceability and baseline controls. Traditionally a great emphasis has been placed on PMP documentation control, especially for space level applications, since often the parts and materials were tested and exercised for the first time in the actual application and minimizing the risk of failure was key to successful space system. Also, since the parts and materials used for space applications were procured in small quantities, often processed in batches with tight controls, it became important to document the manufacturing methodology for future reference. Baseline documentation is a complete set of manufacturing and testing documentation maintained by the vendor, often also bought and delivered to the contractor, for a particular Part or Material. This documentation should cover all the revisions and the sequence of processing for the item. Major changes are validated prior to implementation, and the contractor is notified, while minor changes without impact to form, fit, function, or reliability are implemented.

4.4.2 Recommended process controls Traditionally, space level PMP were sought to have the tightest and highest process controls possible for each part and or material. These controls were documented in the applicable military specification for space level of each item. With the shrinking of space level parts and materials market share and perfection of high volume production controls for commercial product lines, it is recognized that the space level parts and materials of the past will not be available in the future and the contractors will be forced to use parts and materials from product lines such as commercial, third party assembly etc. The following is therefore a criteria that could be used to validate these controls:

4.4.3 Homogeneity Lot homogeneity is a key characteristic of good processing and controls, and it evaluates device to device, or batch to batch of materials variation. Therefore, the manufacturer's controls for maintaining product homogeneity need to be validated.

4.4.4 Production lot Production lot definition varies from manufacturer to manufacturer and from product type to product type but is typically defined as a group of parts or materials that are processed together and carry a unique identifier for future reference and lot traceability. Most manufacturers controls and verification methodology are based on and assume that production lot is homogeneous.

4.4.5 Traceability control for parts, materials, & processes The manufacturer should maintain good traceability records for all parts and materials to Incoming Receiving Inspection, and good change control traceability for processes, to allow for feedback on product performance as necessary.

4.4.6 Rework provisions The manufacturer's processes should be optimized and little or no rework should be allowed by the manufacturers processes that would affect the parts or materials homogeneity.

4.4.7 Process controls verification & validation The manufacturer should have a proven and documented system for process verification and validation that insures the part or material performance.

4.4.8 Screening tests (100%) The production lot, when subjected to 100% screening tests, should meet the accept reject criteria established for performance degradation allowed, Max. Percent Defective Allowed, etc. The established performance requirements should be consistent with the intended application for the product type which are outlined in specific sections of this handbook. NOTE: The screening is not designed to build the quality into the product, and should not be used as such, but instead the screening is designed to screen out the infant mortality defects. As the processes improve, the tendency by the manufacturers is to eliminate the screening tests completely without continuous verification that each subsequent production lot consistently meets the performance requirements. It is therefore, recommended that production lots are subjected to the recommended screens in this handbook.

4.4.9 Lot conformance tests (destructive & non-destructive tests) Lot conformance testing should be performed on each production lot as a basis for final lot acceptance after it has successfully passed the in-process controls and screening tests. The recommended tests are defined in each individual section of this handbook and were designed to verify products performance for the widest possible usage.

4.4.10 Qualification tests (destructive & non-destructive tests) The Part Qualification testing requirements provided, in the Military Specifications and in individual sections of this handbook, for each part type are based on lessons learned and maximum functional and environmental limits of the specific part type to ensure the widest possible usage of the part. The qualification testing required by these specifications is specific to each manufacturer by product line, facility, and part number. However, radiation or other environments associated with specific space applications may not be stated in the military specifications for the parts, or the expected environments may be more severe than the standard levels specified for qualification testing of that part type. In those cases, qualification testing should be based on the actual environments associated with the specific space application, and the qualification test levels should be raised to levels above the maximum predicted usage levels to provide an appropriate margin for derating. The following provide different methods for part qualifications:

New Part Type Qualification: This covers new part types, new technologies, new vendor for an existing part type, and major design changes (that affect form, fit, function, or reliability) to an existing part type without any previous space usage. The qualification is established by the satisfactory completion of the established qualification tests that follow the rules outlined above.

Existing Part Types: This covers existing part types and existing technologies from existing vendors, product lines, and facility with previous record of identical or more severe high reliability performance in space vehicle applications for which previous qualification is still valid. For existing part types with previous record of less severe space application the part should be qualified for the intended application.

4.4.11 Parts and materials data retention The contractor should have a method for retention of data generated for the parts and materials procured for the system for future risk assessment and technical evaluation as needed. In addition the contractor may consider retaining any or all of the destructive and non-destructive qualification samples which could be used for future validation of parts and or materials performance under certain conditions not previously accounted for.

4.4.12 Parts and materials storage and stocking The parts and materials storage and stocking practices should take into consideration the following elements: Shelf Life control and recertification of parts and materials, special packaging and handling consideration that may be required, inventory control and kitting practices, and parts and materials traceability.

SECTION 100 BOARDS, PRINTED WIRING

1.0 Scope

1.1 This section contains information for Printed Wiring Boards (PWB), application and handling, design and construction, and quality assurance provisions.

2. Application

2.1 It is recommended that the design and fabrication criteria of MIL-STD-275, MIL-P-55110 be followed for the rigid Printed Wiring Boards, and MIL - STD - 2118 and MIL-P-50884 for the Flexible and Rigid-Flex Wiring, that are intended to be used in the space applications. Table 100-1 covers the Types of printed wiring boards covered in his section.

TABLE 100-1 Printed Wiring Boards (PWB)

TYPE	DESCRIPTION
Type 1	Single Sided
Type 2	Double Sided
Type 3	Multilayer Board without Blind or Buried Vias
Type 4	Multilayer Board with Blind and/or Buried Vias
Type 5	Multilayer Metal Core Board without Blind or Buried Vias
Type 6	Multilayer Metal Core Board with Blind and/or Buried Vias
Type 7	Double sided printed boards with plated through holes
Type 8	Multilayered printed boards with plated through holes (blind and buried vias permitted)

2.2 **Derating** Although there is no derating criteria per se, for PWBs, there some areas that need to be considered.

Current density(i) through any trace or via should not exceed the criteria of MIL-P-55110.

Component Density The board population should be such that any hot spots due to individual components power dissipation does not cause components to operate in excess of the recommended operating temperatures.

2.3 **Raw Material Storage**

Laminate. It is recommended that Laminates are stored flat in a cool dry environment and are supported over their entire surface area to prevent bow and twist. Also, the corners should be protected to prevent crimping.

Prepreg. It is recommended that Prepreg material is stored in a protective area, containers, or packaging which minimizes its exposure to humidity and dust. Moisture resistant bags containing desiccant are typically used at all times prior to use. During handling and storage adequate packing support is provided for both rolled and sheet material in order to prevent creasing, crazing, or wrinkling For storage longer than 30 days, it is recommended that prepreg material is stored at 5° C ± 4° C at less than 50% relative humidity and in absence of ultra violet light.

2.4 End of Life Considerations The end of life considerations are associated with the system design and component types that populate the boards. Assuming that sound engineering principles were followed through out the design and manufacturing processes the individual components end of life considerations should suffice.

2.5 Aging Sensitivity Follow the items outlined in the MIL-P-55110 and Tables 100-2 and 100-3.

3. DESIGN AND CONSTRUCTION

3.1 Rigid Printed Wiring Boards. Past history has shown that the primary failure mechanisms associated with the Printed Wiring Boards are due to the plated through hole contacts and barrel plating anomalies. Therefore, the criteria included below outlines some practices learned from past history. It is assumed that all rigid printed wiring boards with plated-through holes are in accordance with MIL-P-55110 and MIL-STD-275. Additional elements above and beyond the MIL-P-55110 and MIL-STD-275 are identified in TABLE 100-2.

TABLE 100-2: Design and Construction Considerations

Consideration	Mitigation Strategy	Rationale
Nonfunctional Lands (Internal Layers)	Nonfunctional lands are recommended to be included on internal layers of multilayer boards whenever clearance requirements permit.	
Surface Mount Lands	Recommended that surface mount lands meet a 500 psi of vertical pull 90 degrees to the board surface (tension) after being subjected to the five cycles of soldering and four cycles of desoldering, per IPC-TM-650 Method 2.4.21.	Space applications often require that systems survive high vibration, shock, and pull requirements which are above and beyond the capabilities of normally designed PWBs containing surface mount components.
Etchback	Etchback, of typically between 0.0005” minimum and 0.002” maximum, or equivalent processes proven to ensure complete resin smear removal from the holes of multilayer boards prior to plating are recommended.	This practice has been successful in minimizing the subsequent problems such as open or intermittent open contacts etc. that could result from poor plating coverage.
Flammability	Only flame-retardant material is recommended to be used for the construction of printed wiring boards	Fire prevention
Drill Bit Limit	Recommend that the PWB design is within the board manufacturer developed and maintained matrix, which identifies the optimum number of drill hits allowed for the specific types of materials, number of layers, and hole diameters to be used.	Prevent cracking, crazing, and other premature board failure.
Drilling Roadmap	Drilling of the panel should be such that drilling begins and ends in a coupon associated with each printed wiring board.	The coupons are used to validate the integrity of the boards. This allows for verification of drill bit integrity for the entire PWB.
Drill Changes	Drill bit changes should be documented (either on drill tape or digital storage medium). Do not resharpen the drill bits	

TABLE 100-2: Design and Construction Considerations (cont.)

Consideration	Mitigation Strategy	Rationale
Stacking	Do not stack multilayerred boards or more than two panels for double sided plated through hole boards when drilling holes.	
Solder Mask	Solder mask should meet the IPC-SM-840 class III and the vacuum stability specified in General Section of this handbook.	To meet the outgassing criteria
Tin-lead Plating	Recommended Tin-lead plating thickness is 0.0003" (0.001" and 0.002" before fusing on the surface mount boards to be processed by solder reflow) minimum. No solder plate on any surface which is to be laminated to an insulator, metal frame, heatsink, or stiffener should be allowed. Plating thickness and quality may be verified through coupons.	To provide good connections and to prevent any shorts or intermittent shorts that could cause latent board failure.
Fusing	Limit to one fusing operation, whether or not the fusing process heats one or both sides of the board for all PWBs after solder plating and other processes. Record the fuse time and temperature in accordance with the proven manufacturer's processes. After fusing and touch up, the solder coating should be homogeneous and completely cover the conductors with no pitting or pinholes and show no non-wet areas. Side walls of the conductors need not be solder coated	Prevents solder embrittlement, uneven solder flow, development of cold joints, etc.
Ductility	Verify that the as-plated copper meets a minimum of 12% elongation factor on consistent basis typically once per week or in accordance with the manufacturer's proven procedures.	Process control verification to prevent plating solutions contamination and deterioration.

TABLE 100-2: Design and Construction Considerations (cont.)

Consideration	Mitigation Strategy	Rationale
Copper Lamination	Copper traces for mulilayer boards are recommended to be treated or primed prior to lamination. Subjecting the layers to a copper oxidation process has proven to be successful.	To increase the laminate bonding and prevent layer blistering and delamination
Ground Planes	Position large conductive areas such as ground planes close to the board midpoint thickness. When more than one ground plane is required, position them in layers that are equidistant from the midpoint.	To equalize the distribution of conductive areas in a layer and the distribution of conductive areas among layers.
Electrical interface Terminals	Mount terminal into a non-current carrying plated through hole and make the electrical connection using a redundant wire connecting the terminal to an adjacent current carrying plated through hole. An alternate to redundant wiring is step soldering of the terminal to the printed wiring board to preclude solder reflow during subsequent soldering operations or incorporate small redundant via holes adjacent to the terminal holes with both holes connected at all interfacial layer.	

3.2 Metal Core Boards. For metal core boards, follow the ANSI/IPC-CF-152 criteria for fabrication and design. Table 100-3 outlines additional criteria..

3.3 Flexible Wiring. For flexible printed wiring follow the MIL-P-50884 for fabrication and MIL-STD-2118 for design criteria. The etchback considerations outlined in Table 100-2 is also applicable to flexible wiring.

TABLE 100-3: Design and Construction Considerations (Metal Core PWBs)

Consideration	Mitigation Strategy	Rationale
Fabrication and design Dielectric spacing	ANSI/IPC-CF-152 Dielectric spacing between the metal core and adjacent conducting surfaces should not have more than 1µA at 750V when tested in accordance with IPC-TM-650, Method 2.5.7.	Prevents flashover, arcing, breakdown or leakage exceeding one microampere between conductive areas which could cause board failure at elevated altitudes, elevated temperatures, and high moisture environments.

4. QUALITY ASSURANCE Quality assurance provisions of MIL-P-55110, General Requirements of Section 4 and the additional criteria should be followed:

   Qualifications. The manufacturer should be certified to MIL-P-55110. Board qualification tests are not appropriate since the manufacturer should be a qualified MIL-P-55110 supplier and the populated boards are typically qualified at the assembly level.

   In-process Controls. In-process controls should be adequate to provide the quality of the PWBs needed for the application. The criteria outlined in MIL-P-55110, MIL-STD-275, should be followed for the rigid Printed Wiring Boards, and MIL - 2118 and MIL-P-50884 for the Flexible and Rigid-Flex Wiring, with the additions outlined in Table 100-4 herein.

   Screening (100 percent). In accordance with the general requirements of Section 4 and the requirements of MIL-P-55110. One hundred percent (100%) electrical continuity testing of all connections is recommended on internal layers both prior to lay up and at the completed bare board level. Electrical isolation should be established by hi-pot testing, minimum 1500 volts.

   Lot Conformance Tests. In accordance with the general requirements of Section 4 and the requirements of MIL-P-55110. All deliverable coupons, specified in TABLE 100-4 herein, are sectioned, mounted, and inspected to verify that all applicable requirements have been met.

5. REGISTERED PMP

   Reliability Suspect Designs. Rigid-flex wiring board have been determined to be reliability suspect.

6. PROHIBITED MATERIALS LIST Pure Tin or unfused Tin plating are should not be used due to their tendency of Tin whisker growth under certain environments.

TABLE 100-4: Quality Assurance and Processing Considerations

Consideration	Mitigation Strategy	Rationale
Nonfunctional Lands (Internal Layers)	Verify nonfunctional lands are included on internal layers of multilayer boards whenever clearance requirements permit.	
Surface Mount Lands	Test a minimum of three surface mount lands; verify they meet 500 psi of vertical pull 90° to the board surface (tension) after being subjected to the five cycles of soldering and four cycles of desoldering, per IPC-TM-650 Method 2.4.21.	Space applications often require that systems survive high vibration, shock, and pull requirements which are above and beyond the capabilities of normally designed PWBs containing surface mount components.
Etchback	Verify etchback, of 0.0005" min. and 0.002" max., or equivalent processes is used to ensure complete resin smear removal from the holes of multilayer boards prior to plating.	This practice has been successful in minimizing the subsequent problems such as open or intermittent open contacts etc. that could result from poor plating coverage.
Flammability	Only flame-retardant material is recommended to be used for the construction of printed wiring boards	Fire prevention
Drill Bit Limit	Verify the PWB design is within the board manufacturer developed and maintained matrix, which identifies the optimum number of drill hits allowed for the specific types of materials, number of layers, and hole diameters to be used.	Prevent cracking, crazing, and other premature board failure.
Drill Changes	Recommend that all drill bit changes are documented. Documentation may be in the form of a drill tape or any digital storage medium. Resharpening of drill bits should not be permitted.	Critical process control targeted to minimize board damage due to inner layer cracking, tearing, or metal trace disturbance.

TABLE 100-4: Quality Assurance and Processing Considerations (cont.)

Consideration	Mitigation Strategy	Rationale
Drilling Roadmap	Drilling of the panel should be such that drilling begins and ends in a coupon associated with each printed wiring board.	The coupons are used to validate the integrity of the boards. This allows for verification of drill bit integrity for the entire PWB.
Stacking	Stacking of more than two panels should not be permitted when drilling holes that are to be plated-through for double sided boards. Stacking of multilayered boards is not recommended.	Causes misalignment, uneven hole diameters, board cracking etc.
Solder Mask	Solder mask should meet the IPC-SM-840 class III and the vacuum stability specified in General Section of this handbook.	To meet the outgassing criteria
Tin-lead Plating	Recommended Tin-lead plating thickness is 0.0003" (0.001" and 0.002" before fusing on the surface mount boards to be processed by solder reflow) minimum. No solder plate on any surface which is to be laminated to an insulator, metal frame, heatsink, or stiffener should be allowed. Plating thickness and quality may be verified through coupons.	To provide good connections and to prevent any shorts or intermittent shorts that could cause latent board failure.
Fusing	Recommend only one fusing operation, whether or not the fusing process heats one or both sides of the board for all PWBs after solder plating and other processes. The fuse time and temperature should be recorded and in accordance with the proven manufacturer's processes. After fusing and touch up, the solder coating should be homogeneous and completely cover the conductors with no pitting or pinholes and show no non-wet areas. Side walls of the conductors need not be solder coated	Prevents solder embrittlement, uneven solder flow, development of cold joints, etc.

TABLE 100-4: Quality Assurance and Processing Considerations (cont.)

Consideration	Mitigation Strategy	Rationale
Ductility	Verify the board manufacturer copper plating meets a minimum of 12% elongation factor on consistent basis. Once per week and the rotating cylinder method have been used traditionally.	Process control verification to prevent plating solutions contamination and deterioration.
Process-control Coupons	Recommend the board manufacturer uses the process control coupons as the means for verification and validation of their processes. The process control coupons number to be used per panel should be derived by the manufacturer based on proven methodology. The coupons may be deliverable to the contract or maintained on file by the board manufacturer.	Provide the means for board process verification and validation at future date. The coupons are often used in Failure Analysis for board processing verification, thus saving the much more expensive boards from being destroyed unnecessarily.
Solder Plate Coupons	Remove the solder plate coupons from each board prior to fusing to verify the plating thickness and quality prior to fusing operation.	Independent means for verification of solder plating prior to fusing, used by the contractor as point of reference for incoming receiving inspection, process validation, etc.
Deliverable Coupons	Provide two deliverable A or B coupons, suitable to monitor the processes involved, per board for double-sided and multilayer PWBs, or two deliverable coupons per 150 square centimeters (24 square inches) of panel area, whichever is less for small board sizes.. These deliverable coupons are in addition to the process-control coupons required for each panel. All coupons need to be completely processed with the deliverable boards. For each panel, at least one of these deliverable coupons needs to be break away (partially routed) and delivered attached to a production board on that panel.	The coupons are key to process verification and therefore, their location selection is very important; The following locations have proven to be acceptable; 1st on the panel in positions across the diagonal of each board. 2nd a single coupon located at the center area common to the inside corners of adjoining boards on a panel may be used as one of the required coupons for each of the adjoining boards. For example, for four large boards on a panel, a coupon at each of the four outside corners and a common coupon at the center, for a total of five coupons, are all that are required (See Figure 100-1 for preferred panel layups)

TABLE 100-4: Quality Assurance and Processing Considerations (cont.)

Consideration	Mitigation Strategy	Rationale
Marking	Mark individual boards and each set of quality conformance test circuit strips, and individual coupons in accordance with the master drawing and MIL-STD-130 with the date code (as specified below), the traceability serial number, the part number, and the manufacturers CAGE code. The date code is the date of final copper plating and is formatted as follows: Year — Day of year (from 1 January) 90 — 001	
Traceability	For traceability, it is recommended that each quality conformance test circuitry and all separated individual coupons are identifiable with those corresponding production boards produced on the same panel. Traceability should include all boards and coupons position on the panel, the exact disposition of each board, and documentation with the reason for rejection for the rejected boards.	
Storage and Retrievability	All deliverable coupons should be stored and be readily retrievable for the life of the contract.	
Qualification	The qualification should be based on the higher assembly levels qualification tests only, if the manufacturer is certified and qualified to MIL-P-55110.	

SECTION 200 CAPACITORS, INTRODUCTION

1.0 Scope

This section sets, forth common information for capacitors. Table 200-1 lists, by dielectric type, the capacitor styles included in this section and the applicable section in this handbook where the specific detailed information is located.

Table 200-1 Capacitor Styles Included in Section 200

Section	Dielectric Material	Ref. Specification	Style
210	Ceramic	Mil-C-123, MIL-C-4967	CKS, HVR
230	Metallized/Nonmetallized Film	MIL-C-83421/1, /2, /3, /4, MIL-C-87217, & MIL-C-19978	CRH, CRS, CHS, & CQR
240	Glass & Mica	MIL-C-23269, MIL-C-87164	CYR,
260	Tantalum Foil	MIL-C-39006	CLR
270	Solid Tantalum	MIL-C-39003 /1, /6, /10, & MIL-C-55365	CSR, CSS, & CWR
	Wet Tantalum-Tantalum Case	MIL-C-39006/22	CLR 79
	Wet Tantalum-Tantalum Case	MIL-C-39006/28 & MIL-C-39006/29	CLS 79 & CLS 81

2.0 Application For use of capacitors refer to MIL-STD-198 and the information contained in the capacitor type section of this handbook. For additional tantalum capacitor information refer to NASA TM X-64755.

3.0 Design and Construction The design and construction paragraph within the detailed part section provides information specific to the capacitor for recommended designs, known design and construction problems, known reliability suspect designs, known material hazards, and recommended topics to be addressed in a company unique drawing to control produceability and controlling a baseline from a vendor.

4.0 Quality Assurance The quality assurance section contains the recommended verification and validation during the procurement process, screening tests, lot conformance tests, and qualification tests for each capacitor type.

4.1 Production Lot The recommended production lot for high reliability capacitors is, capacitors of a single capacitance and voltage rating of one design, from the same dielectric material batch, and processed as a single lot through all manufacturing steps on the same equipment, to the same baseline documentation, and identified with the same date and lot code designation. The lot may contain all available capacitance tolerances for the nominal capacitance value.

5.0 Lessons Learned This paragraph has been inserted into this handbook to document information which from past experience and history which is not addressed in any other paragraph. This information was gained during failure reviews, incoming inspection history and any other source available which will give insight into problems which can be rectified.

SECTION 210 CERAMIC (CKS) MIL-C-123, (HVR) MIL-C-49467

1.0 Scope

1.1 This section contains information for fixed ceramic capacitors both general-purpose type (CKS) and High Voltage type (HVR). This section contains multiple styles, where the information is the same the style will not be indicated.

2.0 Application

2.1 This paragraph contains guidelines in Table 210-1 for derating and Table 210-2 for end-of life design limits that are considered minimum for Space Applications. Table 210-3 is an overview of specific product information which should considered prior to selection to an application, and one possible mitigation guide line if the product is selected.

Table 210-1 Derating

Device Type	Parameter	Derating Factor	Comments
CERAMIC			Not recommended for operation above 125°C Ambient Temperature
CKS, HVR	VOLTAGE 1/ CURRENT 2/	.50 of rated .70	Above 85°C derate linearly to 0.30 at 125°C Above 85°C derate linearly to 0.50 at 125°C

NOTES: 1/ Applied Voltage only.
2/ Applies to both Surge Current and Ripple Current

Table 210-2 End-of Life Design Limits

CKS Parameter	General Purpose BX (X7R)	Temperature Compensated BP (NPO)
Capacitance	± 21%	± 1.25% or ± 0.75pF, whichever is greater
Insulation Resistance	50% of initial limit	50% of initial limit
HVR Parameter	**General Purpose BR or BZ**	**Temperature Compensated BP**
Capacitance	± 21%	± 1.25% or ± 0.75pF, whichever is greater
Insulation Resistance	85% of initial limit	85% of initial limit

TABLE 210-3 Design Applications (Ceramic)

Style	Typical Applications	Application Considerations	Possible Mitigation
CKS	General Purpose	**Piezoelectric Concerns** Piezoelectric output: This can be minimized by → **Temperature Concerns** Ceramic cracks easily when subjected to extreme temperature environments.	Mounting chips on their side or on their end on the substrate or by using chips with a reduced length to width ratio. Mounting : Matching of temperature coefficient of expansions when mounting is key. To minimize part cracking, do not allow the capacitor termination to directly contact or come within 0.001 inch of contact to the conductor pads on the substrate.
HVR	High Voltage	**High Voltage Potential** This type of capacitor has the potential of voltage breakdown between the leads of the capacitor, or the capacitor to another potential **Piezoelectric Concerns** Same as CKS **Capacitor Cracking** Same as CKS	Additional encapsulation needs to be applied at mounting.
CKS HVR		**Environmental Limits** shock, vibe, operating ambient temperature, radiation, conformal coatings	Refer to MIL-C-123 Refer to MIL-C-123 & MIL-C-49467
		Handling Extreme care should be taken to avoid excessive thermal stresses when tinning or soldering termination's and leads or when mounting the capacitor on a substrate to prevent cracking.	Observe thermal management techniques during manufacturing operations.

TABLE 210-3 Design Applications (Ceramic) Cont'd

		Aging and Storage Sensitivity These devices are sensitive to cracking and chipping from rough handling or being dropped. No aging sensitivity on this product.	Observe packaging and storage techniques.

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Capacitors designed and qualified to MIL-C-123 for CKS, for HVR types capacitors designed and qualified to MIL-C-49467, screening and lot conformance to MIL-C-49467 and Table 210-9 (screen), Table 210-10 (lot conformance).

Table 210-4 Design and Construction Considerations

Style	Design & Construction Considerations	Possible Mitigation
CKS, HVR	Where avoidance of a significant piezoelectric output is critical to the circuit performance.	BP type dielectric is used in place of BX.

3.2 Known Reliability Suspect Designs The information in Table 210-5 describes products which have caused reliability problems in the past. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 210-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Capacitor type	Variable devices
Maximum Capacitance	50 V dc rated product in the CKS 06 style with a capacitance greater than 0.47 microFarad.
Thin Dielectric Product CKS HVR	 Capacitors containing active dielectric thickness of less then 0.0009" (23 Microns). The maximum stress allowed between plates should not exceed 100 volts/mil for BX dielectric or 200 volts/mil for BP dielectric.
Large Aspect Ratio Product CKS HVR	 Capacitors manufactured with design length-to width aspect ratio of greater than 2 to 1. (This product difficult to manufacturer without delaminations or distortion.) The length-to-width aspect ratio for these thicker ceramic capacitors should not exceed 1.8 to 1.
CKS	Capacitors that are manufactured with a conformally coated epoxy case

Conformal Coated Capacitors	rather than a thicker molded case.
CKS Testing	Capacitors not subjected to non-destructive testing as specified in MIL-C-123.
CKS Testing	Capacitors not subjected to low voltage, 85% relative humidity, 85°C test.

3.3 Known Material Hazards The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 210-6 Known Material Hazards

Material	Precaution
Tin coating	Capacitors with tin-coated leads are subject to tin dendrites.
HVR Encapsulation	The type of material should be carefully considered by the user regarding specific environmental requirements and the ceramic chip physical size.
HVR Conformal Coated	Parts using the dip or fluidized bed process provide a true **glue bond** to the ceramic body. However, severe thermal shock or temperature cycling may cause cracking due to thermal coefficient difference. True **molded cases** are prone to voids between the ceramic and the coating because there is no **glue bond** between the encapsultant and the ceramic. This condition may lead to corona failure on the surface of the ceramic. An **epoxy cup** with the capacitor back filled with resilient material may be subject to internal solder joint damage during vibration.
HVR Solder	Leads should be attached to the ceramic chip body using high temperature solder with a minimum plastic point of 260°C.

3.4 Produceability and Baseline Controls A product baseline should be established for all capacitors not purchased as a QPL MIL-C-123 device. Areas, which need to be specified and controlled in the drawing and baseline, are:

Table 210-7 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to MIL-C-123
Production Lot	Refer to MIL-C-123
Serialization	Refer to MIL-C-123
Traceability Control (Parts, Materials, & Processes)	Refer to MIL-C-123
Rework Provisions	Refer to MIL-C-123
Process Controls verification & validation	Refer to MIL-C-123
Screening Tests (100%)	Refer to MIL-C-123 for CKS & HVR styles additionally Table 210-9 herein for HVR
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-C-123 for CKS, Table 210-10 herein for HVR
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-C-123 for CKS, MIL-C-49467

Note: A manufacturing baseline should be developed and maintained by the manufacturer in accordance with MIL-C-123, and controlled and verified by the procuring organization.

4.0 Quality Assurance Provisions

4.1 The following table outlines the minimum areas, which should be considered and verified when purchasing QPL MIL-C-123 or Company specific ceramic capacitor drawings for styles CKS and HVR.

Table 210-8 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of MIL-C-123.	Lot Homogeneity Production Lot formation Device Serialization Traceability Control Rework Provisions I.A.W. approved procedures Process Controls and their verification & validation elements Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): refer to the requirements of MIL-C-123 for CKS style. Refer to the requirements of the SCD and Table 210-9 for HVR style.	Review screening data (Attributes & Variables). Verify test equipment correlation, repeatability, test windows were met, test conditions, and PDA compliance.
Lot Conformance: refer to the requirements of MIL-C-123 for CKS style. Refer to the requirements of the SCD and Table 210-10 for HVR style..	Review lot conformance data (Attributes & Variables).
Supplier DPA: should be in accordance with MIL-C-123.	Review supplier DPA and compare to incoming DPA.
Qualification Testing: refer to the requirements of MIL-C-123 for CKS style or MIL-C-49467 for HVR style.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

5.0 Lessons Learned

5.1 Screening Multilayer ceramic capacitors inherently have delaminations due to the processing. Adding SLAM as a 100% screen is very successful in finding this type of defect. SLAM should be used in conjunction and before corona testing.

Table 210-9 Screening Table (HVR)

MIL-C-49467 Tests	Additions and Exceptions to MIL-C-49467
Subgroup 1 2/ Thermal Shock Dielectric Withstanding Voltage Voltage Conditioning Partial Discharge Radiographic Inspection	 25 cycles 168 hours min.
Subgroup 2 1/ Visual and Mechanical Examination	
Subgroup 3 Destructive Physical Analysis	 Use sample size, procedures and accept/reject criteria documented in MIL-C-123
Subgroup 4 1/ Solderability	

1/ Use sample size documented in MIL-C-49467
2/ Total Percent Defect Allowed (PDA) for electrical tests in Subgroup 1 should not exceed 5%

Table 210-10 Lot Conformance Table (HVR)

MIL-C-49467 Tests	Additions and Exceptions to MIL-C-49467
Subgroup 1 Thermal Shock 1/ Life Test 1/ Partial Discharge	 100 cycles 1,000 hours
Subgroup 2 Voltage Temperature Limits Terminal Strength Moisture Resistance Resistance to Solder Heat Resistance to Solvents	Total subgroup sample 10 pieces, reject on 1

1/ Use sample size and accept/reject criteria documented in MIL-C-123

SECTION 230 FIXED, FILM METALLIZED/NONMETALLIZED (CRH,CRS) MIL-C-83421 /1,/2,/3,/4 (CHS) MIL-C-87217, AND (CQR) MIL-C-19978

1.0 **Scope** This section contains multiple styles of metallized film fixed capacitors, where the information is the same the style will not be indicated.

2.0 **Application** These film capacitors are used in DC and AC applications. Due to their non-clearing failure-to short characteristic and the general availability of parts of equivalent electrical performance and size within MIL-C-83421, it is recommended that the use of Style CQR capacitors be limited to those applications where capacitors covered by MIL-C-83421 are not available.

Table 230-1 Derating

Device Type	Parameter	Derating Factor	Comments
CRH CRS, CHS CQR			
Polypropylene 3/	VOLTAGE 1/ CURRENT 2/	.50 .65	Above 70°C derate linearly to 0.25 at 100°C
Polycarbonate 4/	VOLTAGE 1/ CURRENT 2/	.50 .65	Above 85°C derate linearly to 0.25 at 100°C
Vib environment	3db from screening 6db from QCI		

1/ Applied Voltage only.
2/ Applies to both Surge Current and Ripple Current
3/ Maximum operating temperature +70°C
4/ Maximum operating temperature +85°C

Table 230-2 End-of Life Design Limits

Capacitance	Insulation Resistance
± 2% of initial tolerance limits	70% of minimum limit

TABLE 230-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
CRH, CRS, CQR	High Energy and AC (E>500 µJ)	Not for circuits with less than 500 µJ of energy, or circuits that would be degraded by short duration voltage transients. Resistance Variance Polycarbonate capacitors may vary from 1 to 10,000MΩ at +125°C for capacitors values below 1.0µF.	**Caution:** Pin holes occur within the metallized film causing voltage transients. Energy is needed for clearing. Observe temperature derating
CHS	Low Energy (100µJ <E ≤500µJ)	These capacitors can exhibit momentary breakdowns in low-energy applications caused by pin holes within the metallized film. 100µJ of energy is needed to insure clearing breakdowns.	The circuit which uses capacitors of 0.1µF and greater capacitance value should be capable of providing at least 100µJ of energy. If circuit does not provide minimum energy needed it should be insensitive to momentary breakdowns.
CRH, CRS, CQR		Environmental Limits	Refer to MIL-C-83421
CHS		Environmental Limits	Refer to MIL-C-87217
	AC/DC Applications	Ac rated devices can be used in DC applications. However DC rated devices should not be used in AC applications because: 1. Dielectric heating 2. Pre-corona discharge 3. Resistance heating (Rs)	Use only AC rated devices for AC applications.
	Higher frequency applications	Needing stability at higher frequency	The equivalent series resistance (ESR) of each capacitor should be measured either at 100Khz or at a frequency approximately that of its intended application, which ever is higher.

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Capacitors designed and qualified to MIL-C-87217 (CHS), MIL-C-83421 /1, /2, /3, /4 (CRH, CRS) failure level S or MIL-C-19978 (CQR) failure level R and the additional tests of Screening Table 230-9, Lot Conformance Table 230-10

Table 230-4 Design and Construction Considerations

Construction	Information
CRH Style	Design information can be found in slash sheets 1 & 2
CRS Style	Design information can be found in slash sheets 3 & 4
CHS Style	Design information can be found in MIL-C-87217
CQR Style	Design information can be found in MIL-C-19978
Double-Wrap	Capacitors made with an extra layer of non-metallized film have a low percentage of parts exhibiting shorting and clearing. This design may also have reduced ac current capabilities.
Film Cleaning	Film used should be vacuum baked for 48 hours prior to winding to remove contaminant residues.
Winding Installation	Windings installed in cases whose diameter is 0.312 inch or larger needs to be wrapped or encapsulated to prevent radial motion during shock and vibration.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 230-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Develops shorts in the 10 - 10,000Ω range.	Metallized/non-metallized film capacitors are made with very thin polymeric film which causes pin holes, which cause shorts exhibiting itself as a momentary transient.
Intermittent operation	The believed cause is ionic contamination within the capacitor enclosure, it can cause spurious, random conduction when operated during temperature changes and where the total circuit energy is less than 500 microjoules.
High Frequency applications	When device ESR readings are greater than twice the standard deviation above the lot average, even though within specified limits, those devices are a reliability risk to use in space applications.
CQR - DC voltage	Parts whose voltage rating is less than 50 volts.

3.3 Known Material Hazards_ The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 230-6 Known Material Hazards

Material	Precaution
Aluminum Alloy	Should not be used due to the thinness of the films and the contamination level of a normal alloy, when aluminum is used it should be 99.9% pure
Polycarbonate film	Devices manufactured with 2.0 or less microns.
Polypropylene film	Devices manufactured with 4.0 or less microns

3.4 Produceability and Baseline Controls A product baseline should be established for all capacitors not purchased as a QPL MIL-C-83421 CRS style or QPL MIL-C-87217 CHS style device. Areas which need to be specified and controlled in the drawing and baseline are:

Table 230-7 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-C-83421 (CRH, CRS), MIL-C-87217 (CHS), OR MIL-C-19978
Process Controls Verification & Validation	Refer to MIL-C-83421(CRH, CRS), MIL-C-87217 (CHS), or MIL-C-19978
Screening Tests (100%)	Refer to MIL-C-83421 and Table 230-9 for CRH and CQR style. MIL-C-83421 /3, /4 for CRS style. MIL-C-87217 for the CHS style
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-C-83421 Table 230-10 for CRH and CQR style. MIL-C-83421 /3, /4 for CRS style. MIL-C-87217 for the CHS style
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-C-83421 for CRH style. MIL-C-83421 /3, /4 for CRS style. MIL-C-87217 for the CHS style and MIL-C-19978

Note: A manufacturing baseline should be developed and maintained by the manufacturer and controlled and verified by the procuring organization for (company unique drawings),.for QPL reliability level S capacitors the manufacturing baseline should be verified by the procuring organization.

4.0 Quality Assurance Provisions

4.1 The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-C-87217 and company specific capacitor drawings for styles CRH or QPL MIL-C-83421 /3 & /4 for CRS style, QPL MIL-C-87217 for CHS style and QPL MIL-C-19978 and company specific drawings for style CQR.

Table 230-8 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline. CRH and CQR style CRH style	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests) Specifically the following verifications are essential for this product: 1. Internal visual examination at 5X minimum of the lead attachment to capacitor end metallization 2. Axial push test to verify tight fit between element and case. (Not necessary for potted parts or capacitors whose case diameter is less than 0.312 inch.) 3. Lot sample pull test to verify attachment of lead wires to end metallization.
Screening (100 percent): refer to the requirements of the company unique drawing and MIL-C-83421 and Table 230-9 for CRH and CQR styles. MIL-C-83421 /3, /4 for CRS style. MIL-C-87217 for the CHS style.	Review screening data (Attributes & Variables).
Lot Conformance: refer to the requirements of the company unique drawing and MIL-C-83421 and Table 230-10 for CRH and CQR styles. MIL-C-83421 /3, /4 for CRS style. MIL-C-87217 for the CHS style	Review lot conformance data (Attributes & Variables).
Qualification Testing: refer to the requirements of MIL-C-83421 for CRH style. MIL-C-83421 /3, /4 for CRS style. MIL-C-87217 for CHS style and MIL-C-19978 for	Review qualification data (Attributes & Variables).

CQR style	
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

Table 230-9 Screening Table

MIL-C-83421 Screens for CRH/CQR style	Additions and Exceptions to the Methods and Criteria of MIL-C-83421
Thermal Shock	MIL-STD-202, Method 107, Cond. B except: 55^{o}C to 100^{o}C for 10 cycles
DC Burn-In	168 hours min. @ +100^{o}C
AC Burn-In 1/	48 hours min. @ 100^{o}C Maximum AC current, 120% of IAC rated @ 40 kHz 2/
Seal	
Dielectric Withstanding Voltage	
Insulation Resistance	
Capacitance	
Dissipation Factor	
ESR	Only AC applications
Visual/Mechanical Examination (External)	
Radiographic Inspection	To MSFC-STD-355; 2 views 90^o.apart by x-ray, or 360^o view by Vidicon. The use of "real-time" x-ray systems capable of viewing through 360^o rotation is encouraged.
N-Ray (For potted parts only)	Verify that no detectable potting voids are present.

1/ Not necessary for DC applications only.
2/ VAC should not exceed 240 VRMS under any conditions

Table 230-10 Lot Conformance Table

MIL-C-83421 Screens for CRH/CQR style	Additions and Exceptions to Methods and Criteria of MIL-C-83421
Subgroup 1	
DC Life (Accelerated)	4 devices for 2,000 hours
AC Life (Accelerated) AC Application Only	4devices with the highest ESR readings for 250 hours Maximum AC current, 120 % of IAC (RMS); Minimum current 3 times the system application, adjusted for 40 kHz operation. VAC frequency of 40 kHz +2%. 1/
Capacitance Dissipation Factor Insulation Resistance Seal	Readings taken @ +25°C and +125°C
Subgroup 2	
Vibration (Random) (Sine)	Sample of 6, MIL-STD-202, Method 214, test Cond. II K Vib axis 2 orthogonal planes, 15 minutes vibration
Terminal Strength	
Dielectric Absorption	
Capacitance Dissipation Factor Insulation Resistance Seal	
Subgroup 3	
Shock	Sample of 6, MIL-STD-202, Method 213, Cond. D (500g)
Solderability	
Temperature Coefficient	
Capacitance Dissipation Factor Insulation Resistance Seal	

1/ VAC should not exceed 240 VRMS under any conditions

SECTION 240 FIXED GLASS CAPACITORS (CYR) MIL-C-23269, (CMS) MIL-C-87164

1.0 Scope This section contains information on two styles of fixed glass capacitors, where differences occur they will be noted by style.

2.0 Application, These parts are useful in ultrastable and high-frequency applications.

Table 240-1 Derating

Style	Parameter	Derating Factor	Comments
			Not recommended for operation above 85°C Ambient Temperature
CYR	VOLTAGE 1/ CURRENT 2/	.80 .70	Above 25°C derate linearly to .25 at 85°C

NOTES:

1/ Applied Voltage only.
2/ Applies to both Surge Current and Ripple Current

Table 240-2 End-of Life Design Limits

Style	Capacitance	Insulation Resistance
CYR	± 0.5% of initial limits or 0.5pf, whichever is greater	500,000 megohms @ +25°C 50,000 megohms @ +125°C
CMS	± 0.5% of initial limits	70% of initial minimum limit

TABLE 240-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
CYR, CMS	Ultrastable and High Frequency	Capacitance range limited to 10,000pf	Follow derating guidelines
		Glass capacitors are relatively expensive, have poor volumetric efficiency	
		Dielectric has near perfect properties (high IR, high Q, ultrastable capacitance, low dielectric absorption, and fixed TC	
CMS		Not hermetically sealed device	Use in a controlled environment application

3.0 Design and Construction Design and construction information can be found in MIL-C-23269(CYR) or MIL-C-87164 (CMS). The following table documents some key information about the design and construction of these type of capacitors.

Table 240-4 Design and Construction Considerations

Construction	Information
CYR Style	Hermetically sealed
CMS Style	Not hermetically sealed
CMS Style	Electrical characteristics almost identical to the CYR style
CYR Style	Design and construction information contained in MIL-C-23269
CMS Style	Design and construction information contained in MIL-C-87164

3.1 Recommended Design for Space and Launch Vehicles Capacitors designed and qualified to MIL-C-23269 failure level S, recommended styles CYR10, 15, 20, 30 only, or MIL-C-87164 CMS when application is a controlled environment.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 240-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Radial lead devices	CYR41, 42, 43, 51, 52, and 53 styles
Non-hermetic device	CMS Style

3.3 Produceability and Baseline Controls A product baseline should be established for all capacitors not purchased as a QPL MIL-C-23269 CYR style or QPL MIL-C-87164 CMS style device. Areas which need to be specified and controlled in the drawing and baseline are:

Table 240-5 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-C-23269 (CYR),or MIL-C-87164 (CMS)
Process Controls Verification & Validation	Refer to MIL-C-23269 (CYR),or MIL-C-87164 (CMS)
Screening Tests (100%)	Refer to MIL-C-23269 (CYR),or MIL-C-87164 (CMS)
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-C-23269 (CYR),or MIL-C-87164 (CMS)
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-C-23269 (CYR),or MIL-C-87164 (CMS)

Note: A manufacturing baseline should be developed and maintained by the manufacturer and controlled and verified by the procuring organization for (company unique drawings),.for QPL reliability level S capacitors the manufacturing baseline should be verified by the procuring organization.

4.0 **Quality Assurance Provisions** The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-C-23269 or company specific capacitor drawings for style CYR, or QPL MIL-C-87164 CMS style.

Table 240-6 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): refer to the requirements of MIL-C-23269 for CYR, MIL-C-87164 for CMS	Review screening data (Attributes & Variables).
Lot Conformance: refer to the requirements of MIL-C-23269 for CYR, MIL-C-87164 for CMS	Review lot conformance data (Attributes & Variables).
Qualification Testing: refer to the requirements of MIL-C-23269 for CYR, MIL-C-87164 for CMS	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

SECTION 260 FIXED, TANTALUM FOIL (CLR)MIL-C-39006

1.0 Scope

1.1 This section covers fixed tantalum-foil capacitors styles CLR 25, 27, 35, and 37.

2.0 Application

2.1. MIL-C-39006 tantalum foil capacitors are not recommended for new designs. This is a single-source item, there is a likelihood that the supplier will not support users needs indefinitely. These capacitors are recommended for either medium or high voltage applications where high capacitance is required.

Table 260-1 Derating

Device Type	Parameter	Derating Factor	Comments
CLR	VOLTAGE 1/ CURRENT 2/	.70 .70	Above 25°C derate linearly to .5 at 85°C Not recommended for operation above 85°C Ambient Temperature

NOTES:

1/ Applied Voltage only.
2/ Applies to both Surge Current and Ripple Current

Table 260-2 End-of Life Design Limits

Capacitance	Insulation Resistance
± 15% of initial tolerance limits	130% of maximum limit

TABLE 260-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
CLR 25, 27, 35, 37	Medium or High Voltage	Should not be used at temperatures above 85°C	Specially established derating is required, or reliability study needs to be performed as there is lack of evidence these parts will perform reliability at higher temperatures.
CLR 25,27	High capacitance	The etched-foil provides as much as 10 times the capacitance per unit area as the plain for a given size.	
CLR 35,37	High ripple currents, Temperature coefficient characteristics	This style can withstand approximately 30% higher ripple currents, has better temperature coefficient characteristics and a lower dissipation factor.	
	Shock or vibration environment	Excessive shock or vibration environment.	Only "H" designed devices should be used, with design capability and qualification of the parts.
		Polarized Style These styles can only withstand a maximum of three (3) volts dc reverse voltage at 85°C. Under these conditions Electrical characteristics changes which are possible are: Capacitance: ±10% of initial value. Leakage Current: 125% of initial max. limit.	Assure application is tolerant to these changes or limit reverse dc voltage. Use in applications below 85°C, use non-polarized style.
		CLR 25 & 35 are polarized CLR 27 & 37 are non-polarized	Mounting Care should be taken to ensure correct polarity.
	Potted Modules	Glass end seals are designed to withstand high internal pressure	Potted Modules End seals need to be protected to withstand high external pressures that can result from curing of the encapsulant.

3.0 Design and Construction Design and construction information can be found in MIL-C-39006. The following table documents some key information about the design and construction of these types of capacitors.

Table 260-4 Design and Construction Considerations

Construction	Information
Plain	Style CLR 35 and 37
Etched-foil	Style CLR 25 and 27
Tantalum Capacitor Packs	See NASA TM X-64755
Glass end seals	The glass end seals are designed to withstand internal pressure. When parts are potted, end seals should be protected to withstand high external pressures that can result from curing of the encapsulant.
Vibration spacer	Needed to prevent axial motion in a vibration environment.
Wrapped capacitive element	Needed to ensure element is securely positioned within the case in a vibration environment.
Internal lead wire welds	Should not be used in a shock or vibration environments.
Design and Construction	Design and construction is documented in MIL-C-39006.

3.1 Recommended Design for Space and Launch Vehicles Capacitors designed and qualified to MIL-C-39006 failure level R or higher and the additional test of this Handbook.

3.2 Produceability and Baseline Controls A product (manufacturing) baseline should be established for all capacitors purchased to MIL-C-39006. Areas which need specific attention in the drawing and manufacturing baseline are:

Table 260-5 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-C-39006
Process Controls Verification & Validation	Refer to MIL-C-39006
Screening Tests (100%)	Refer to MIL-C-39006 and Table 260-7 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-C-39006 and Table 260-8 herein.
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-C-39006, Table I.

4.0 Quality Assurance Provisions The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-C-39006 and company specific capacitor drawings for style CLR.

Table 260-6 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation 1. Verify that each capacitor element fits snugly within the case and that vibration spacers are installed. Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): refer to the requirements of MIL-C-39006 and Table 260-7 herein.	Review screening data (Attributes & Variables).
Lot Conformance: refer to the requirements of MIL-C-39006 and Table 260-8 herein	Review lot conformance data (Attributes & Variables).
Qualification Testing: refer to the requirements of MIL-C-39006 Table I	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

Table 260-7 Screening Table

MIL-C-39006 Screens	Additions & Exceptions to MIL-C-39006
Thermal Shock	• -65°C to +125°C for 5 cycles • Transfer between chambers 5 minute max.
Constant Voltage Conditioning	• Maximum series resistance: 33 Ohms • Burn-in time 168 hours at +85°C
DC Leakage	
Capacitance	
Dissipation Factor	
Seal	Test conditions A and C
Radiographic Inspection	• To MSFC-STD-355; 2 views 90°.apart by X-Ray, or 360° view by using “real-time” X-Ray systems capable of viewing through 360° rotation. • Moderate “telescoping” of roll is acceptable • Case Size — Max Width Incl. Telescoping • G1 — 0.350" • G2 — 0.4375" • G3 — 0.7175" • G4 — 1.4219" • G5 — 2.00"
Visual/Mechanical Examination (External)	

Table 260-8 Lot Conformance Table

MIL-C-39006 Screens	Additions and Exceptions to Methods and Criteria of MIL-C-39006
Subgroup 1	
Thermal Shock	During last cycle, monitor capacitance to verify no opens.
Surge Voltage	Maximum series impedance: 33 Ohms
Life	At +85°C for 1,000 hours
DC Leakage	At +25°C and +85°C
Capacitance	
Dissipation Factor	
ESR	At 40 Khz or greater Does not apply to DC applications
Seal	Test condition A and C
Visual/Mechanical Examination (External)	
Subgroup 2	
Thermal Shock	20 cycles
Mechanical Shock	500g's
Vibration (Random)	MIL-STD-202, Method 214, Test Condition II, K for 15 minutes each axis.
Moisture Resistance	
Reverse Voltage	
DC Leakage	At +25°C and +85°C
Capacitance	
Dissipation Factor	
Seal	Test conditions A and C
Visual and Mechanical Examination (External)	

SECTION 270 FIXED, ELECTROLITIC, TANTULUM SOLID (CSR 13, CSR 33) MIL-C-39003 /1 and /6 and (CWR) MIL-C-55365

1.0 Scope This section describes information for two styles of capacitors CSR (packaged) and CWR (chip). This section identifies the information which is different between the two styles by identifying the style the information applies to. Where the information is the same there is no notation of style.

2.0 Application

Table 270-1 CSR and CWR Derating

Device Type	Parameter	Derating Factor	Comments
CSR CWR	VOLTAGE 1/ CURRENT 2/	.70 .70	Above 25°C derate linearly to .5 at 85°C Not recommended for operation above 85°C Ambient Temperature

NOTES:

1/ Applied Voltage only.
2/ Applies to both Surge Current and Ripple Current

TABLE 270-2 CWR Surge Voltage Ratings

Voltage (volts, dc) Symbol	Steady State Rated (+85°C)	Voltage Derated (+85°C)	Maximum Surge Voltage (-55°C to +85°C)
B	3	2.1	3
C	4	2.8	4
D	6	4.2	6
F	10	7.0	10
H	15	10.5	15
J	20	14.0	20
K	25	17.5	25
L	30	21.0	30
M	35	24.5	35

TABLE 270-3 End-of Life Design Limits

Capacitance	Insulation Resistance
± 10% of initial limits	200% of initial maximum limit

TABLE 270-4 Design Applications Solid Tantalum

Style	Description	Typical Application	Application Considerations	Possible Mitigation
CSR13 & 33	Solid Tantalum	Low Energy Greater than 1ohm per volt applications	This style is polarized	Mounting Care should be taken to ensure correct polarity
			should not be used in mission significant circuits with an impedance of less than 1 ohm per volt.	CSS types may be directly substituted for CSR style parts of equal capacitance and voltage.
			Capacitors of this type with voltage rating of more than 75 volts require thicker dielectrics, containing more impurities	Capacitors with a dc working voltage rating of 75 volts or less should be used.
			These devices exhibit high temperature coefficients of capacitance.	This part is recommended where a high capacitance to volume ratio is required and where relatively high temperature coefficients of capacitance can be tolerated.
CSR13 & 33	Solid Tantalum	Low Energy Less than 1ohm per volt applications	Source impedance of at least 1 ohm should be used in all circuits containing these parts to act as a transient suppressor	Source impedance current limiting in circuits is needed to guarantee that the effective maximum current is not exceeded.
			This style is polarized	Mounting Care should be taken to ensure correct polarity
			These devices exhibit high temperature coefficients of capacitance.	Recommended where a high capacitance to volume ratio is required and where relatively high temperature coefficients of capacitance can be tolerated
CWR	CHIP	Minimum Circuit Impedance Circuit impedance of 1W per volt or more.	Device is unencapsulated Provide improved protection from handling damage	Mount last in the assembly sequence. Perform detailed visual examination for surface damage before applying the circuit conformal coating or hybrid sealing. Apply a thin protective coating.

3.0 **Design and Construction** This table documents some key information about the design and construction of these type of capacitors.

TABLE 270-5 Design and Construction

Construction	Information
Style CSR13	Design and construction information documented in MIL-C-39003 /1
Style CSR33	Design and construction information documented in MIL-C-39003 /6
Style CWR	Design and construction information documented in MIL-C-55365
Style CSS	Design and construction information documented in MIL-C-39003/10
CWR Outer Case	This style has no outer case, nor does it have encapsulation to protect it.
CWR Terminations	Are either wrap around or T-bar.
CWR Protective Coating	The body of the CWR style needs to be covered by a thin protective coating to provide improved resistance to handling damage.
CSR 13, 33 and CSS 13, 33	Capacitors should be designed with a dc working voltage of 75 volts or less (Higher voltage ratings require thicker dielectrics, containing more impurities, while the lower voltage parts utilize a small tantalum slug).

3.1 **Recommended Design for Space and Launch Vehicles** Capacitors designed and qualified to MIL-C-39003 styles CSS13, CSS33, failure level "C" when available or use failure rate "B", CSR13 AND CSR33 failure level C or higher, and MIL-C-55365 style CWR failure level R or C or higher and the additional tests of this Handbook.

3.2 **Known Reliability Suspect Designs** The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. History from MIL-STD-1547 is included.

TABLE 270-6 Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
CWR - Highest Capacitance	The highest capacitance value in any given size is suspect
CWR - Terminations	The extended termination designs are more susceptible to handling damage than more compact termination designs.

3.3 **Known Design and Manufacturing Problems** The following table describes design and manufacturing problems which have been identified as the cause of reliability problems.

TABLE 270-7 Reliability Problems

Material	Precaution
CSR Thicker Dielectric	Contain more impurities. Device with a dc working voltage of 75 volts or less use small tantalum slug.

3.4 **Produceability and Baseline Controls** A product (manufacturing) baseline should be established for CSS style purchased to MIL-C-39003 /10, CSR style purchased to MIL-C-39003 /1 and /6, and for CWR style purchase to MIL-C-55365. Areas which need specific attention in the drawing and manufacturing baseline are:

Table 270-8 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot for CSS and CSR For CWR	Refer to Section 200 A Production lot is: all the capacitors of a single nominal capacitance (may include contain all available capacitance tolerances for that nominal value) and voltage rating of one design, processed as a single lot through all manufacturing steps on the same equipment and identified with the same date and lot code designation as outlined below: a. Raw materials (tantalum powder, manganese nitrate, colloidal carbon, and termination materials) should be from the same lot batch and the same manufacturer. b. Lot numbers should be assigned at anode formation and should be traceable to the anode pressing batch and tantalum powder batch used. c. The anode should be pressed in a continuous run on the same pressing machine and should be sintered and temperature-processed as a complete batch (not split during sintering or subsequent temperature conditioning). d. The entire production lot should be voltage-formed (at the same time and in the same tank), impregnated, and otherwise processed through final sealing as a complete production lot with all parts receiving identical processing at the same time. e. Terminations and lead materials (including and solder flux) should each be from a single receiving inspection lot and a single vendor.
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-C-39003 /1 and /6 for CSR styles, MIL-C-55365 for CWR style and MIL-C-39003/10 for CSS.
Process Controls Verification & Validation	Refer to MIL-C-39003 /1 and /6 for CSR styles, MIL-C-55365 for CWR style and MIL-C-39003/10 for CSS
Screening Tests (100%)	Refer to MIL-C-39003 /1 and /6 for CSR styles, MIL-C-55365 for CWR and Table 270-10 herein and MIL-C-39003/10 for CSS.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-C-39003 /1 and /6 for CSR styles, and Table 270-11 herein, MIL-C-55365 for CWR and MIL-C-39003/10 for CSS..
Qualification Tests (Destructive & Non-	Refer to MIL-C- MIL-C-39003 /1 and /6 for CSR

destructive tests)	styles, MIL-C-55365 for CWR style and MIL-C-39003/10 for CSS.

4.0 **Quality Assurance Provisions** The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-C-39006 and company specific capacitor drawings for style CLR.

Table 270-9 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-C-39003 /1 and /6 for CSR styles, MIL-C-55365 for CWR and Table 270-10 herein and MIL-C-39003/10 for CSS	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-C-39003 /1 and /6 for CSR style, and Table 270-11 herein, MIL-C-55365 for CWR and MIL-C-39003/10 for CSS.	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to MIL-C- MIL-C-39003 /1 and /6 for CSR styles, MIL-C-55365 for CWR style and MIL-C-39003/10 for CSS	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

TABLE 270-10 Screening

CSR Styles MIL-C-39003 /1 & /6 CWR Style MIL-C-55365 Screens	Additions to Group A Inspection (exponential distribution) MIL-C-39003 /1 and /6 for CSR Styles MIL-C-55365 for CWR Style
Thermal Shock	10 cycles
Surge Current a) b)	5 cycles at -55°C and +85°C Maximum impedance in series with each capacitor: 1Ω including a fast blow fuse (10%), wiring, fixturing, and output impedance of power supply.

c)	Minimum peak current to each capacitor: 25A in 5µ seconds
Voltage Aging	Weibull aging conditions of MIL-C-39003 or MIL-C-55365 to achieve a minimum of “C” failure rate.
DC Leakage	+25°C and +85°C
Capacitance	
Dissipation Factor	
ESR	a) For AC applications only b) At 40 Khz c) If the application involves frequencies above 1 MHz, measurement should be a minimum frequency of 1 MHz.
Seal	
Radiographic Inspection	To MSFC-STD-355; 2 views 90°.apart by X-Ray, or 360° view by using “real-time” X-Ray systems capable of viewing through 360° rotation.
Visual/Mechanical Examination (External)	

TABLE 270-11 Lot Conformance

MIL-C-39003 /1 & /6 Screens	Additions to the Methods and Criteria of MIL-C-39003 /1 and/6 (Weibull distribution)
Thermal Shock	20 cycles
Stability at Low & High Temperature	
Surge Voltage	
Life (+85°C)	Maximum series resistance: 1.0 Ω
DC Leakage	At +25°C and +85°C
Capacitance	
Dissipation Factor	
Seal	
Visual and Mechanical Examination	

SECTION 280 FIXED, TANTALUM-TANTALUM CAPACITOR (Sintered Wet Slug, CLS 79 & CLS 81, (MIL-C-39006/28 & /29) and CLR 79, (MIL-C-39006/22)

1.0 Scope

1.1 This section describes information for Class S wet sintered tantalum slug capacitors in tantalum cases. Also, CLR 70 style.

2.0 Application

Table 280-1 Derating

Device Type	Parameter	Derating Factor	Comments
CLR CLS	VOLTAGE 1/ CURRENT 2/	.70 .70	Above 25°C derate linearly to .5 at 85°C Not recommended for operation above 85°C Ambient Temperature

NOTES:

1/ Applied Voltage only.
2/ Applies to both Surge Current and Ripple Current

TABLE 280-2 End-of Life Design Limits

Capacitance	Insulation Resistance
± 10% of initial limits	130% of initial maximum limit

TABLE 280-3: Design Applications Solid Tantalum

Style	Description	Typical Application	Application Considerations	Possible Mitigation
CLS 79 & 81 and CLR 79	Wet tantalum slug	Low impedance	These are polarized devices	Mounting Care should be taken to ensure correct polarity
			Reverse voltage	Use at 3.0 Vdc @ +85°C or 20% of the rated dc voltage, which ever is less.
		High frequency applications		For applications between 10KHz and 100KHz measure and read and record 100% Equivalent Series Resistance (ESR) during Group A testing.
CLR 79			These parts can generate voltage spikes in active circuits during vibration or shock environments. Vibration and shock environments	Perform design analysis to assure circuit is robust for voltage spikes. Use "H" vibration screened parts tested to 80G sine vibration (0.06 double amplitude) from 10 to 2000 Hz for 1 1/2 hours in each orthogonal axis. Parts have been shocked to 100g for 6 milliseconds with saw tooth pulse.

3.0 Design and Construction This table documents some key information about the design and construction of these type of capacitors.

TABLE 280-4 Design and Construction

Construction	Information
Style CLS 79	Design and construction information documented in MIL-C-39006 /28
Style CLS 81	Design and construction information documented in MIL-C-39006 /29
Style CLR 79	Design and construction information documented in MIL-C-39006 /22

3.1 Recommended Design for Space and Launch Vehicles Capacitors designed and qualified to MIL-C-39006 styles CLS 79 & CLS 81, Class "S.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. History from MIL-STD-1547 is included.

TABLE 280-5 Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Acid leaking	Single sealed CLR 79 design (identified with its compression seal construction) incorporating liquid electrolytes are reliability suspect and constitute a safety hazard.
Silver dendrites	Silver cased, CLR wet slug types

3.3 Produceability and Baseline Controls A product (manufacturing) baseline should be established for CLR styles purchased to MIL-C-39006 /22. Areas which need specific attention in the drawing and manufacturing baseline are:

Table 280-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-C-39006 /22
Process Controls Verification & Validation	Refer to MIL-C-39006 /22. In addition, each capacitor anode assembly should be inspected at a minimum of 10X magnification. All parts note meeting the following requirements should be rejected: a. The tantalum anode (slug) should be straight, not bent or distorted. All anodes in a given lot should be the same size. b. The anodes should be of the same uniform color. c. The anode should fit snugly and be firmly seated within the top and bottom PTFR vibration spacers.
Screening Tests (100%)	Refer to MIL-C-39006 /22 and Table 280-9 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-C-39006 /22, and Table 280-10 herein.
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-C-39006 /22

4.0 **Quality Assurance Provisions** The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-C-39006 and company specific capacitor drawings for style CLR.

Table 280-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-C-39006 /22 and Table 280-9 herein.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-C-39006 /22 and Table 280-10 herein.	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to MIL-C-39006 /22	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

4.1 **Table 280-8 Quality Assurance Provisions for CLS type Capacitors**

Quality Assurance Consideration	Recommended Verifications and Validations
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.

TABLE 280-9 Screening

MIL-C-39006 /22 Screens	Additions and Exceptions to the Method and Criteria of MIL-C-39006 /22
Thermal Shock	10 cycles
Constant Voltage Conditioning	Maximum series resistance: 33°Ω Burn-in time: 168 hours @ +85°C
DC Leakage	
Capacitance	
Dissipation Factor	
ESR	a) For AC applications only b) At 10 KHz to 100 KHz c) Equivalent series resistance measurements should be read and recorded during Group A testing on 100% basis for data collection.
Vibration screening	When vibration screening is required the following test conditions apply a) Direction of Vibration - The direction of vibration should be perpendicular to the cylindrical axis of the capacitor. b) Test Potential - The rated voltage of each part should be applied. c) Sinusoidal Vibration - All parts should be tested per MIL-STD-202, Method 214, Test Condition H, (80 g) d) Random Vibration - All parts should be tested per MIL-STD-202, Method 214, Test Condition II, K (51.1 g rms) e) Continuous Monitoring - During all vibration tests the dc leakage current should be continuously monitored across a 10 kilohms resistor connected in series with each part under test. f) Post-Vibration Measurements - After completion of all testing, parts should be subjected to dc leakage measurements at +25°C and +125°C and capacitance and dissipation factor measurements at +25°C, all per MIL-C-39006 /22. g) Failure Criteria - All parts should be rejected whose post-vibration electrical measurements are not within the limits specified in MIL-C-39006 /22 or who exhibit intermittent voltage spikes of 0.3 milliseconds or greater duration, or arcing, open, or short circuiting during vibration testing. h) Visual and Mechanical Examinations - All parts should be visually examined per MIL-C-39006 /22 after testing. Any part showing evidence of mechanical damage or electrolyte leakage should be rejected.
Seal	
Visual/Mechanical Examination (External)	

TABLE 280-10 Lot Conformance

MIL-C-39006 /22 Screens	Additions and Exceptions to the Methods and Criteria of MIL-C-39006 /22)
Subgroup I	
Thermal Shock	During last cycle, monitor capacitor to verify no opens
Life	
DC Leakage	At +25°C and +85°C
Capacitance	
Dissipation Factor	
Seal	
Visual and Mechanical Examination	
Subgroup II	
Thermal Shock	100 cycles
Mechanical Shock	500g, 0.5 sine (1 millisecond duration)
Vibration (Random)	MIL-STD-202, Method 24, Test Condition 11K for 15 minutes each axis.
Moisture Resistance	
Reverse Voltage	
DC Leakage	At +25°C and +85°C
Capacitance	
Dissipation Factor	
Seal	
Visual and Mechanical Examination	

SECTION 300 CONNECTORS

1.0 Scope

This section contains detailed information for space qualified connectors. Additional information and guidance for the general use of connectors can be found in MIL-STD-1353.

2.0 Application

The following tables contain information about space qualified connectors to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 300-1 Derating

Parameter	Derating Factor	Comments
Current	Based on max. rated temperature minus 50C	See TABLE 300-3 for temperature calculations
Altitude Voltage		Use the Voltage Derating at Altitude from AFSCP-800-27, Section I or 50% of the High Altitude Voltage listed in the detail specification.

End of life Design Considerations. The service life of a connector is dependent on the temperature rating of the insert, the contact resistance of the contacts, the current flowing through the contacts, and other environmental factors. It is recommended that no contact carries sufficient current to cause a hot spot temperature which reduces the connector's expected service life less than that required for the application. The service life versus hot spot temperatures relationship Figure 7.04 is provide for guidance. It is recommended that the selected insert have a temperature rating which provides twice the service life of the system requirements (test and operational).

TABLE 300-2- Insert Temperature Rise (ΔT°C) Determination

Insert Type	Amperes Per Contact	Contact Gauge				
		26	22	20	16	12
A,B,C,D	1	2	1	1	1	0
A,B,C,D	2	8	4	2	2	0
A,B,C,D	3	16	8	5	4	1
A,B,C,D	4	27	13	8	5	1
A,B,C,D	5	41	19	13	8	2
A,B,C,D	6		27	18	10	3
A,B,C,D	7		36	23	13	4
A,B,C,D	8		46	30	16	5
A,B,C,D	9		57	37	19	6
A,B,C,D	10		70	45	41	7
Note 1	15			96	70	15
Note 2	20				106	26
A,B,C,D	25					39
A,B,C,D	30					54
A,B,C,D	35					72
A,B Only	40					92
$\Delta T=2.100(i)^{1.85}$		26 Gauge Contacts				
$\Delta T=0.989(i)^{1.85}$		22 Gauge Contacts				
$\Delta T=0.640(i)^{1.85}$		20 Gauge Contacts				
$\Delta T=0.274(i)^{1.85}$		16 Gauge Contacts				
$\Delta T=0.100(i)^{1.85}$		12 Gauge Contacts				
ΔT= Insert Temperature Rise						
i= Amperes per Contact						
ΔT= 5°C		RF Coaxial Connectors				
ΔT= 50°C		High Power Applications of RF Coaxial Connectors				

Note 1: Use A,B Insert types only for 20 Gauge Contacts carrying 15A.

Note 2: Use A,B Insert types only for 16 Gauge Contacts carrying 20A.

TABLE 300-3 Design Applications

Typical Applications	Application Considerations	Possible Mitigation
Whenever possible		Use closed - entry - type socket contacts.
Blind Installation	Hard to reach areas	Use scoop - proof connectors
Critical signal and vibration applications	Prevent loss of connection	Use redundant contacts.
Axial Alignment and orientation		Use guide devices that do not carry current.
Frequent mating and demating	Connection and or joints wearout or breakage.	Provide strain relief for wires, harnesses, and cables. Use connector savers.
Severe shock and vibration environments	Possible connection loss.	Provide strain relief for wires, harnesses, and cables
Connector protection	Connector contamination and possible ESD system damage.	Use ESD connector covers (brightly colored for non-flight covers) until connectors are mated.
Hermetic Sealed applications	Loss of contact and hermetic seal integrity.	Use soldered contacts and encapsulate.
Coaxial Connectors SC series, TNC - type, and SMA - type.		Use only captivated contacts
		Use contact termination of the cable's center conductor for Right-angle connectors configurations
	Intermodulation of signals	Use Nickel, Ferromagnetic, or Ferrimagnetic materials.
	Contact corrosion	Use gold or passivated stainless steel plating or finish.

3.0 **Design and Construction** The connector styles and their associated specifications are documented below in Tables 300-4, 300-5, and 300-6.

Table 300-4 - Connectors (Except Printed Circuit Boards) Styles Included

Specification	Description	Comments
MIL-C-24308	Rack and Panel (Rectangular)	Recommended for space applications
MIL-C-28748	Rack and Panel	Note 1
MIL-C-28804	Rack and Panel	Note 1
MIL-C-83513	Rack and Panel	Note 1
MIL-C-83733	Rack and Panel (Rectangular)	Recommended for space applications
MIL-C-5015	Circular	Recommended for space applications
MIL-C-26482	Circular	Recommended for space applications
MIL-C-28840	Circular	Note 1
MIL-C-38999	Circular (High density)	Recommended for space applications
MIL-C-81511	Circular	Note 1
MIL-C-83723	Circular	Recommended for space applications
MIL-C-3607	Coaxial, RF	Note 1
MIL-C-3643	Coaxial, RF	Note 1
MIL-C-3650	Coaxial, RF	Note 1
MIL-C-3655	Coaxial, RF	Recommended for space applications
MIL-C-25516	Coaxial, RF	Note 1
MIL-C-39012	Coaxial, RF	Recommended for space applications
MIL-C-55235	Coaxial, RF	Note 1
MIL-C-55339	Coaxial, RF	Note 1
MIL-C-3767	Power	Note 1
MIL-C-22992	Power	Note 1
MIL-C-49142	Triaxial, RF	Note 1

Note 1: Follow the closest connector type "recommended for space application" for the application, Design and Construction, and Quality Assurance provisions guidelines outlined in this section.

Table 300-5 - Connectors (Printed Circuit Boards) Styles Included

Specification	Description	Comments
MIL-C-21097	One-Piece Connector	Note 1
MIL-C-55302	Two-Piece Connector	Recommended for space applications

Note 1: Follow the closest connector type "recommended for space application" for the application, Design and Construction, and Quality Assurance provisions guidelines outlined in this section.

Table 300-6 - Connectors (Integrated Circuit Sockets) Styles Included

	Specification	Description	Comments
7.3	MIL-S-83734	IC Sockets, Plug-in	Note 1

Note 1: Follow the closest connector type "recommended for space application" for the application, Design and Construction, and Quality Assurance provisions guidelines outlined in this section.

TABLE 300-7: Insert Material Determination

Configuration	Specification	Possible Insert Materials A	B	C	D
Rack and Panel	MIL-C-28748		X		
	MIL-C-83733		X		
	MIL-C-24308	X	X		
	MIL-C-28804	X	X		
	MIL-C-83513	X	X		
Circular	MIL-C-5015		X		X
	MIL-C-26482	X	X		X
	MIL-C-28840	X	X		
	MIL-C-38999	X	X		
	MIL-C-81511		X		
	MIL-C-83723		X		
Power	MIL-C-3767		X		X
	MIL-C-22992		X		X
Coaxial	MIL-C-3607			X	
	MIL-C-3643			X	
	MIL-C-3650			X	
	MIL-C-3655			X	
	MIL-C-25516			X	
	MIL-C-39012			X	
	MIL-C-55235			X	
	MIL-C-55339		X	X	
Triaxial	MIL-C-49142		X	X	

TABLE 300-8: Insert Materials Characteristics

Insert Material Type	Common Insert Materials	Insert Temperature Range (°C)
A	Vitreous Glass, Alumina Ceramic, Polyimide.	-55 to +250
B	Diallylphtalate, Melamine, Fluorosilicone, Silicone Rubber, Polysulfone, Epoxy Resin	-55 to +200
C	Polytetrafluorethylene (Teflon)	-55 to-+125
D	Polyimide (Nylon), Polychloroprene (Neoprene), Polyethylene	-55 to +125

3.1 Recommended Design for Space and Launch Vehicles All connectors listed in Tables 300-8.

Table 300-8 - Connectors Styles Recommended for use

Specification	Description	Comments
MIL-C-24308	Rack and Panel	Rev B (rack and panel, rectangular)
MIL-C-83733	Rack and Panel	Rack and panel, rectangular
MIL-C-5015	Circular	Class L, Series MS345X only.
MIL-C-26482	Circular	Miniature, quick disconnect
MIL-C-38999	Circular (High density)	Accepted configuration for space use
MIL-C-83723	Circular	Series III only.
MIL-C-39012	Coaxial, RF	
NASA MSFC	40M38277	
NASA MSFC	40M38298	
NASA MSFC	40M39569	
MIL-C-39029	CONTACTS	
MIL-C-55302	Printed Circuit Boards	
MIL-C-85049	Backshell and Hardware	

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 300-9 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Silver dendrites	Silver contact overplate or underplate
Outgassing and contamination	Inserts of nonapproved organic materials
Intermittent/ open contacts	Noncaptivated contact coaxials
Signal Interference	Nickel, Ferromagnetic, or ferrimagnetic materials on RF connectors
Signal Interference	Filter pins
Corrosion	Dissimilar metal mates
	External flat cable connectors
Outgassing and contamination	Cadmium or Zinc plating
Intermittent contact	Wire wrap contacts
Tin whiskers	Tin coated shells or contacts

3.3 Produceability and Baseline Controls A product baseline should be established for all custom resistors. Areas which need to be specified and controlled in the drawing and baseline are:

Table 300-10 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 4
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to appropriate Military Specification
Process Controls Verification & Validation	Refer to appropriate Military Specification
Screening Tests (100%)	Refer to appropriate Military Specification
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to appropriate Military Specification
Qualification Tests (Destructive & Non-destructive tests)	Refer to appropriate Military Specification

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of the appropriate Military Sp

Table 300-11 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Incoming Inspection: Verification of resistor received on a sample basis.	Review incoming data for accuracy of test.
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

SECTION 400 QUARTZ CRYSTALS, MIL-C-49468

1.0 **Scope** This section sets forth detailed information for precision quarz crystals units.

2.0 **Application**.

Table 400-1 Derating 2/, 3/

Device Type	Parameter	Derating Factor	Comments
Crystals	Power	0.25	Rated max. input power (Rated drive level) 1/ Drive is 1.0 ±0.2 mA through the crystals.

Notes:

1/ Cut of crystal will affect frequency and start up

2/ This derating applies to parts procured to MIL-C-49468 or via a specification control drawing that duplicates the MIL-C-49468 power ratings.

3/ Crystals procured to SCDs that specify the optimum operating power for the devices require no power derating.

TABLE 400-2 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
	Timing circuits or circuits requiring frequency stability	Operation at high drive levels may cause degradation of normal aging characteristics, of spectral purity, and of short-term stability.	Use low drive levels in applications needing normal aging characteristics, spectral purity and/or frequency stability
		Aging is the drift of resonant frequency with time.	Aging as a drift rate vs. time should be considered for each application. Add shelf life criteria where stability over time is critical
		Crystal can easily be damaged during Installation and Handling	Handling and mounting precautions should be taken to prevent seal damage or excessive mechanical shock or vibration to the crystal. Precautions should be taken when trimming wire leads to minimize mechanical shock to the resonator.

3.0 **Design Construction** Design and construction information can be found in MIL-C-49468. This table documents some of the key information about design and construction for crystal usage.

3.1 **Recommended Design for Space and Launch Vehicles** Quartz crystals designed and qualified to MIL-C-49486 Class S and screening and lot conformance to Table 400-9 (screen), Table 400-10 (lot conformance).

Table 400-3 Design and Construction

Construction	Information
General	The design of the crystal should be such that the required frequency stability and drift can be maintained at a drive current of 1.0 ±0.2 mA through the crystal.
Controlled environment of non-hermetic crystal units.	Non hermetically-sealed crystals may be used inside hermetically sealed oscillators when the oscillator manufacturer also manufacturers the crystal and provides for controlled transport of the crystal to the oscillator manufacturing area.
Sealing	It is highly, recommended that individual crystal units be sealed using cold-weld or resistance-weld techniques. Or a form of sealing that ensures a leak rate of or less than 10^{-8} atm-cc/sec.
Metallization	Metallization should be selected to provide the necessary adhesion of the electrode contacts. If gold electrodes are used, an undercoat such as chromium or tungsten is needed.
Crystal support/mounting	Crystals should be supported by a minimum 3 point mount 120° apart. **Note:** MIL-H-10056/ 21/23/27/29/30/31/32/33/34/39 do not meet this criteria.
Type of Quartz	Cultured, premium Q quartz per EIA Standard RS-477 is recommended. For use in radiation environments, the quartz should be prepared by the electrodiffusion process. Quartz prepared by the electrodiffusion process is recommended for all applications because of its low levels of Al and Na ions.
Gold Plating	Gold plating on package surfaces should be in accordance with MIL-G-45204, Type, grade, and class should be specified for each finish system. Examples are: Type 1, Grade C, Class 2 (0.000100" min.) over copper underplate (0.000010"min.). As an alternative Gold (0.000050"min.) over Nickel (0.000100") with Gold thickness maximum equal to 0.000200".

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 400-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Two point mount internal construction	These devices were identified in MIL-STD-1547 as reliability suspect.
Plug-in packages	These devices were identified in MIL-STD-1547 as reliability suspect.

3.3 Known Material Hazards The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 400-5 Known Material Hazards

Material	Precaution
Solder sealed packages	These devices were identified in MIL-STD-1547 as reliability suspect.
Gold metallization without barrier metal	These devices were identified in MIL-STD-1547 as reliability suspect.
Quartz other than EIA STD RS-477 premium Q type.	These devices were identified in MIL-STD-1547 as reliability suspect.
Non swept quartz in radiation (space) environments	These devices were identified in MIL-STD-1547 as reliability suspect.
Tin plated packages and leads	100% tin causes tin whiskers which allows a current path causing a intermittent shorts or arcing.

3.4 Produceability and Baseline Controls A product baseline should be established for all capacitors purchased as a QPL MIL-C-49468 with a company unique drawing reflecting the information in this handbook. Areas which need to be specified and controlled in the drawing and baseline are:

Table 400-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to MIL-C-49468
Production Lot	Refer to MIL-C-49468
Serialization	Refer to MIL-C-49468
Traceability Control (Parts, Materials, & Processes)	Refer to MIL-C-49468
Rework Provisions	Refer to MIL-C-49468
Process Controls Verification & Validation	Refer to MIL-C-49468 and the following: Pre-Cap Visual and Mechanical Inspection IAW Table 400-8 of this section Motional capacitance IAW Table 400-8 this section. Quality Factor IAW Table 400-8 of this section. Controls documented in In-Process Appendix I of this section.
Screening Tests (100%)	Refer to Table 400-8 of this section.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to Table 400-9 of this section.
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-C-49468 first article or qualification tests, Separate first article or qualification tests are not required for a manufacturer listed on the QPL for MIL-C-49468 for the slash sheet that best fits the component design required.

Note: A manufacturing baseline should be developed and maintained by the manufacturer and controlled and verified by the procuring organization for (company unique drawings),.for QPL reliability level S quartz crystals the manufacturing baseline should be verified by the procuring organization.

4.0 Quality Assurance Provisions

The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-C-49468 and company specific quartz crystal drawings reflecting the information in this handbook.

Table 400-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests) Specifically the following verifications are essential for this product: Pre-Cap Visual and Mechanical Inspection IAW Table 400-8 of this section Motional capacitance IAW Table 400-8 this section. Quality Factor IAW Table 400-8 of this section. Controls documented in In-Process Appendix I of this section.
Screening (100 percent): refer to the requirements of the company unique drawing and Table 400-8 of this handbook.	Review screening data (Attributes & Variables).
Lot Conformance: refer to the requirements of the company unique drawing and Table 400-9 of this handbook.	Review lot conformance data (Attributes & Variables).
Qualification Testing: refer to the requirements of the company unique drawing.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

Table 400-8 100% Screening Table

MIL-C-49468 Screens	Additions to the Methods and Criteria of MIL-C-49468
Pre-Seal Visual	Visual per MIL-C-49468, @ a min. of 30X. Units exhibiting one or more of the following anomalies are to be removed: Cracks or holes in the weld contact area where crystal support members are welded to the holder base terminal pins. Loose or broken terminal pins or crystal mounting supports. Cracks or separations in electrically conductive bonding cement between quartz crystal and support member. Fractures of any size and any location in the crystal quartz resonator; or cracked or flaked edges; or fractures, cracks, or peeling of the electrodes. Loose weld spatter, bonding cement, or other particulate matter. Less than 0.005” clearance between quartz crystal and the package wall. Quartz crystal resonator not parallel or perpendicular to crystal holder base within 10°. Joining of packages by interference, friction, crimping or similar methods unreinforced by welding. Any surface, including cover, exhibiting contamination/corrosion (adhering particulate, film, flux residue, finger print, or other type of material). Non-uniform quantities of bonding cement at mounting points; bonding cement in areas other than mounting points is acceptable if deliberately applied to the resonator surface to suppress harmonic responses. Adhering weld splatter exceeding 0.03” dimension through any plane. Weld splatter should be considered adherent when it cannot be removed with 20 psig gas blow of dry, oil-free nitrogen. Base terminal and crystal mounting support exhibiting nicks, misalignment, cuts, cracks, or distortion, Quartz crystal not centered within +0.030” in its mounting with respect to the quartz crystal holder base. Dimensions out of tolerance.
Subgroup 1 Visual/Mechanical External Examination Mechanical Shock Frequency Resistance vs Temp Frequency vs Temp (static) Coupled Modes Condensibles Unwanted Modes Capacitance Shunt Motional	When specified When specified, The motional capacitance, C1, is defined in accordance with EIA Standard 512. The resonant frequency (F_R) is measured using two load capacitances connected successively in series with the crystal unit. The results obtained with two load capacitors C_{L1} and C_{L2} can be combined so that:

Table 400-9 Lot Conformance Table

MIL-C-83421 Screens for CRH/CQR style	Additions and Exceptions to Methods and Criteria of MIL-C-83421
Subgroup 1	
DC Life (Accelerated)	Sample of 4, 2,000 hours
AC Life (Accelerated) AC Application Only	Sample of 4, samples should have the highest ESR readings 250 hours Maximum AC current, 120 % of IAC (RMS); Minimum current 3 times the system application, adjusted for 40 kHz operation. VAC frequency of 40 kHz +2%. 1/
Capacitance Dissipation Factor Insulation Resistance Seal	Readings taken @ +25°C and +125°C
Subgroup 2	
Vibration (Random) (Sine)	Sample of 6, MIL-STD-202, Method 214, test Cond. II K Vib axis 2 orthogonal planes, 15 minutes vibration
Terminal Strength	
Dielectric Absorption	
Capacitance Dissipation Factor Insulation Resistance Seal	
Subgroup 3	
Shock	Sample of 6, MIL-STD-202, Method 213, Cond. D (500g)
Solderability	
Temperature Coefficient	
Capacitance Dissipation Factor Insulation Resistance Seal	

1/ VAC should not exceed 240 VRMS under any conditions

SECTION 500 - DIODES

1. ORGANIZATION: This section covers the following device types Light Emitting, Rectifier, Schottky Barrier, Switching, Varactor, Voltage Reference, Voltage Regulator, Transient Suppresser, Silicon Control Rectifier, and Photodiode.

2. APPLICATION

TABLE 500-1 - SEMICONDUCTOR DEVICES DERATING

DEVICE TYPE	PARAMETER	DERATING FACTOR	COMMENTS
Axial Lead, Small Signal, Switching, Silicon & Schottky Rectifiers	PIV I Surge Io Tj	.70 .50 .50 80% of Tj Max	Not to exceed 105°C
SCR	Off-State Voltage I Surge On-State Current Tj	.70 .50 .50 80% of Tj Max	Not to exceed 105°C
VARACTOR	Forward Current Peak Inverse Voltage Power Disipation Tj	.75 .75 .5 80% of Tj Max	Not to exceed 105°C
PHOTODIODES	Io Tj	.50 80% of Tj Max	Not to exceed 105°C
TRANSIENT SUPPRESSORS	P_D Transient Current Zeener Voltage (Vz) Tj	.75 .75 .70 80% of Tj Max	Not to exceed 105°C
ZEENERS	P_D Zeener Current Tj	.50 .80 80% of Tj Max	Temperature Compensate[d] zeeners should be operate[d] at the specified point Not to exceed 105°C

Table 500-2 End-of Life Design Limits

Device Type	Parameter	Parameter Design Value
Axial Lead, Small Signal, Switching, Silicon & Schottky Rectifiers	Leakage Current (I_R) Forward Voltage (Vf)	100% of initial maximum limit ± 100mV from the original maximum limit
Varactors	Leakage Current (I_R) Forward Voltage (Vf)	100% of initial maximum limit ± 100mV from the original maximum limit
SCR	Gate Leakage Current Latching Voltage	100% of initial maximum limit ± 100mV from the original maximum limit
Photodiode	Input Current (If) Output photocurrent	50% of the max rated 25% of the initial value
Transient Supressors	Leakage Current (I_R)	100% of initial maximum limit
Zeeners	Zeener Voltage (Vz)	±10% of initial operating point

3. DESIGN AND CONSTRUCTION

BACKGROUND: Semiconductor devices Design and Construction has traditionally been maintained in accordance with the requirements of the applicable specifications (MIL-S-19500 and its Slash Sheets). The JANS design rules within the specifications were applied where available. The metallurgical bond for axial leaded devices and monometallic wire bond were two of the more disputed issues. However, with the push for the use of plastic encapsulated devices, and replacement of traditional JANS controls with the more cost effective high volume production line process controls the designer has to evaluate the acceptability of the proposed design and construction for the application. In addition, some of the old technology was never designed to meet the high reliability applications needs and application of the JANS rules was often limited to just screening the quality in.

The new approaches such as Surface Mount package, Multi Chip Module (MCM) technology, and Power Module technology that are currently beginning to be employed in the space application designs are often based on old technology, either old die designs, old package types etc., that are modified and supplied as Surface Mount, MCM, and Power Modules. As such the modifications are often performed after the discrete devices were screened and the final product is rarely verified and validated for the intended application. Therefore, the designer or the component engineer needs to ensure that the supplied components meet the application requirements. Table 500-3 provides some of the known Design and Construction Considerations.

Table 500-3 Design and Construction Considerations

Device Type	Design & Construction Considerations	Possible Mitigation
Axial Lead Devices	Pressure contact, Dumet or Soft Glass construction.	Monitored Temperature Cycling with hot monitored lead pull test.
	Point contact whisker cavity construction.	Forward and Backward Instability Shock Tests (FIST & BIST).
	Axial lead metal can with single crimp lead area.	X-Ray crimp area for inadequate contacts.
Cavity Devices	Lead solder based compounds used for die attach medium.	Maintain the moisture levels below 5000ppm to prevent solder decomposition.
	Silver filed Epoxy or Silver glass die attach mediums.	Maintain under 5000 ppm moisture, perform Transient Thermal Response and qualify process to 1000hrs. Power Burn-In.
	Organic passivating or conformal coating materials.	Qualify process to 1000 hr HTRB, perform extended vacuum bake prior to device sealing, maintain low moisture levels.
	Gold wire bonds on Aluminum die metalization and aluminum wire on gold substrates.	Qualify wire bond process to survive 300°C without Au-Al intermetalic formation.
	Aluminum wire bonds on Silver die metalization and on Ni plated Au flash posts.	Qualify process to survive an acceptable number (to the design application) of Intermittent Operating Life Cycles followed by wire pull test without any wire lifts.
	Au flash on Ni plated posts.	Maintain gold to 5 - 10µin over Ni plating on posts.
Hot Welded Cans	A high potential for loose conductive particles inside the cans.	Monitored cap welding and PIND test.
Glass to metal seals	High probability of developing glass cracks during testing and handling of devices.	Qualify packages to survive acceptable number of Temperature Cycles for the proposed application followed by die penetrant.

Produceability and Baseline Controls A product baseline should be established for all devices not purchased as a MIL-PERF-19500 QPL device. Areas which need to be specified and controlled in the drawing and baseline are:

Table 500-4 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to MIL-PERF-19500 for JANS
Wafer Lot	Refer to MIL-PERF-19500 for JANS
Wafer Lot Acceptance	Refer to MIL-PERF-19500 for JANS
Radiation Hardening Performance	Refer to MIL-PERF-19500 for JANS
Assembly Lot accumulation period	
Manufacturing Location	
Assembly processes and their verification	
Inspection Lot formation	Refer to MIL-PERF-19500 for JANS
Test equipment validation	
Serialization	Refer to MIL-PERF-19500 for JANS
Traceability Control (Parts, Materials, & Processes)	Refer to MIL-PERF-19500 for JANS
Rework Provisions	Refer to MIL-PERF-19500 for JANS
Process Controls verification & validation	Refer to MIL-PERF-19500 for JANS
MRB and Change Control Authority	
Screening Tests (100%)	Refer to MIL-PERF-19500 Table II and Detail Specification as applicable
Quality Conformance Inspection (Destructive & Non-destructive tests)	Refer to MIL-PERF-19500 for Tables III, IVa, V, and Detail Specification as applicable
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-PERF-19500 for Table VI and Detail Specification as applicable

Note: A manufacturing baseline should be developed and maintained by the manufacturer in accordance with MIL-PERF-19500, and controlled and verified by the procuring organization.

4. QUALITY ASSURANCE There are four major areas to be covered under the Quality Assurance provisions. These are the Wafer Fabrication, Assembly, 100% Test or Screening, and Quality Conformance Inspection and Qualification. MIL-S-19500 has provided guidance for both the device manufacturers and designers in all of the four areas. The designer and component engineer has to understand the device application, the need for and application tolerance of device to device performance variation and how the device manufacturer controls in each of the four areas impact the performance. Table 500-5 provides a summary of the recommended controls for space level devices.

Table 500-5 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Wafer Fabrication: In process controls should be per MIL-PERF-19500 Appendix D.	Wafer Lot formation Wafer Fabrication rework Wafer Lot Acceptance Wafer Fabrication Location
Assembly: In process controls should be per MIL-PERF-19500 Appendix D	Lot Homogeneity Production Lot formation Traceability Control Rework Provisions I.A.W. approved procedures Process Controls, their verification & validation elements Assembly Location
Screening Tests (100%): Screening should follow the MIL-PERF-19500 Table II and detailed specification. Quality Conformance Inspection (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)	Electrical parameters and performance specified meets application. Screening Temperature Range, QCI and Qualification specified meet application Test equipment accuracy and repeatability Accept and Reject criteria Failure Analysis and Corrective action.
Screening (100 percent): refer to the requirements of MIL-PERF-19500 for JANS and the detailed specification.	Review screening data (Attributes & Variables). Verify test equipment correlation, repeatability, test windows were met, test conditions, and PDA compliance.

Table 500-5 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Quality Conformance Inspection: refer to the requirements of MIL-PERF-19500 for JANS and the detailed specification.	Review lot conformance data (Attributes & Variables), sampling techniques, and stress levels.
Qualification Testing: refer to the requirements of MIL-PERF-19500 and the detailed specification.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier documentation.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

5.0 Lessons Learned

Wafer Fabrication: This is probably the most critical area that determines the device reliability and performance. Traditionally this area has been downplayed in its importance to the reliability of the end product and consequently controlled by OEMs through a flow chart at best. With the change from “screening of devices to meet quality requirements” to “building of quality into devices” this area becomes the only area that builds quality into the die. Table 500-6 outlines some of the areas that need specific attention.

NOTE: For most of the older semiconductor device technologies the wafer fabrication process is typically designed to a nominal level that would produce a range of device types and device families on the same line and may not be cost effective target the process for only one device type.

Assembly: This is area where the die or chips, processed through wafer fabrication, are put in packages or assembled so that they can used in systems. These packages and assembly materials used determine in most cases, where the die ratings outperform the package ratings, the final device ratings such as Power Dissipation, Operating and Storage Temperature Ranges, Output Steady State Current, and Thermal Resistance. It is very important that the assembly processes are closely monitored and controlled so that defects are not introduced. MIL-S-19500 Appendix D has traditionally provided the guidelines for process controls for semiconductor devices. Table 500-7 outlines some of the areas that need specific attention.

Screening: This area covers the 100% testing (electrical, mechanical, and environmental) that are applied to devices in order to eliminate the defects associated with infant mortality portion of the "Bathtub" reliability curve (see Figure 500-9). The Percent Defect Allowable (PDA), test windows post HTRB and Burn-In, and other controls determine the number of random defects expected when using the lot of devices. The implementation of effective process controls in the front areas, wafer fabrication and assembly, makes device to device performance variability more consistent, and therefore, could allow lots to be evaluated on a sample basis rather than screened on 100% basis. The intended design application requirements provide the basis for device performance valuation. Table 500-8 outlines some of the areas that need specific attention.

Quality Conformance Inspection (QCI): This area covers the sample verification of the lot integrity to be used in the application. The stress levels applied traditionally have been at the levels established, for the particular technology and product type, to simulate the end of life characteristics under accelerated conditions. Table 500-10 outlines some of the areas that need specific attention.

Table 500-6 - Wafer Fabrication

Area of Concern	Effect on Performance	Potential Remedy
Wafer Lot formation	Determines die lot performance homogeneity	Use wafers from single batches and manufacturers.
Wide resistivity and thickness, epi and epi thickness specifications	Allows wide range of electrical characteristics which lead to new device types and or product downgrading.	Use only the devices for which the target specifications of the raw wafers were designed and not the downgraded by products.
High defect count per cm^2.	Increase of device to device variation, risk of premature device failure, lower yields.	Lower the acceptable number of defects per cm on the incoming wafers.
Wafer Fab. Processing	Determines the device performance	
Particle size and count allowable in the clean room.	Depending on the device type, geometry, and technology may impact device reliability and electrical performance. Ionic contamination.	Use positive air flow interlocks and entries, air filters, process only devices for which the clean room characteristics were proven to be acceptable.
Water purity and Diffusion cleanness	Potential for ionic contamination.	Use water filters, test for bacteria, C-V plots.
Rework	Increase of device to device variation, risk of premature device failure, lower yields.	If allowed, verify that the rework did not have adverse effects on device performance in the intended application.
Wafer Fab Location	Use of foundries and other manufacturer's die leads to loss of visibility into wafer fab processing and controls may impact device performance.	Verify the supplier of devices has visibility and control over the wafer fabrication processes, changes, and implementation.
Wafer Lot Acceptance	Data provided does not correlate or tie into the wafer fab process controls for oxide, die, metalization, and passivation layer thickness. Sampling may not be valid.	Ensure wafer lot acceptance provides meaningful data to ascertain the wafer fabrication process and controls.
Radiation Tolerance	Wafer fab design and processing are not conducive to rad hard characteristics.	Provide circuit design solutions to prevent system failure.

Table 500-7 - Assembly

Area of Concern	Effect on Performance	Potential Remedy
Die attach is not consistent	Devices fail prematurely due to voids which cause over heating and or current crowding effects	Implement die attach monitors such as Transient Thermal Response and die shear.
Attach materials are not optimized for the package and design application.	Devices fail prematurely due to die attach degradation when operated under simulated and accelerated application conditions.	Qualify and validate the attach process and materials for the intended design application.
Pressure contact, Ag bump, Dumet glass construction.	Devices may intermittently open during temperature transitions while under operation.	Validate and monitor the process through Monitored Temp Cycle and Hot Lead Pull.
Multiple Lots formation and loss of Lot Traceability	Increase potential for lot failure due to loss of traceability to individual lots.	Maintain traceability to individual lots.
Rework Provisions	Allowing rework on the production line may not enforce corrective action implementation and promote loose process controls.	If rework was allowed maintain traceability to the reworked portion of the lot for future valuation of adverse rework effects.
Purple Plague (Au wire on Al metalization)	Open circuit.	Validate process through extensive High temperature storage; subject lot to 300°C.
Purple Plague (Al wire on Au metalization	No impact if Gold is thin and the bonding is to the Ni under plate. Otherwise will lead to open circuit.	Validate process through Temperature and Operating Cycles; peel wire to verify bond.
Al wire bonds on Ag metalization.	Open circuit due to operating and Thermal cycles.	Validate process through Temperature and Operating Cycles;
Particles inside cavity	Potential short due to conductive particle such as Die attach slag, weld splash, etc.	Validate the processes to ensure loose particles are not introduced. Institute PIND.

Table 500-8 - 100% Screening

Screening Test (MIL-S-19500 Table II)	Effect on Performance	Rationale for Test Conditions
Pre-Cap Visual Inspection	Ensures the devices are free of defects prior to encapsulation	Depending on the manufacturer's process controls this may be done on a sample basis.
High Temperature Storage	Some device technologies require this to stabilize the junction characteristics.	Select the max. device rated temperature storage.
Temperature Cycling	Intended to screen out infant mortality defects due to die attach and other package mismatch defects.	20 cycles were initially established as sufficient to pass the infant mortality stage. Devices should reach temperature extremes.
Constant Acceleration	Test designed to stress the wire bonds and die attach areas.	The G-force level is determined by the package capability and should be above the application requirements.
Transient Thermal Response	Non-destructive die attach screen for voids outside the process capabilities.	Applicable only to devices with negative voltage temperature coefficient. Limits should track back to maximum $R_{\theta JC}$, P_D, and or Surge characteristics.
Surge Testing	Developed to screen out devices with die attach, junction, and or bulk silicon defects.	Surge should not exceed the max. designed capability of the die.
PIND	Developed to screen out devices with loose particles inside the cavity.	Set-up sensitivity, location and tester mounting, shock/ co-shock and vibration levels, and transducer couple medium are important to effective PIND screening.
Pre-HTRB electrical tests	Electrical parameters (at T_A=25°C) established for each technology and device type to be indicative of a good device.	Parameters most likely to change if ionic contamination is present such as Leakage currents, Forward Voltage, Breakdown Voltage

Table 500-8 - 100% Screening (cont.)

Screening Test (MIL-S-19500 Table II)	Effect on Performance	Rationale for Test Conditions
HTRB	Stress test designed to screen out ionic contaminated devices using DC Bias Voltage and Temperature to accelerate the effects. Ions are made mobile through Temperature exposure while the DC Bias Voltage acts as dipole magnet attracting the ions on each positive and negative side of the power supply.	The applied Temperature should be that of the Max. Operating Ambient without heat sink, and the applied voltage should be 80% of the rated breakdown voltage of the stressed junction. The magnitude of the exposing temperature and applied bias directly affect the result. Applying AC Voltage or removal of the bias before devices reached approx. 35°C will negate the test.
Post-HTRB electrical tests	Repeat of Pre-HTRB electrical tests to validate devices did not drift outside the established limits. Test should be performed within 16 hrs of bias removal.	Ionic contamination, if free to move around will cause a change in the device electrical characteristic. Depending on the contaminant type and level the ions will eventually return to original state.
Percent Defective Allowable (PDA)	Establishes the random failure rate expected during the useful life of the devices.	Typical PDA is 5% max. with a one time resubmission if Percent Defective (PD) < 20%. Lots failing this criteria are should be considered reliability suspect.
Power Burn-In	Test designed to screen out assembly defects.	Test conditions are typically established such that device junction temperature approaches that of the maximum Operating Junction Temperature Ratings.

Table 500-8 - 100% Screening (cont.)

Screening Test (MIL-S-19500 Table II)	Effect on Performance	Rationale for Test Conditions
Post Power Burn-In electrical tests	Verify that devices still meet the established electrical characteristics.	Repeat the Post HTRB (Pre Burn-In) electrical tests plus the rest of the DC characteristics including those at high and low temperatures.
Percent Defective Allowable (PDA)	Establishes the random failure rate expected during the useful life of the devices.	Typical PDA is 5% max. with a one time resubmission if Percent Defective (PD) < 20%. Lots failing this criteria are should be considered reliability suspect.
X-Ray	Test was developed for workmanship verification (it does not replace Pre-Cap Visual Inspection).	Criteria and level of inspection is based on the package and defect type.

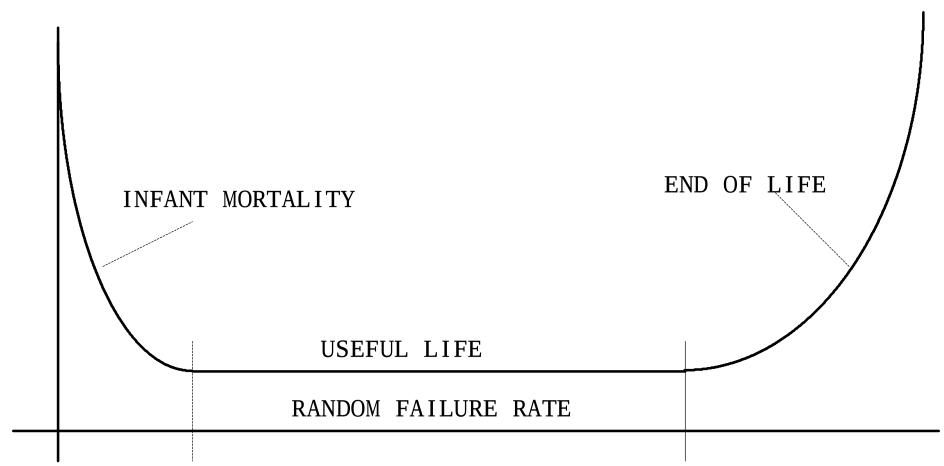


Figure 500-9: Reliability Bath Tub Curve

Table 500-10 - Quality Conformance Inspection

Test Name	Effect on Performance	Test Rationale
Group A	Verifies device electrical performance under DC, AC or transient conditions, and over the Rated temperature range.	Validates device capability to meet its electrical characteristics. Usually performed on each lot on a sample basis after 100% screening was completed.
Group B	Verifies device operational performance within the useful life portion of the bath tub curve. This includes package design integrity verification (Temperature Cycling, Intermittent Operating Life, and Thermal Resistance Subgroups), device operational performance (Accelerated Life Test).	Validates lot homogeneity and process/design operational performance capability on a lot by lot basis. Validates screening was performed correctly and no defects were introduced.
Group C	Verifies device mechanical performance and operational performance up to 1000 hrs. Operational Life or 6000 Intermittent Operation Cycles.	Validates the processing and device design provide up to 1000 hrs. and or 6000 cycles of useful life under accelerated conditions. Most military and space design applications reliability predictions use this as basis for predictions.
Group D	Verifies the die design capability to withstand the radiation effects that some applications may require to operate under.	Validates wafer fabrication device design and processing are capable to meet 100K Rads of total exposure and Single Event Upset capabilities.
Group E	Verifies end of life device design capability	Validates that the device processing and design end of life are outside the Thermo-Mechanical and Operational boundaries established for useful life.

Table 500-11 Recommended Electrical Parameters

Device Type	Parameter	Measurement Point	Measurement Temperature (1)
Rectifiers Small Signal, Switching, Silicon & Schottky Rectifiers	Forward Voltage (Vf) Leakage Current (I_R) Breakdown Voltage (V_{RB}) ΔV_F and ΔI_R Surge and Reverse Energy Junction Capacitance C_J Reverse Recovery Time	At rated I_F At 80% of rated B_{VR} At 10x I_R Post HTRB, Burn-In, Life Tests, and Temperature Cycling Peak Rated Current At specified Voltage and frequency At specified V_R, I_R load resistance, load capacitance.	At room, hot, and cold. At room and hot temp. At room and cold Room Temperature Room Temperature Room Temperature Room Temperature
Varactors	Forward Voltage (Vf) Leakage Current (I_R) Breakdown Voltage (V_{RB}) ΔV_F and ΔI_R Quality factor Q	At rated I_F At 80% of rated B_{VR} At 10x I_R Post HTRB, Burn-In, Life Tests, and Temperature Cycling At specified voltage and frequency	At room, hot, and cold. At room and hot temp. At room and cold Room Temperature Room Temperature
Photodiode	Forward Voltage (Vf) Leakage Current (I_R) Power Output (P_O) ΔV_F, ΔI_R , and ΔP_O	At rated I_F At 80% of rated B_{VR} Post HTRB, Burn-In, Life Tests, and Temperature Cycling	At room, hot, and cold. At room and hot temp. Room Temperature
Transient Suppressers	Forward Voltage (Vf) Leakage Current (I_Z) Breakdown Voltage (V_Z) ΔV_F, ΔI_Z, ΔV_Z Reverse Surge Capability	At rated I_F (Zeeners) At 80% of rated B_Z At specified I_Z Post HTRB, Burn-In, Life Tests, Surge, and Temperature Cycling At rated peak current	At room, hot, and cold. At room and hot temp. At room, hot, and cold Room Temperature Room Temperature

Table 500-11 Recommended Electrical Parameters (cont.)

Device Type	Parameter	Measurement Point	Measurement Temperature (1)
Zeeners, Temperature Compensated	Forward Voltage (Vf) Leakage Current (I_Z) Breakdown Voltage (V_Z) Zeener Impedance (Z_Z) ΔV_F, ΔI_Z, ΔV_Z, and ΔZ_Z Temperature Coefficient (a V_z)	At rated I_F (Zeeners) At 80% of rated B_Z At specified I_Z At 25% and 125% of specified IZ Post HTRB, Burn-In, Life Tests, and Temperature Cycling V_Z value over temperature	At room, hot, and cold. At room and hot temp. At room, hot, and cold Room Temperature Room Temperature At room, hot, and cold

NOTES: 1. Room Temperature =25±5°C, Cold Temperature = Low rated Temperature (-55°C or -65°C typically), Hot Temperature = High Rated Temperature (above 125°C typically)

Reliability Suspect designs The following designs have been determined from past experience to be reliability suspect. However, with improved materials, process controls, and through sound engineering the problems associated with these designs could be alleviated. For each of these see Table 500-7, 500-8, and 500-10 Assembly, Screening, and Quality Conformance for possible validation:

a) Hot welded cans
b) Nonpassivated dice
c) Bimetallic bonds at the die
d) Point contact (whisker) devices
e) Silver bump, ramrod construction
f) Nonmetallurgically bonded construction (except schottky devices), unless supported by operational thermal cycle life data
g) Germanium devices
h) Gallium Arsenide devices
I) Flip chip units
j) Glass or silver filled epoxy die attach
k) Parts containing organic materials, unless supported by HTRB and Life Test data
l) All plastic encapsulated devices, unless supported by full design application validation and qualification
m) Pure and unfused tin coated packages and leads.

SECTION 600 - EMI AND RF FILTERS

1. ORGANIZATION: This section covers RF and EMI filters.

2. APPLICATION

Table 600-1 - RF and EMI Derating

DEVICE TYPE	PARAMETER	DERATING FACTOR	COMMENTS
All	Applied Voltage DC Current Tj Surge Current(Is)	.50 .75 80% of Tj Max $(t_S)x(I_S)<1.4I_R$	At the specified Temperature At the specified Temperature Not to exceed 105°C With no load current flowing and where t_S is the surge duration and I_R is the Rated DC current.

Table 600-2 End-of Life Design Limits

Device Type	Parameter	Parameter Design Value
All	Capacitance	± 20% from the original maximum limit
	Insulation Resistance	50 percent of specification limit
Ceramic discoidal capacitors using BX and X7R Dielectric	Capacitance	Allow for a 2 - 4% decrease per decade hour.

Table 600-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
All	General Purpose	Under certain conditions, the current parameters of the filter are governed by the transient surge current (I_s). I	To determine whether a filter can withstand a know surge current, the following analysis should be used. A filter should not be exposed to a transient current that could damage the device. **1.2** Transient Current With no load current flowing: I_S = surge current (amps) I_R = Rated DC current (amps)t t_S = Duration of I_S (µs) Then, if tS multiplied by IS is less than 1.4 I_R, the filter should not be damaged. **2.2** Rated Load Current With rated load current I_R flowing:

			Then, if t_S multiplied by I_S is less than 0.4 IR, the filter should not be damaged.
Stud Mounted	General Purpose	Insulation and Soldering	Follow the established procedures for the specific application to provide adequate Insulation and to prevent device degradation during soldering operation.
		Connecting wires	Heat sink the filter stud lead to prevent damage to the high temperature solder seals in stud leads.
		Mounting torque	Do not exceed specified torque; Do not hold on to filter body to keep filter from turning under torque; Use tooth stile lockwasher between filter and mounting surface only. Insulation resistance or DWV should be performed after torquing.

3. DESIGN AND CONSTRUCTION

The Class S rules of MIL-F-28861 have traditionally been followed for most of the space level applications of EMI and RF filters. In addition the Class S rules for the individual piece parts used in the manufacture of these filters have also been followed very successfully to the extent possible. The Table 600-4 below provides a quick application reference.

Table 600-4 Design Application Considerations

Typical Applications	Design & Considerations
Low power EMI filters with low RF currents	Ceramic capacitors; Follow the individual governing specification and section 200 herein.
High power EMI filters.	L, C, Pi, or T sections of toroidal wound or ferrite bead inductors and capacitors. Feedthrough capacitors. Follow the individual governing specification and appropriate sections herein

3.1 Space & Launch Vehicles Recommended Designs: Follow the information provided in individual Capacitor, Inductor, and MIL-F 28861.

3.2 Known Reliability Suspect Designs: Follow the information provided in individual Capacitor, Inductor, and MIL-F 28861.

Table 600-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Built with suspect piece parts.	Individual sub-components such as capacitors, inductors etc. are reliability suspect; See individual sections.
Non-hermetic filters (polymeric seals) Gold plated polymeric sealed devices	Filters without glass end seals are not hermetically sealed and are both subject to corrosion and may outgas significantly. Gold-plated parts with polymeric end seals are especially subject to moisture penetration and outgassing.
Tubular Ceramic Elements	EMI or RF filters containing tubular ceramic elements are not recommended for use in space applications unless proven that the design application is robust and can accommodate the use of these devices without failure.
Unfused Tin plated packages and terminals	Unfused Tin plating has been proven to develop whisker growth under certain conditions and is not recommended for use in space applications.
External tooth locking hardware	Not recommended for high shock and vibration environments.

3.3 Known Material Hazards: Follow the information provided in individual Capacitor, Inductor, and MIL-F 28861.

3.4 Produceability and Baseline Controls A product baseline should be established for all filters not purchased as a QPL MIL-F-28861 device. Areas which need to be specified and controlled in the drawing and baseline are:

Table 600-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to MIL-F-28861 for Class S
Production Lot	Refer to MIL-F-28861 for Class S
Serialization	Refer to MIL-F-28861 for Class S
Traceability Control (Parts, Materials, & Processes)	Refer to MIL-F-28861 for Class S
Rework Provisions	Refer to MIL-F-28861 for Class S
Solder Dip/Retinning Option	Use a qualified process; Perform specified 100% subsequent testing per MIL-F-28861.
Process Controls verification & validation	Refer to MIL-F-28861 for Class S
Screening Tests (100%)	Refer to MIL-F-28861 for Class S
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-F-28861 for Class S
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-F-28861 for Class S

Note: A manufacturing baseline should be developed and maintained by the manufacturer in accordance with MIL-F-28861, and controlled and verified by the procuring organization.

4. QUALITY ASSURANCE

4.1 The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-F-28861 or Company specific filter drawings.

Table 600-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of MIL-F -28861.	Lot Homogeneity Production Lot formation Device Serialization Traceability Control Rework Provisions I.A.W. approved procedures Process Controls and their verification & validation elements Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): refer to MIL-F-28861 for Class S.	Review screening data (Attributes & Variables). Verify test equipment correlation, repeatability, test windows were met, test conditions, and PDA compliance.
Lot Conformance: refer to MIL-F-28861 Group B for class S.	Review lot conformance data (Attributes & Variables).
Supplier DPA: should be in accordance with MIL-F-28861.	Review supplier DPA and compare to incoming DPA.
Qualification Testing: refer to the requirements of MIL-F-28861 for class S.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

SECTION 700 Fuses (MIL-F-23419)

1.0 Scope
This section contains detailed information for fixed, high reliability sealed fuses.

2.0 Application
The following tables contain information about fixed, high reliability sealed fuses to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 700-1 Derating

Device Type	Parameter	Derating Factor	Comments
Link or similar fuses and molded	Current ratings	0.70	For atmospheric conditions @ +25°C.
	2 A 1 A ½ A 3/8 A ¼ A 1/8 A	0.50 0.45 0.40 0.35 0.30 0.25	For vacuum conditions @ +25°C. Decrease linearly 0.5%/C (for Link or similar fuses) and 0.2% (for solid molded fuses) above 25C or the manufacturer suggested derating factor up to maximum allowed temperature

TABLE 700-2 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
	Electrical overload protection	The current ratings of the fuses should be determined at specified operating conditions.	Consideration should be given to the following areas for each application: 1. Ambient temperature 2. Connections to the circuit 3. Ventilation 4. Vacuum adhere to the derating criteria.
		Electrical Considerations	Factors to be considered should include the likely variation of fuse element resistance from fuse to fuse, deterioration of fuse rating resulting from repeated turn-on and turn-off of the fuse, other current surge characteristics, and maximum open circuit voltage tolerance
		Do not use in t applications where open circuit voltage exceeds the max specified voltage rating for the fuse.	Adhere to derating .
		Mounting environments including heat sinking should be considered.	Heat sinking is recommended for all fuses.

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Fuses designed and qualified to MIL-F-23419 and the additional screening documented in this handbook. And the following information:

Table 700-3 Design and Construction Considerations

Construction	Information
General	Designs should be considered for space use only if they can be demonstrated to not alter current ratings more than 10% when used under vacuum (i.e., loss of pressure within fuses) or if hermeticity can be demonstrated to provide the above stability over a 10 year period in vacuum. (Extrapolations from leak rate measurements may be used.)

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 700-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Intermittent contact	Fuses requiring fuse holders. These fuses were documented as a prohibited part in MIL-STD-1547.
Tin Whiskers	Fuses with plated tin package or leads. These fuses were documented as a prohibited part in MIL-STD-1547.

3.3 **Lessons Learned** Fuses which are not hermetic used in a non hermetic environment fail standard visual assembly inspection due to oxidation. The oxidation will cause a change in electrical resistance.

3.4 **Known Material Hazards** The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 700-5 Known Material Hazards

Material	Precaution
Tin plated packages or leads	100% tin plate has caused tin whiskers which have the potential of causing a short or arc. This material was documented as a prohibited part in MIL-STD-1547.

3.4 Produceability and Baseline Controls A product baseline should be established for all fuses purchased as a QPL MIL-F-23419 device, with the additional screening tests documented in this handbook. Areas which need to be specified and controlled in the drawing and baseline are:

Table 700-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-F-23419
Process Controls Verification & Validation	Refer to MIL-F-23419
Screening Tests (100%)	Refer to MIL-F-23419 and Table 600-8, in this handbook.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-F-23419 quality conformance tests, Subgroup 1, 2, and 5 of Group C inspections.
Lot conformance tests for critical applications or where more predictable results in alien environments are needed, and/or vibration and shock applications.	Refer to Table 700-9 in this handbook.
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-F-23419.

Note: A manufacturing baseline should be developed and maintained by the manufacturer and controlled and verified by the procuring organization for (company unique drawings).

4.0 Quality Assurance Provisions

The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-F-23419 fuses with the additional screening documented in this handbook.

Table 700-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests) The following verifications are essential for this product: 1. Fuse element attachment is visually inspected on all items at 10X mag. Min. 2. Radiographic inspection on all opaque body fuses (in-lieu of visual), viewed at 7X min. Should be acceptable at a min. Of 2 orthogonal views or 360° turn.
Screening (100 percent): Refer to MIL-F-23419 and Table 700-8, in this handbook.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-F-23419 quality conformance tests, Subgroup 1, 2, and 5 of Group C inspections.	Review lot conformance data (Attributes & Variables).
Lot Conformance Tests: for critical applications or where more predictable results in alien environments are needed, for vibration and shock applications. Refer to Table 700-9 in this handbook.	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to the requirements of MIL-F-23419	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of fuses.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

Table 700-8 Screening Table

MIL-F-23419 Screens	Additions and Exceptions to the Methods and Criteria of MIL-F-23419
Thermal Shock	MIL-STD-202, Method 107, Condition B; Monitor for continuity during last cycle.
Seal, Hermetic	MIL-STD-202, Method 112. Gross Leak per Test Condition A, or equivalent. Not applicable to non-hermetic devices.
Terminal Strength and DC Resistance	1. Simultaneous dc resistance measurement. 2. Test current used should be 10% of rated value during strength measurement. 3. Test at +25°C. 4. Resistance data within spec at all times during strength measurement.
Burn-In	Test @ +85°C +0°C -3°C for 168 hours, at rated DC voltage, with 50% rated DC current.
DC Resistance	Test @ +25°C, Current is 10% of rated value. Resistance data within spec at all times, and Resistance data to be within +8% of initial reading at all times.
Voltage Drop	Test @ 50% rated current, measurement taken after 5 minutes, Accept fuses within +2 standard deviation of lot average.
Visual/Mechanical (External)	Marking and identification Defects and damage; i.e., body finish, lead finish, misalignment, cracks.
Radiographic Inspection	1. Per MSFC-STD-355; 2 views 90 deg. Apart by x-ray, or 360 deg. View by real-time x-ray. Use of “real-time” x-ray systems capable of viewing through 360 deg rotation is encouraged. 2. Test is not required except for ceramic and molded body devices.

Table 700-9 Lot Conformance Tests

Tests	Additions to the Methods and Criteria of MIL-F-23419
Vibration and Shock	The shock level is 500, +50 g for ½ second sinewave input, the vibration level is per MIL-STD-202, Method 214, Condition IIK. (Monitor continuity during shock and vibration). 1. Measure resistance by current plots in excess of monitored display for elimination of unusual characteristics. 2. Record parameters over various temperatures 3. Thermal vacuum testing

SECTION 800 Magnetic Devices (Transformers, Inductors, & Coils

1.0 Scope

This section contains detailed information for transformers, inductors, & coils.

2.0 Application

The following tables contain information about transformers, inductors, & coils to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 800-1 Derating

Device Type	Parameter	Derating Factor	Comments
All magnetics	Voltage	.050 of min. rated wire insulation voltage	Maximum winding-to-winding and winding-to-case voltages are derated.
	Temperature	Max. operating temp not to exceed T_I - 30°C	T_I is the insulation class temperature of the lowest temperature insulation material used in the device. The max. operating temperature is the same as the sum of the ambient temperature and the device temperature rise.

Table 800-2 End-of Life Design Limits

Temperature Exposure	Organic Insulating Materials
The operational life of a magnetic device is limited by the various temperatures to which the insulation may be exposed.	The design service life is reduced 50% for each 10°C increase in hot-spot temperature.

TABLE 800-3 Design Applications

Specifications	Typical Applications
Mil-T-27	Audio, Power, & High-Power Pulse Transformers & Inductors
MIL-T-21038	Low-Power Transformers
MIL-C-15305 & MIL-C-39010	Fixed & Variable Radio Frequency Coils
MIL-STD-981	Custom Magnetic Devices
MIL-C-83446/5	Fixed Chip Radio Frequency Coils

3.0 Design and Construction

3.1 **Recommended Design for Space and Launch Vehicles** Design and construction should be in accordance with the applicable specification and the recommendations of this handbook.

Table 800-4 Design and Construction Considerations

Construction	Information
< 200 V devices	Minimum magnetic wire size should be as defined for Class S parts in Table I of MIL-STD-981.
≥ 200 V devices	Minimum wire size is AWG size #36.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 800-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Inadequate design for reliable operation	Wire size less than the size specified in Table I of MIL-STD-981.
Inadequate design for reliable operation	Wire size < # 36 for > 200 V devices.
Shorting and Arcing	Tin plated devices or leads.

3.3 **Known Material Hazards** The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 800-6 Known Material Hazards

Material	Precaution
Tin plating	100% tin causes tin whiskers.

3.4 Produceability and Baseline Controls A product baseline should be established for all custom magnetics. Areas which need to be specified and controlled in the drawing and baseline are:

Table 800-7 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-STD-981 for Class S.
Process Controls Verification & Validation	Refer to MIL-STD-981 for Class S.
Screening Tests (100%)	Refer to MIL-STD-981 for Class S. The 96 hour burn-in under no load conditions should be omitted from screening.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-STD-981 for Class S.
Qualification Tests (Destructive & Non-destructive tests)	Refer to Lot Conformance Tests.

4.0 Quality Assurance Provisions

The following table outlines the minimum areas which should be considered and verified when purchasing Magnetic devices to company specific Magnetic drawings.

Table 800-8 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): refer to the requirements of the company unique drawings, MIL-STD-981 and this handbook.	Review screening data (Attributes & Variables).
Lot Conformance: refer to the requirements of the company unique drawing, MIL-STD-981 and this handbook.	Review lot conformance data (Attributes & Variables).
Qualification Testing: refer to the requirements of company unique drawing, MIL-STD-981 and this handbook.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

SECTION 900 - MICROCIRCUITS

1 ORGANIZATION: This section covers Digital and Linear monolithic microcircuits (Integrated Circuits).

2 APPLICATION

Electrical Considerations. The circuit design should make allowances for worst case variations in output voltage or current, and propagation delays. All strategic parameters used in the application (all Subgroups) should be verified, and any radiation effects on those parameters over the life of the application considered.

TABLE 900-1 DIGITAL MICROCIRCUITS DERATING

PARAMETER	DERATING FACTOR (Nominal)/	DERATING FACTOR (Worst Case)	COMMENTS
Total Output Load Current	.80	.90	Not Applicable to single fanout devices.
Vcc specified nominal supply voltage	1.1Vcc	1.1Vcc	
Transients	1.2 Vcc	1.2 Vcc	Transient peaks not to exceed the specified value.
Propagation Delay	110 %	110 %	
Fanout			Derate by one load or to 80 percent of maximum rating (whichever is greater), except where fanout is rated as one
Power Dissipation, PD	.80	.90	
Max. Junction or “Hot-Spot” Temperature	+105 Degrees C	+125 Degrees C	Tj = Not to exceed +105C
Supply Voltage for CMOS	.70	.80	

TABLE 900-2 LINEAR MICROCIRCUITS DERATING

PARAMETER	DERATING FACTOR (Nominal)	DERATING FACTOR (Worst Case)	COMENTS
Input Signal Voltage	.70	.80	
Output Current	.75	.85	
Operating Frequency (application)	.75	.85	
Transients (4.)	1.20Vcc	1.4Vcc	Transients not to exceed the specified value
Gain (application)	.75	.85	
Power Dissipation, PD	.75	.85	
Max. Junction or “Hot-Spot” Temperature	+105 Degrees C	+125 Degrees C	Tj = Not to exceed +105C

TABLE 900-3 LINEAR VOLTAGE REGULATOR MICROCIRCUIT DERATING

PARAMETER	DERATING FACTOR (Nominal)	DERATING FACTOR (Worst Case)	COMENTS
Input Current	.80	.90	
Input Voltage	.80	.85	
Output Current	.75	.85	
Power Dissipation, PD	.75	.85	
Max. Junction or “Hot-Spot” Temperature	+105 Degrees C	+125 Degrees C	

3. DESIGN AND CONSTRUCTION

3.1 Background: Microcircuit devices Design and Construction have traditionally been maintained in accordance with the requirements of the applicable specifications (MIL-M-38510 and its Slash Sheets). The JAN Class S design rules within the specifications were applied where available. However, with the push for the use of plastic encapsulated devices, and replacement of traditional JAN Class S controls with the more cost effective high volume production line process controls the designer has to evaluate the acceptability of the proposed design and construction for the application (including Radiation Effects).

The new approaches such as Surface Mount package, Multi Chip Module (MCM) technology, and Power Module technology that are currently beginning to be employed in the space application designs are often based on old technology, either old die designs, old package types etc., that are modified and supplied as Surface Mount, MCM, and Power Modules. As such the modifications are often performed after the discrete devices were screened and the final product is rarely verified and validated for the intended application. Therefore, the designer or the component engineer needs to ensure that the supplied components meet the application requirements. Table 900-4 provides some of the known Design and Construction Considerations.

3.2 Reliability Suspect designs The following designs have been determined from past experience to be reliability suspect. However, with improved materials, process controls, and through sound engineering the problems associated with these designs could be alleviated:

- Hot welded cans
- Nonpassivated devices
- Plastic encapsulated units
- Packages other than those defined in MIL-STD-1835
- Programmable units which do not program with a single pulse
- Internal organic / polymeric materials (lacquers, varnishes, coatings, adhesives, or greases)
- Internal desiccants
- Flip chips
- Beam leaded devices
- Bimetallic lead bond at die
- Ultrasonic cleaned parts
- All tin coated packages or leads

Table 900-4 Design and Construction Considerations

Device Type	Design & Construction Considerations	Possible Mitigation
Cavity Devices	Lead solder based compounds used for die attach medium. Silver filed Epoxy or Silver glass die attach mediums. Organic passivating or conformal coating materials. Gold wire bonds on Aluminum die metalization and aluminum wire on gold substrates. Aluminum wire bonds on Silver die metalization and on Ni plated Au flash posts. Au flash on Ni plated posts.	Maintain the moisture levels below 5000ppm to prevent solder decomposition. Maintain under 5000 ppm moisture, perform Die Shear Monitors (beginning of shift / every 2 hours / end of shift) and qualify process to Temperature Cycling. Qualify process to 1000 hr HTRB, perform extended vacuum bake prior to device sealing, maintain low moisture levels. Qualify wire bond process to survive 300°C without Au-Al intermetalic formation. Qualify process to survive an acceptable number (to the design application) of Intermittent Operating Life Cycles followed by wire pull test without any wire lifts. Maintain gold to 5 - 10µin over Ni plating on posts.
Hot Welded Cans	A high potential for loose conductive particles inside the cans.	Monitored cap welding and PIND test.
Glass to metal seals	High probability of developing glass cracks during testing and handling of devices.	Qualify packages to survive acceptable number of Temperature Cycles for the proposed application followed by die penetrant.

3.3 Produceability and Baseline Controls A product baseline should be established for all devices not purchased as a MIL-PRF-38535 QPL device. Areas which need to be specified and controlled in the drawing and baseline are:

Table 900-5 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to MIL-PRF-38535 for Class S
Wafer Lot	Refer to MIL-PRF-38535 for Class S
Wafer Lot Acceptance	Refer to MIL-PRF-38535 for Class S
Radiation Hardening Performance	Refer to MIL-PRF-38535 for Class S
Assembly Lot accumulation period	Refer to MIL-PRF-38535 for Class S
Manufacturing Location	Refer to MIL-PRF-38535 for Class S
Assembly processes and their verification	Refer to MIL-PRF-38535 for Class S
Inspection Lot formation	Refer to MIL-PRF-38535 for Class S
Test equipment validation	Refer to MIL-PRF-38535
Serialization	Refer to MIL-PRF-38535 for Class S
Traceability Control (Parts, Materials, & Processes)	Refer to MIL-PRF-38535 for Class S
Rework Provisions	Refer to MIL-PRF-38535 for Class S
Process Controls verification & validation	Refer to MIL-PRF-38535 for Class S
MRB and Change Control Authority	Refer to MIL-PRF-38535
Screening Tests (100%)	Refer to MIL-PRF-38535 for Class S and Detail Specification as applicable
Quality Conformance Inspection (Destructive & Non-destructive tests)	Refer to MIL-PRF-38535 for Class S and Detail Specification as applicable
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-PRF-38535 for Class S and Detail Specification as applicable

Note: The manufacturing baseline should be developed and maintained by the manufacturer in accordance with MIL-PRF-38535, and controlled and verified by the procuring organization.

4. QUALITY ASSURANCE

There are four major areas to be covered under the Quality Assurance provisions. These are the Wafer Fabrication, Assembly, 100% Test or Screening, and Quality Conformance Inspection and Qualification. MIL-PRF-38535 has provided guidance for both the device manufacturers and designers in all of the four areas. The designer and component engineer has to understand the device application, the need for and application tolerance of device to device performance variation and how the device manufacturer controls in each of the four areas impact the performance. Table 900-6 provides a summary of the recommended controls for space level devices.

Table 900-6 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Wafer Fabrication: In process controls should be per MIL-PRF-38535, Appendix A.	Wafer Lot formation (mask revision), (5.) Wafer Fabrication rework control (5.) Wafer Lot Acceptance Wafer Fab Location (5.)
Assembly: In process controls should be per MIL-PRF-38535, Appendix A	Lot Homogeneity Production Lot formation Traceability Control Rework Provisions I.A.W. approved procedures Process Controls, their verification & validation elements Assembly Location
Screening Tests (100%): Screening should follow the MIL-PRF-38535 Table IA or IB, and detailed specification. Quality Conformance Inspection (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)	Electrical parameters and performance specified (including Radiation Effects) meets application. Screening Temperature Range, QCI and Qualification specified meet application Test equipment accuracy and repeatability Accept and Reject criteria Failure Analysis and Corrective action.
Screening (100 percent): refer to the requirements of MIL-PRF-38535 for Class S and the detailed specification.	Review screening data (Attributes & Variables). Verify test equipment correlation, repeatability, test-period windows were met, test parameters / conditions, and PDA compliance.

NOTES: (5.) To assure characterized electrical performance and characterized radiation hardness immunity for flight hardware (and future procurement).

Table 900-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Quality Conformance Inspection: refer to the requirements of MIL-PRF-38535 for Class S, and the detailed specification.	Review lot conformance data (Attributes & Variables), sampling techniques, and stress levels.
Qualification Testing: refer to the requirements of MIL-PRF-38535 for Class S, and the detailed specification.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier documentation.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

5.0 Lessons Learned

Wafer Fabrication: This is probably the most critical area that determines the device reliability and performance. Traditionally this area has been downplayed in its importance to the reliability of the end product and consequently controlled by OEMs through a "flow chart" at best. With the change from "screening of devices to meet quality requirements" to "building of quality into devices" this area becomes the only area that builds quality into the die. Homogeneity of the wafer fabrication process (with regard to exact process, exact mask set, exact fabrication module / equipment, etc.) as characterized, is paramount for known electrical and radiation performance. Many semiconductor companies are contracting-out wafer fabrication (in efforts to reduce costs), the component engineer should ascertain that the flight hardware was manufactured on the same line as the characterized product to assure electrical performance over the life of the program, including radiation effects. Table 900-8 outlines some of the areas that need specific attention.

Assembly: This is the area where the die, or chips, after being processed through wafer fabrication, are put in packages or assembled so that they can used in systems. The packages and assembly materials used determine in most cases, where the die ratings outperform the package ratings. Sound engineering process monitors, SPC, and continuous qualification feedback to assembly is important in controlling process variations. Many semiconductor companies are contracting-out package assembly (in efforts to reduce costs), the component engineer should ascertain that the flight hardware is assembled in the same certified facility as the characterized/qualified product to protect the Program schedule from surprises. Table 900-9 outlines some of the areas that need specific attention.

Screening: This area covers the 100% testing (electrical, mechanical, and environmental) that is applied to devices in order to eliminate the defects associated with infant mortality portion of the "Bathtub" reliability curve (see Figure 900-10). The Percent Defect Allowable (PDA), test windows post HTRB and Burn-In, and other controls determine the number of random defects expected when using the lot of devices. The implementation of effective process controls in the front areas, wafer fabrication and assembly, makes device to device performance variability more consistent, and therefore, could allow lots to be evaluated on a sample basis rather than screened on 100% basis. The intended design application requirements provide the basis for device performance valuation. Table 900-10 outlines some of the areas that need specific attention.

Quality Conformance Inspection (QCI): This area covers the sample verification of the lot integrity to be used in the application. The stress levels applied traditionally have been at the levels established, for the particular technology and product type, to simulate the end of life characteristics under accelerated conditions. Table 900-11 outlines some of the areas that need specific attention.

Table 900-8 - Wafer Fabrication

Area of Concern	Effect on Performance	Potential Remedy
Wafer Lot formation	Determines die lot performance homogeneity	Use wafers from single batches and manufacturers.
Wide resistivity and thickness, epi and epi thickness specifications	Allows wide range of electrical characteristics which lead to new device types and/or product downgrading.	Use only the devices for which the target specifications of the raw wafers were designed and not the downgraded by-products.
High defect count per cm^2.	Increase of device to device variation, risk of premature device failure, lower yields.	Lower the acceptable number of defects per cm on the incoming wafers.
Wafer Fab. Processing	Determines the device performance	
Particle size and count allowable in the clean room.	Depending on the device type, geometry, and technology may impact device reliability and electrical performance. Ionic contamination.	Use positive air flow interlocks and entries, air filters, process only devices for which the clean room characteristics were proven to be acceptable.
Water purity and Diffusion cleanness	Potential for ionic contamination.	Use water filters, test for bacteria, C-V plots.
Rework	Increase of device to device variation, risk of premature device failure, lower yields.	If allowed, verify that the rework did not have adverse effects on device performance in the intended application.
Wafer Fab Location	Use of foundries and other manufacturer's die leads to loss of visibility into wafer fab processing and controls may impact device performance.	Verify the supplier of devices has visibility and control over the wafer fabrication processes, changes, and implementation. Recharacterize.
Wafer Lot Acceptance	Data provided does not correlate or tie into the wafer fab process controls for oxide, die, metalization, and passivation layer thickness. Sampling may not be valid.	Ensure wafer lot acceptance provides meaningful data to ascertain the wafer fabrication process and controls (MIL-STD-883, Method 5007).
Radiation Tolerance	Wafer fab design and processing are not conducive to radiation hardened characteristics.	Verify homogeneity of wafer process/masks/fab. Provide circuit design solutions to prevent system failure.

Table 900-9 - Assembly

Area of Concern	Effect on Performance	Potential Remedy
Die attach is not consistent	Devices fail prematurely due to voids which cause over heating and or current crowding effects	Implement die attach monitors such as die shear.
Attach materials are not optimized for the package and design application.	Devices fail prematurely due to die attach degradation when operated under simulated and accelerated application conditions.	Qualify and validate the attach process and materials for the intended design application.
Multiple Lots formation and loss of Lot Traceability	Increase potential for lot failure due to loss of traceability to individual lots.	Maintain traceability to individual lots.
Rework Provisions	Allowing rework on the production line may not enforce corrective action implementation and promote loose process controls.	If rework was allowed, maintain traceability to the reworked portion of the lot for future valuation of adverse rework effects.
Purple Plague (Au wire on Al metalization)	Open circuit, or degraded electrical performance.	Validate process through extensive High temperature storage; subject lot to 300°C.
Purple Plague (Al wire on Au metalization	No impact if Gold is thin and the bonding is to the Ni under plate. Otherwise will lead to open circuit.	Validate process through Temperature and Operating Cycles; peel wire to verify bond.
Al wire bonds on Ag metalization.	Open circuit due to operating and Thermal cycles.	Validate process through Temperature and Operating Cycles;
Particles inside cavity	Potential short due to conductive particle such as Die attach slag, weld splash, etc.	Validate the processes to ensure loose particles are not introduced. Institute PIND.

Table 900-10 100% Screening

Screening Test	Effect on Performance	Rationale for Test Conditions
Pre-Cap Visual Inspection	Ensures the devices are free of defects prior to encapsulation	Depending on the manufacturer's process controls this may be done on a sample basis.
High Temperature Storage	Some device technologies require this to stabilize the junction characteristics.	Select the max. device rated temperature storage.
Temperature Cycling	Intended to screen out infant mortality defects due to die attach and other package mismatch defects.	20 cycles were initially established as sufficient to pass the infant mortality stage. Devices should reach temperature extremes.
Constant Acceleration	Test designed to stress the wire bonds and die attach areas.	The G-force level is determined by the package capability and should be above the application requirements.
PIND	Developed to screen out devices with loose particles inside the cavity.	Set-up sensitivity, location and tester mounting, shock/ co-shock and vibration levels, and transducer couple medium are important to effective PIND screening.
Pre-HTRB electrical tests	Electrical parameters (at T_A=25°C) established for each technology and device type to be indicative of a good device.	Parameters most likely to change if ionic contamination is present such as Leakage currents, Forward Voltage, Breakdown Voltage

Table 900-10 100% Screening (cont.)

Screening Test	Effect on Performance	Rationale for Test Conditions
HTRB	Stress test designed to screen out ionic contaminated devices using DC Bias Voltage and Temperature to accelerate the effects. Ions are made mobile through Temperature exposure while the DC Bias Voltage acts as dipole magnet attracting the ions on each positive and negative side of the power supply.	The applied Temperature should be that of the Max. Operating Ambient without heat sink, and the applied voltage should be 80% of the rated breakdown voltage of the stressed junction. The magnitude of the exposing temperature and applied bias directly affect the result. Applying AC Voltage or removal of the bias before devices reached approx. 35°C will negate the test.
Post-HTRB electrical tests	Repeat of Pre-HTRB electrical tests to validate devices did not drift outside the established limits. Test should be performed within 16 hrs of bias removal.	Ionic contamination, if free to move around will cause a change in the device electrical characteristic. Depending on the contaminant type and level the ions will eventually return to original state.
Percent Defective Allowable (PDA)	Establishes the random failure rate expected during the useful life of the devices.	Typical PDA is 5% max. with a one time resubmission if Percent Defective (PD) < 20%. Lots failing this criteria are should be considered reliability suspect.
Power Burn-In	Test designed to screen out assembly defects.	Test conditions are typically established such that device junction temperature approaches that of the maximum Operating Junction Temperature Ratings.

Table 900-10 100% Screening (cont.)

Screening Test	Effect on Performance	Rationale for Test Conditions
Post Power Burn-In electrical tests	Verify that devices still meet the established electrical characteristics.	Repeat the Post HTRB (Pre Burn-In) electrical tests plus the rest of the DC characteristics including those at high and low temperatures.
Percent Defective Allowable (PDA)	Establishes the random failure rate expected during the useful life of the devices.	Typical PDA is 5% max. with a one time resubmission if Percent Defective (PD) < 20%. Lots failing this criteria are should be considered reliability suspect.
X-Ray	Test was developed for workmanship verification (it does not replace Pre-Cap Visual Inspection).	Criteria and level of inspection is based on the package and defect type.

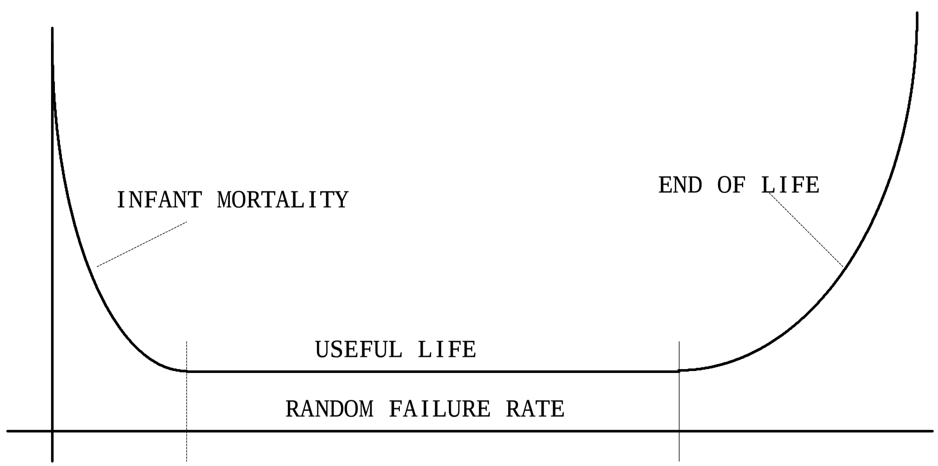


Figure 900-10: Reliability Bath Tub Curve

Table 900-11 - Quality Conformance Inspection

Test Name	Effect on Performance	Test Rationale
Group A	Verifies device electrical performance under DC, AC or transient conditions, and over the Rated temperature range.	Validates device capability to meet its electrical characteristics. Usually performed on each lot on a sample basis after 100% screening was completed.
Group B	Verifies device operational performance within the useful life portion of the bath tub curve. This includes package design integrity verification (Temperature Cycling, Intermittent Operating Life, and Thermal Resistance Subgroups), device operational performance (Accelerated Life Test).	Validates lot homogeneity and process/design operational performance capability on a lot by lot basis. Validates screening was performed correctly and no defects were introduced.
Group C	Verifies device mechanical performance and operational performance up to 1000 hrs. Operational Life or 6000 Intermittent Operation Cycles.	Validates the processing and device design provide up to 1000 hrs. and or 6000 cycles of useful life under accelerated conditions. Most military and space design applications reliability predictions use this as basis for predictions.
Group D	Verifies package end of life device design.	Validates that the device processing and design end of life are outside the Thermo-Mechanical and Operational boundaries established for useful life.
Group E	Verifies the die design capability to withstand the radiation effects environment in which some applications may operate during their useful life.	Validates wafer fabrication device design and processing are capable of meeting the total radiation exposure of the system operating life without electrical degradation .

SECTION 960 - HYBRIDS

1. ORGANIZATION: This section covers hybrid microcircuits, multi-chip-modules (MCM), and power modules.

2. APPLICATION

TABLE 960-1 HYBRID MICROCIRCUIT DERATING

DEVICE TYPE	DERATING FACTOR
HYBRID	Use the appropriate Derating Factor for each element covered in this Handbook

2.1 Verification. Verification of junction-case thermal resistance by testing and thermal mapping is recommended for new designs and use of new technology.

2.2 Electrical Considerations. The circuit design for each die should make allowances for worst case variations of the actual output logic "L" state sink current, actual logic "H" state sink current, propagation delays, gain, offset voltage, and bias current. The temperature range of Space Quality Hybrids is -55 to +125 Degrees C, however, application specific temperature range lower than this can be used with appropriate application qualification and verification. All strategic parameters used in the application (Dynamic and Static parameters) should be verified and should include any radiation and storage environments degradation effects on those parameters over the life of the application.

3. DESIGN AND CONSTRUCTION

BACKGROUND: Hybrid microcircuit devices Design and Construction have traditionally been maintained in accordance with the requirements of the applicable specifications (MIL-M-38510, MIL-H-38534, and MIL-STD-883, Method 5009). The Class K (previously Class "S") design rules within the specifications were applied where available. However, with the push for the use of plastic encapsulated devices, and replacement of traditional Class K controls with the more cost effective high volume production line process controls, the designer has to evaluate the acceptability of the proposed design and construction for the application (including Radiation Effects).

The new approaches such as Surface Mount components, Multi Chip Module (MCM) technology, and Power Module technology that are currently beginning to be employed in the space application designs are often based on old technology, either old die designs, old package types, etc., that are modified and supplied as Surface Mount, MCM, and Power Modules. As such, the modifications are often performed after the discrete devices were screened and the final product is rarely verified and validated for the intended application. Therefore, the designer or the component engineer needs to ensure that the supplied components meet the application requirements. Table 960-2 provides some of the known Design and Construction Considerations.

Table 960-2 Design and Construction Considerations

Device Type	Design & Construction Considerations	Possible Mitigation
Hybrid Packages	Lead solder based compounds used for die attach medium.	Maintain the moisture levels below 5000ppm to prevent solder decomposition.
	Silver filed Epoxy or Silver glass die attach mediums.	Qualify process meet mechanical, environmental (i.e. Temperature Cycling), and thermo-electrical application requirements (i.e. Hot spots, power distribution, etc.) Maintain under 5000 ppm moisture, maintain process monitors such as Die attach monitors (beginning of shift / every 2 hours / end of shift).
	Organic passivating or conformal coating materials.	Qualify process to 1000 hr HTRB, perform extended vacuum bake prior to device sealing, maintain low moisture levels.
	Gold wire bonds on Aluminum die metalization and aluminum wire on gold substrates.	Not recommended, if used, qualify wire bond process to survive 300°C without Au-Al intermetalic formation.
	Aluminum wire bonds on Silver die metalization and on Ni plated Au flash posts.	Qualify process to survive an acceptable number (to the design application) of Intermittent Operating Life Cycles followed by wire pull test without any wire lifts.
	Au flash on Ni plated posts.	Maintain gold to 5 - 10µin over Ni plating on posts.

Table 960-2 Design and Construction Considerations

Device Type	Design & Construction Considerations	Possible Mitigation
Welded, Brazed, or Soldered Lids	A high potential for loose conductive particles inside the package.	Monitored lid welding/sealing, and PIND test.
Hard Glass or Ceramic to metal seals	High probability of developing glass/ceramic cracks during testing and handling of devices.	Qualify packages to survive acceptable number of Temperature Cycles for the proposed application followed by die penetrant.

Produceability and Baseline Controls A product baseline should be established for all devices not purchased as a MIL-PRF-38534 QPL device. Areas which need to be specified and controlled in the drawing and baseline are:

Table 960-3 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to MIL-PRF-38534 for Class K
Wafer Lot	Refer to MIL-PRF-38534 for Class K
Element Evaluation / Wafer Lot Acceptance	Refer to MIL-PRF-38534 for Class K
Radiation Hardening Performance	Refer to MIL-PRF-38534 for Class K
Assembly Lot accumulation period	Refer to MIL-PRF-38534 for Class K
Manufacturing Location	Refer to MIL-PRF-38534 for Class K
Assembly processes and their verification	Refer to MIL-PRF-38534 for Class K
Inspection Lot formation	Refer to MIL-PRF-38534 for Class K
Test equipment validation	Refer to MIL-PRF-38534
Serialization	Refer to MIL-PRF-38534 for Class K
Traceability Control (Parts, Materials, & Processes)	Refer to MIL-PRF-38534 for Class K
Rework Provisions	Refer to MIL-PRF-38534 for Class K
Process Controls verification & validation	Refer to MIL-PRF-38534 for Class K
MRB and Change Control Authority	Refer to MIL-PRF-38534
Screening Tests (100%)	Refer to MIL-PRF-38534 for Class K and Detail Specification as applicable
Quality Conformance Inspection (Destructive & Non-destructive tests)	Refer to MIL-PRF-38534 for Class K and Detail Specification as applicable
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-PRF-38534 for Class K and Detail Specification as applicable

Note: A manufacturing baseline should be developed and maintained by the manufacturer in accordance with MIL-PRF-38534, and controlled / verified by the procuring organization.

4. QUALITY ASSURANCE There are four major areas to be covered under the Quality Assurance provisions. These are: the Element Evaluation, Assembly, 100% Test or Screening, and Quality Conformance Inspection and Qualification. TraMIL-H-38534 Appendix A required the manufacturers to develop a comprehensive Quality Assurance Plan covering all of the four areas. The designer and component engineer needs to understand the device application, the application need, the device to device performance variation impact to the application, and how the device manufacturer established controls in each of the four areas impact the device performance. Table 960-4 provides a summary of the recommended controls for space level devices.

Table 960-4 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Element Evaluation: In process controls should be per MIL-PRF-38534, Appendix A.	Microcircuit & Semiconductor Dice (1.) & (2.) Passive Elements (2.) Saw Elements (2.) Substrates (3.) Packages
Assembly: In process controls should be per MIL-PRF-38534, Appendix A	Lot Homogeneity Production Lot formation Traceability Control Rework Provisions I.A.W. approved procedures Process Controls, their verification & validation elements Assembly Location
Screening Tests (100%): Screening should follow the MIL-PRF-38534 Table X, and detailed specification.	Electrical parameters and performance specified (including Radiation Effects) meets application.
Screening (100%): Refer to the requirements of MIL-PRF-38534 for Class K and the detailed specification.	Review screening data (Attributes & Variables). Verify test equipment correlation, repeatability, test-period windows were met, test parameters / conditions, and PDA compliance.
Quality Conformance Inspection (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)	Screening Temperature Range, QCI and Qualification specified meet application. Test equipment accuracy and repeatability. Accept and Reject criteria Failure Analysis and Corrective action.

NOTES: (1.)Data to be representative of the devices to be used (i.e. Same manufacturer, same wafer fabrication module, same mask revision, same process) to assure characterized performance including potential processing, storage, and radiation degradation effects for flight hardware (and future procurement).

(2.) Was element designed to meet military temperature range (-55 to +125° C) or was it screened for the operation?

(3.) If coupons are used, are they representative of process? Exact metal, etc.?

Table 960-5 Qualification Quality Assurance

Quality Assurance Consideration	Recommended Verifications and

	Validations
Quality Conformance Inspection: refer to the requirements of MIL-PRF-38534 for Class K, and the detailed specification.	Review lot conformance data (Attributes & Variables), sampling techniques, and stress levels.
Qualification Testing: refer to the requirements of MIL-PRF-38534 for Class K, and the detailed specification.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier documentation.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

5.0 Lessons Learned

Element Evaluation:

Wafer Fabrication of microcircuit and semiconductor dice: This is probably the most critical area that determines the device reliability and performance. The circuit designer should assure that all elements used were designed to and meet the full temperature range and the full radiation environment(s) at end of life. Historically, hybrid manufacturers do not manufacture the die (active and passive elements) used in the finished hybrid. Traditionally this area has been downplayed in its importance to the reliability of the end product and consequently controlled by OEMs through a “flow chart” at best. With the change from “screening of devices to meet quality requirements” to “building of quality into devices”, this area becomes the only area that builds quality into the die, and therefore, the hybrid device. Homogeneity of the wafer fabrication process (with regard to exact process, exact mask set, exact die manufacturer, exact fabrication module / equipment, etc.) as characterized, is paramount for known electrical and radiation performance. Assuring that the die (and other components) are military grade (i.e.: probed to function in the -55 to +125 Degree C environment) saves time and money prior to assembly. Since many semiconductor manufacturers are contracting-out wafer fabrication (in efforts to reduce costs), the component engineer should ascertain that the flight hardware die / elements were manufactured on the same line as the characterized product to assure electrical performance over the life of the program, including radiation effects. Table 960-6 outlines some of the areas that need specific attention.

Preselection of passive elements and SAW elements to function over the full temperature range (-55 to +125 degrees C) and environment often saves expensive assembled device failures later.

Substrate evaluation by the use of coupons (where approved) should be representative of the actual substrate. Assuring same exact materials assures representative wire bond evaluations and die shear evaluations.

Assembly: This is the area where the active and passive elements are put in packages or assembled so that they can used in systems. The packages and assembly materials used determine, in most cases, where the die ratings outperform the package ratings. Sound engineering process monitors, SPC, and continuous qualification feedback to assembly is important in controlling process variations. Many hybrid companies are contracting-out package assembly (in efforts to reduce costs) and the component engineer should ascertain that the flight hardware is assembled in the same certified facility as the characterized/qualified product to protect the Program schedule from failures / surprises. Table 960-7 outlines some of the areas that need specific attention.

Screening: This area covers the 100% testing (electrical, mechanical, and environmental) that is applied to devices in order to eliminate the defects associated with infant mortality portion of the "Bathtub" reliability curve (see Figure 960-8). The Percent Defect Allowable (PDA), test-period windows post Burn-In, and other controls determine the number of random defects expected when using the lot of devices. The implementation of effective process controls in the front areas (wafer fabrication and assembly), makes device to device performance variability more consistent, and therefore, could allow lots to be evaluated on a sample basis rather than screened on 100% basis. The intended design application requirements provide the basis for device performance valuation. Table 960-8 outlines some of the areas that need specific attention.

Quality Conformance Inspection (QCI): This area covers the sample verification of the lot integrity to be used in the application. The stress levels applied traditionally have been at the levels established, for the particular technology and product type, to simulate the end of life characteristics under accelerated conditions. Table 960-9 outlines some of the areas that need specific attention.

Table 960-6 Element Evaluation Semiconductor Wafer Fabrication

Area of Concern	Effect on Performance	Potential Remedy
Wafer Lot formation	Determines die lot performance homogeneity	Use wafers from single batches and manufacturers.
Wide resistivity and thickness, epi and epi thickness specifications	Allows wide range of electrical characteristics which lead to new device types and/or product downgrading.	Use only the devices for which the target specifications of the raw wafers were designed and not the downgraded by-products.
High defect count per cm^2.	Increase of device to device variation, risk of premature device failure, lower yields.	Lower the acceptable number of defects per cm on the incoming wafers.
Wafer Fab. Processing	Determines the device performance	Evaluate devices for application performance.
Particle size and count allowable in the clean room.	Depending on the device type, geometry, and technology may impact device reliability and electrical performance. Ionic contamination.	Use positive air flow interlocks and entries, air filters, process only devices for which the clean room characteristics were proven to be acceptable.
Water purity and Diffusion cleanness	Potential for ionic contamination.	Use water filters, test for bacteria, C-V plots.
Rework	Increase of device to device variation, risk of premature device failure, lower yields, loss of radiation effects immunity.	If allowed, verify that the rework did not have adverse effects on device performance in the intended application, including radiation effects.
Wafer Fab Location	Use of foundries and other manufacturer's die leads to loss of visibility into wafer fab processing and controls; may impact device performance.	Verify the supplier of devices has visibility and control over the wafer fabrication processes, changes, and implementation. Recharacterize electrical and radiation performance.
Wafer Lot Acceptance	Data provided does not correlate or tie into the wafer fab process controls for oxide, die, metalization, and passivation layer thickness. Sampling may not be valid.	Ensure wafer lot acceptance provides meaningful data to ascertain the wafer fabrication process and controls (MIL-STD-883, Method 5007). Verify homogeneity of wafer process/masks/fab.
Radiation Tolerance	Wafer fab design and processing are not conducive to radiation hardened characteristics.	Provide circuit design solutions to prevent system failure.

Table 960-7 - Assembly

Area of Concern	Effect on Performance	Potential Remedy
Die attach is not consistent	Devices fail prematurely due to voids which cause over heating and or current crowding effects	Implement die attach monitors such as die shear.
Attach materials are not optimized for the package and design application.	Devices fail prematurely due to die attach degradation when operated under simulated and accelerated application conditions.	Qualify and validate the attach process and materials for the intended design application.
Multiple Lots formation and loss of Lot Traceability	Increase potential for lot failure due to loss of traceability to individual lots.	Maintain traceability to individual lots.
Rework Provisions	Allowing rework on the production line may not enforce corrective action implementation and promote loose process controls.	If rework was allowed, maintain traceability to the reworked portion of the lot for future valuation of adverse rework effects.
Purple Plague (Au wire on Al metalization)	Open circuit, or degraded electrical performance.	Validate process through extensive High temperature storage; subject lot to 300°C.
Purple Plague (Al wire on Au metalization	No impact if Gold is thin and the bonding is to the Ni under plate. Otherwise will lead to open circuit.	Validate process through Temperature and Operating Cycles; peel wire to verify bond.
Al wire bonds on Ag metalization.	Open circuit due to operating and Thermal cycles.	Validate process through Temperature and Operating Cycles;
Particles inside cavity	Potential short due to conductive particle such as Die attach slag, weld splash, etc.	Validate the processes to ensure loose particles are not introduced. Institute PIND.
Assembly Location	Use of contract facilities leads to loss of visibility into the assembly processes and change controls; may impact device performance.	Verify that Contractor has visibility into assembly processes, changes, and implementation. Recharacterize / requalify.

Table 960-8 100% Screening

Screening Test	Effect on Performance	Rationale for Test Conditions
Internal Visual Inspection	Insures the devices are free of defects prior to encapsulation	Depending on the manufacturer's process controls this may be done on a sample basis.
Temperature Cycling	Intended to screen out infant mortality defects due to die attach and other package mismatch defects.	20 cycles were initially established as sufficient to pass the infant mortality stage. Devices should reach temperature extremes.
Constant Acceleration	Test designed to stress the wire bonds and die attach areas.	The G-force level is determined by the package capability and should be above the application requirements.
PIND	Developed to screen out devices with loose particles inside the cavity.	Set-up sensitivity, location and tester mounting, shock/ co-shock and vibration levels, and transducer couple medium are important to effective PIND screening.
Pre Burn-in electrical tests	Electrical parameters (at T_A=25°C) established for each technology and device type to be indicative of a good device.	Parameters most likely to change if ionic contamination is present such as Leakage currents, Forward Voltage, Breakdown Voltage

Table 960-8 100% Screening (cont.)

Screening Test	Effect on Performance	Rationale for Test Conditions
Burn - In Test	Stress test designed to screen out ionic contaminated devices using DC Bias Voltage and Temperature to accelerate the effects. Ions are made mobile through Temperature exposure while the DC Bias Voltage acts as dipole magnet attracting the ions on each positive and negative side of the power supply.	Test conditions are typically established such that device junction temperature approaches that of the maximum Operating Junction Temperature Ratings.
Post Burn-In electrical tests	Repeat of Pre Burn-In electrical tests to validate devices did not drift outside the established limits. Test should be performed within 96 hours of bias removal.	Ionic contamination, if free to move around will cause a change in the device electrical characteristic. Depending on the contaminant type and level the ions will eventually return to original state.
Percent Defective Allowable (PDA)	Establishes the random failure rate expected during the useful life of the devices.	Typical PDA is 2% maximum. Lots failing this criteria are should be considered reliability suspect.
X-Ray	Test was developed for workmanship verification (it does not replace Internal Visual Inspection).	Criteria and level of inspection is based on the package and defect type.

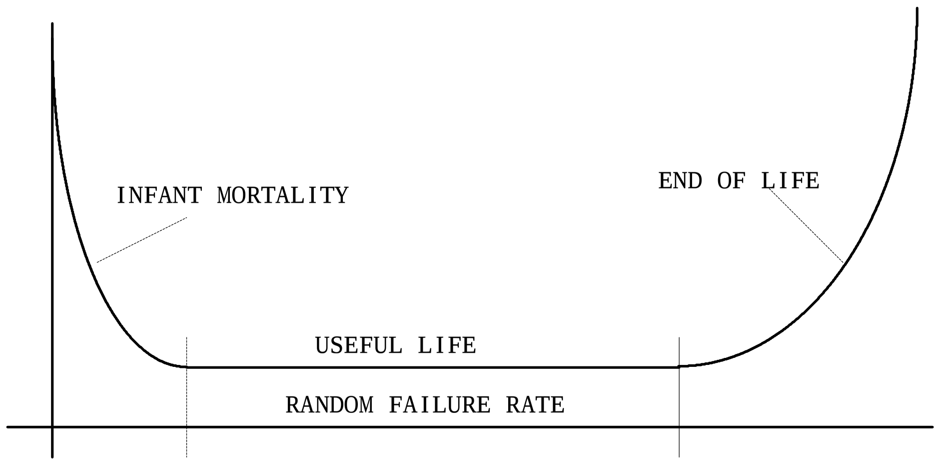


Figure 960-8: Reliability Bath Tub Curve

Table 960-9 Quality Conformance Inspection

Test Name	Effect on Performance	Test Rationale
Group A	Verifies device electrical performance under DC, AC or transient conditions, and over the Rated temperature range.	Validates device capability to meet its electrical characteristics. Usually performed on each lot on a sample basis after 100% screening was completed.
Group B	Verifies workmanship and package homogeneity and capability.	Validates lot homogeneity and process/design operational performance capability on a lot by lot basis. Validates screening was performed correctly and no defects were introduced.
Group C	Verifies device mechanical performance and operational performance up to 1000 hours Operational Life.	Validates the processing and device design provide up to 1000 hours of useful life under accelerated conditions. Most military and space design applications reliability predictions use this as basis for predictions.
Group D	Verifies package end of life device design.	Validates that the device processing and design end of life are outside the Thermo-Mechanical and Operational boundaries established for useful life.
Group E	Verifies the die design capability to withstand the radiation effects environment in which some applications may operate during their useful life.	Validates wafer fabrication device design and processing are capable of meeting the total radiation exposure of the system operating life without electrical degradation .

6.0 Reliability Suspect designs The following designs have been determined from past experience to be reliability suspect. However, with improved materials, process controls, and through sound engineering the problems associated with these designs could be alleviated:

- Hot welded cans
- Nonpassivated die
- Plastic encapsulated units
- Packages other than those defined in MIL-STD-1835
- Programmable units which do not program with a single pulse
- Internal organic / polymeric materials (lacquers, varnishes, coatings, adhesives, or greases)
- Internal desiccants and getters
- Flip chips
- Uninspectable surface mount devices
- Bimetallic lead bond at die
- Any internal parts, packages, or leads with tin coating

SECTION 1000 - RELAYS (CURRENT RATING OF 25A OR LESS)

1. ORGANIZATION: This section covers electromechanical relays with current rating of 25 amperes or less.

2. APPLICATION

TABLE 1000-1 - RELAY DERATING

DEVICE TYPE	PARAMETER	DERATING FACTOR	COMENTS
Relays	Coil Voltage (Steady State conditions) 1/	100% of rated	Operation at less, or higher than rated coil voltage compromises relay operating life cycles
	Coil Voltage (Pulsed conditions) 1/	<150% of rated	Duty Cycle < 10%, Max. on time 50ms
	Resistive Load	.75 of rated Resistive load	
	Inductive Load	.40 of rated Resistive load	
	Motor Load	.20 of rated Resistive load	Or .75 of rated Inductive Load
	Filament Load	.10 of rated Resistive load	Or .75 of rated Motor Load
	Capacitive Load	.75 of rated Resistive load	Or .75 of rated Filament Load
	Tj	.50 80% of Tj Max	Not to exceed 105°C

NOTE 1: The caution is specified by both MIL-R-6106 and MIL-R-39016:

Table 1000-2 End-of Life Design Limits

Parameter	End of Life Values)
Contact Resistance	Same as the specified Life Test endpoints
Pick-up and Drop out voltages	Same as the specified Life Test endpoints

TABLE 1000-3 Design Applications

Typical Applications	Application Considerations	Possible Mitigation
Capacitive Load	Currents may exceed Dc rated resistive loads levels	Use series resistance to limit current levels
General	Protect the coil against transient voltages of greater than twice the rated voltage.	Use external diodes to protect the coil as needed.
	Low or Intermediate loads (relative to the rated load) applications.	Qualify the relays at these levels as well to insure relay performance.
	Operating with current loads in excess of the rated resistive loads.	Relay is qualified at the operating current levels with twice the number of cycles of the actual application. Lot-by Lot verification of this performance is maintained through testing.

3. DESIGN AND CONSTRUCTION

3.1 Recommended Design for Space and Launch Vehicles Relays designed and qualified to MIL-R-6106, MIL-R-28776, MIL-R-39016, and MIL-R-83726 and are processed to Table 1000-8 (manufacturing), Table 1000-9 (screening), Table 210-10 (lot conformance).

Table 1000-4 Design and Construction Considerations

Design & Construction Considerations	Possible Mitigation
Electronic components such as diodes, transistors, capacitors, and hybrids used in the manufacture of the relays.	Follow the applicable Military Specifications for Space level devices and applicable sections in this handbook.
Magnet Wire	Coil wire should be 44 AWG or larger and use a polyimide (or equivalent) insulation
Teflon strands used as an integral part and extension of the Teflon coil wrap or coil lead insulation are acceptable	Insure no loose Teflon strands are inside which can interfere with the normal actuation and operation of the relay.

3.2 Known Reliability Suspect Designs: The information in Table 1000-5 describes products which have caused reliability problems in the past. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1000-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Uncontrolled critical processes and procedures that have critical effect on the fabrication, function, reliability, or service life of the article	Raw material certification and property sample tests, coil assembly, carrier assembly, contact assembly, armature assembly, coil core and pole piece assembly, motor assembly, relay subassembly prior to closure, and final assembly and closure are considered critical to the performance of relays.
Uncontrolled critical materials	Critical materials are: coil assembly, carrier assembly, contact assembly (contacts), armature assembly, coil core, pole piece assembly, motor assembly, wires, and header
Loose particles inside the relays	Relays were not canned and final assembly was not performed in clean environment (Class 100), were not properly cleaned, etc.
Use of outgassing materials inside the relays.	Vacuum bake the Relay coil assemblies to ensure no film buildup on the contacts and increase in contact resistance.
Loose or partially attached Weld splatter or weld expulsion balls	Weld splatter or weld expulsion balls should not be allowed, if not capable of withstanding a probing force of 125 ± 5 grams applied using a force gage calibrated for a range of 110 to 135 grams pressure force. Probe each suspect weld one time only during pre-cap.
Scratches and Burns	Scratches or tool marks wholly below the surface of the metal are acceptable. Burrs protruding above the surface are not acceptable.
Cracks in greater than .1" glass seals. Soldered-sealed cases Units not subjected to a vibration miss test External dielectric coatings Plug-in devices Internal suppression diode Tin plated packages or terminals	Screen out the relays with cracks in the header pin glass seals, if the crack length from the pin or outer edge is more than one-third the radius of the seal. Use of clear coating materials on the glass seal (if not fully qualified as required in MIL-R-6106, MIL-R-28776, MIL-R-39016, and MIL-R-83726) will hide the seal cracks without any added benefit.

Table 1000-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	See NOTE 1.
Control of critical processes, materials, and components	Table 1000-5, and NOTE 1.
Production Lot	See NOTE 1.
Serialization	See NOTE 1.
Traceability Control (Parts, Materials, & Processes)	See NOTE 1.
Rework Provisions	See NOTE 1.
Process Controls verification & validation	See NOTE 1.
Screening Tests (100%)	See NOTE 1.
Lot conformance Tests (Destructive & Non-destructive tests)	See NOTE 1.
Qualification Tests (Destructive & Non-destructive tests)	See NOTE 1.

NOTE 1: Follow MIL-R-6106, MIL-R-28776, MIL-R-39016, and MIL-R-83726

4.0 Quality Assurance Provisions

4.1 The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL-R-6106, MIL-R-28776, MIL-R-39016, and MIL-R-83726 or custom relays purchased under Source, Selected Item, and Specification Control Drawing.

Table 1000-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: Follow MIL-R-6106, MIL-R-28776, MIL-R-39016, MIL-R-83726, and the following:	Critical components and materials Lot formation, Traceability, and Homogeneity. Production Lot formation Device Serialization Traceability Control Rework Provisions I.A.W. approved procedures Process Controls and their verification & validation elements Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Visual Inspection criteria: Perform in a Class 100 environment per FED-STD-209 using a minimum of 10X magnification on relays prior to final clean prior to capping.	Inspect contact assembly, contact surfaces, stationary and movable contacts, springs, coil, pole piece, armature, header. Inspect the entire relay assembly for scratches, burns, particulate, etc. (See Table 1000-8 for details)
Screening (100 percent): refer to the requirements of MIL-R-6106, MIL-R-28776, MIL-R-39016, MIL-R-83726.	Review screening data (Attributes & Variables). Verify test equipment correlation, repeatability, test windows were met, test conditions, and PDA compliance.
Lot Conformance: refer to the requirements of MIL-R-6106, MIL-R-28776, MIL-R-39016, MIL-R-83726.	Review lot conformance data (Attributes & Variables).
Supplier DPA: should be in accordance with MIL-STD-1580.	Review supplier DPA and compare to incoming DPA.
Qualification Testing: refer to the requirements of MIL-R-6106, MIL-R-28776, MIL-R-39016, MIL-R-83726 and application requirements.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

Table 1000-8 Visual Inspection

Visual Inspection Criteria	Rationale
Moving Contact Assembly and Springs. Inspect the moving contact assembly for proper installation and position. The springs should clear all adjacent parts for both positions of the armature. Inspect support brackets for the moving contact assembly for cracks and loose fractures (20X, 10X minimum for relays larger than 1 ampere).	Insure that Moving Contact Assembly and Springs operation is not hindered.
Contact Surfaces (Fixed and Movable). Inspect surfaces for scratches or burrs in contact mating area and cracked or peeling plating. Inspect mating contact surfaces for proper alignment for both positions of the armature, underside of contact supports for tool marks, fibers and other contaminants, and weld splatter.	Insure contacts have optimum performance characteristics and provide the expected cycling life.
Coil Inspection. Inspect and probe the coil lead welds for adequate quality and evidence of weld on each coil lead wire; weld splatter at coil terminals; Verify coils are not kinked, nicked, proper lead coil dress with clearance to all moving and conductive surfaces, and the teflon insulation is not loose or frayed.	To avoid future latent broken, open, or shorting of the coil wires.
Armature and Pole Piece. Inspect armature and pole piece gap for weld splatter and contamination.	Prevent loose particles from developing and affect future relay operation.
Header. Inspect header for Tool marks that affect reliability, glass seal defects, weld splatter, cracked or peeling plating, misalignment of header and frame.	

5.0 Lessons Learned Relays are electromechanical devices that require very careful magnetic and mechanical adjustments to for optimum operation. Therefore, their manufacturing and testing should be documented and verified for each procurement.

Cleaning. All electromechanical relays should be cleaned. To insure cleaning is effective is recommended to be performed in a Class 100 environment. and that relays are degaussed and the permanent magnets demagnetized if they can be re-magnetized and stabilized after canning. The relays are typically demagnetized with a Thomas and Skinner Model DM 35 or equivalent equipment. Cleaned relays should be stored in Class 100 environment. There are various methods for cleaning: Ultrasonic, Vacuum, and Millipore Cleaning which are outlined below.

Ultrasonic Cleaning. Ultrasonically clean relay trays and covers. Clean a sufficient quantity of trays and covers for storage and transport of relays, cans, and other parts for the remainder of required cleaning. Store in Class 100 environment per FED-STD-209. Ultrasonically clean relays, cans, and any other parts and subassemblies that constitute the final assembly. Immediately after cleaning, store the parts in covered trays in a Class 100 environment per FED-STD-209.

Vacuum Cleaning. Vacuum clean parts in a laminar flow bench. Using a pressure gun and filtered air flowing through a static eliminator, blow filtered air on the parts, holding the parts in front of a vacuum inlet to trap loosened particles. Immediately store cleaned parts in clean covered trays.

Cleaning and Small Particle Pre-seal Inspection. Test relays, cans, and any other parts or subassemblies that constitute the final assembly using the following procedure. First obtain Freon (or equivalent EPA approved) from a pre-filtered supply. Assemble pre-cleaned 1000 milliliter flask, vacuum pump, filter holder, pre-cleaned 0.80 micrometer filter, and pre-cleaned funnel. Fill funnel with pre-filtered Freon and turn vacuum pump on. Repeat until flask is filled. Fill a pressurized container with cleaned Freon. Clean filter by blowing both surfaces with ionized air. Using the pressurized container, wash both sides of the filter with clean filtered Freon. Observe filter under 30X magnification; if any particles are observed, repeat the cleaning process until no particles are observed. Place the filter holder and cleaned filter on a clean empty 1000 milliliter flask under funnel. Air blow all parts to be millipore-cleaned using ionized air. Place parts in funnel. Using 1000 milliliter flask of filtered Freon, pour the Freon into the funnel, covering the parts to be cleaned. Cover funnel. Turn on vacuum pump. When all the Freon has passed through the filter, turn off vacuum pumps. Remove filter and examine under 30X magnification. If one or more particles 2.5 micrometers (0.001 inch) or larger are present, or three or more visible particles under 2.5 micrometers (0.001 inch) are present on the filter, repeat the process until no additional particles are observed. Place cleaned parts in cleaned covered trays in preparation for canning the relays.

4.2 Screening (100 percent). Screen (100 percent) of MIL-R-39016 type relays in accordance with the "M" level of the Group A inspections in MIL-R-39016 and ER level for MIL-R-6106 with the addition and exceptions in Table 1000-9

Table 1000-9 Screening Table

MIL-R-39016 &6106 Level M and ER GRP. A Respectively	Additions/Exceptions to MIL-R-39016 and 6106
Monitored Vibration	MIL-STD-202, Method 214, Test Condition II, K; Perform Random Vibration to the requirements of the application onto 3 orthogonal planes for 3 minutes each; Monitor for contact chatter or transfer greater than 10μs per MIL-STD-202, Method 310, Circuit B with equipment capable of detecting closures of 1μs and greater. No contact transfer is allowed. Mounting fixture cannot add or remove energy from the relay. Energize/latch the non-latching/ latching relays during 1st half of the test and de-energize/latch the other during the second half for non-latching and latching relays respectively.
Thermal Shock	Per MIL-R-6106, Group A, operational reliability requirements perform five thermal shocks and record pickup and dropout voltage; For relays with coil gauge wire of AWG 44 or smaller, continually monitor coil continuity with 350 μA (maximum current) during last temperature cycle. Monitor relay for Miss Test during fifth cycle of thermal shock
PIND	Perform Particle Impact Noise Detection (PIND) per MIL-STD-202, Method 217 with the following criteria: The lot may be tested a maximum of 5 times. If less than 1% of the lot fails during any of the 5 runs, the lot may be accepted. All defective devices should be removed after each run. Lots which do not meet the 1% PDA on the fifth run, or exceed 25% defectives cumulative, should be rejected. Substitute Vibration Miss Test for those relays in which the noise signature is characterized by mechanical chatter, the Particle Impact Noise Detection (PIND) test may not detect particles. Vibrate relay with a 10 g peak sine wave at a fixed frequency of 10 Hz for 3 ± 0.1 minutes on an axis perpendicular to the motion of the contacts. Operate the relay at 9.9 Hz while monitoring the contacts for any misses. Reject all relays with misses.
Electrical Characteristics	Determine in accordance with the requirements in MIL-R-39016: Contact Resistance, Operating Voltage, Release Voltage, Hold Voltage, Operate and Release Times, Contact Bounce, Coil Resistance, Transient Suppression, and Reverse Polarity Protection.
Insulation Resistance	
Dielectric Withstanding-Voltage	Sea Level Only
Radiographic	Per MSFC-STD-355; 2 views 90° apart by X-ray inspection, or 360°. view by Vidicon. Use of "real-time" X-ray systems capable of viewing through 360 deg rotation is encouraged.
Hermetic Seal	Per MIL-R-6106 or MIL-R-39016 (as applicable)

External Visual and Mechanical Examination	Per MIL-R-6106 or MIL-R-39016 (as applicable)

Table 1000-10 Lot Conformance TestsTable

MIL-R-39016 &6106	Additions/Exceptions to MIL-R-39016 and 6106
Random Vibration and Shock	Perform per Table 1000-9 herein
Resistance to solder heat	Per MIL-R-39016
Internal moisture	Per MIL-R-6106
Qualification Tests	Per MIL-R-39016 and application requirements

SECTION 1100 RESISTORS, INTRODUCTION

1.0 ORGANIZATION: This section covers the common information for resistors and thermistors. Table 1100-1 lists, the types and style included in this section and the applicable section in this handbook where the specific detailed information is located.

Table 1100-1 Types and Style Included in Section 1100

Section	Resistor Type	Ref. Specification	Style
1110	Fixed Carbon Composition	MIL-R-39008	RCR
1120	Fixed Film	MIL-R-39017	RLR
1125	Fixed Film Chips	MIL-R-55342	RM
1130	Fixed Metal Film	MIL-R-87254	RSC
1140	Variable, Nonwire-Wound) & Wire-Wound	MIL-R-39035, 39015	RJR, RTR
1160	Wire-Wound, Accurate	MIL-R-39005	RBR
1170	Wire-Wound, Power-Type & Chassis-Mounted		RWR, RER
1190	Resistor Network	MIL-R-874	RZR
1195	Thermistor	MIL-T-23648	RTH

2.0 Application

For use of resistors refer to MIL-STD-199 and the information contained in the applicable section of this handbook.

2.1 Derating Power derating requirements are based on conditions of temperature and stress that are used for testing to establish failure rate levels. Improved part failure rates result when reduced part stress ratios or reduced temperatures are used. Derating requirements given are based on operation in vacuum.

2.2 End-of-Life Design Limits End-of-life design limits do not include item tolerances and are therefore additive to values specified in each applicable section.

Table 1100-2 Electrical Considerations

Electrical Considerations	Information for the designer and selector.
Power Ratings	Selection of resistor types and power ratings should be used based on intended application and allowable failure rate.
Pulse Applications	In applications where pulse voltages are present, the maximum pulse amplitude (including any steady-state voltage) should not exceed the value established by derating, regardless of resistance value.
Repetitive pulses	The average power should not exceed the established derated value. Average power is defined by: P (avg) = P (t/T) where P= pulse power, calculated from the equation ($P = E^2/R$) t =pulse width, and T = cycle width
Nonrepetitive pulses	The thermal time constant of the resistor in the particular application should be determined and the pulse power limited to a value that does not result in a temperature rise at the resistor surface which is greater than the temperature rise that would result from the applied derated dc power level. When actual test pulse power data exist, the data should be listed in Company documentation.

3.0 Design and Construction

The design and construction paragraph within the detailed part section provides information specific to the resistor for recommended designs, known design and construction problems, known reliability suspect designs, known material hazards, and recommended topics to be addressed in a company unique drawing to control produceability and controlling a baseline from a vendor.

TABLE 1100-3 Design and Construction Considerations

Design and Construction	Information
Solder Dip/Retinning Option	When solder dip/retinning is exercised, the subsequent 100% testing, as specified in the applicable military specification should be performed. The supplier should have been previously qualified to perform the process to the applicable military specification.

Table 1100-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Significant change of resistance value in a short period of time, regardless of storage conditions.	All carbon film
Has changed resistance value during operation.	All variable types.
	Films over solid cores without initial undercoating
Silver migration	Chip devices with silver or silver/palladium terminations that have no barrier metallization
	Film chips with films < 350 Angstroms thick
	Non-hermetic film resistors with aluminum terminations
	Wirewound resistors with crimped or soldered terminations
	Wirewound resistors with wire size < 0.001 inch
Nichrome migrates and causes opens	Nichrome film networks
	Network resistors using tantalum nitride films < 350 Angstroms thick.
	Non-welded networks
Corrosion	Nonhermetic resistor networks
	Non-hermetic hollow core (ceramic) film types. This construction was prohibited by MIL-STD-1547.
	All hermetic hollow ceramic core film resistors with internal metallization. This construction was prohibited by MIL-STD-1547.
Tin plate causes tin whiskers, which carries current to short or arc devices on a PWB.	Parts with tin-plated leads. This construction was prohibited by MIL-STD-1547.

4.0 Quality Assurance

The quality assurance section contains the recommended verification and validation during the procurement process, screening tests, lot conformance tests, and qualification tests for each resistor type.

4.1 Production Lot

The recommended production lot for high reliability resistors is, resistors of a single resistance and voltage rating of one design, from the same material batch, and processed as a single lot through all manufacturing steps on the same equipment, to the same baseline documentation, and identified with the same date and lot code designation. The lot may contain all available resistance tolerances for the nominal resistor value.

5.0 Lessons Learned

This paragraph has been inserted into this handbook to document information which from past experience and history which is not addressed in any other paragraph. This information was gained during failure reviews, incoming inspection history and any other source available which will give insight into problems which can be rectified.

SECTION 1110 FIXED COMPOSITION, INSULATED, CARBON COMPOSITION RCR (MIL-R-39008)

1.0 Scope

This section contains detailed information for fixed composition resistors (commonly called carbon comp resistors).

2.0 Application

The following tables contain information about fixed, composition resistors to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1110-1 Derating

Device Type	Parameter	Derating Factor	Comments
COMPOSITION RCR	POWER HOT-SPOT TEMPERATURE	.50 .80 of Max Rated	Nor recommended for space applications Above 70°C derate linearly to 0 Power at 98°C Ambient Temperature

TABLE 1110-2 End-of Life Design Limits

Resistance	
± 15 % for approved application	± 20% for worst case application

TABLE 1110-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
RCR		Changes in resistance of ± 15% due to moisture and temperature effects.	When closer tolerance or higher accuracy is needed, metal film or precision wire-wound devices are preferred.

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Carbon composition resistors are not recommended for any application requiring a resistor tolerance of 20% or less. Design and construction information is found in MIL-R-39008, and the following information of this handbook:

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1110-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
	Carbon film types (prolitic carbon film deposited on glass or ceramic core).
Change of resistance value in excess of ±20%	Carbon composition (RCR) resistors should be limited to applications where a resistance accuracy (excluding initial tolerance) in excess of ±20% is allowed by the design.

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-39008 unless other wise specified.

Table 1110-5 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Incoming Inspection: Verification of resistor received on a sample basis.	Review incoming data for accuracy of test.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

5.0 Lessons Learned

5.1 In coastal areas of U.S. these resistors can change as much as 50% and cannot be baked out after normal storage. Carbon comps will absorb moisture from organics during vacuum bake of hermetically sealed assemblies.

5.2 Performing DPA on this type of resistor has no added value.

SECTION 1120 Fixed Film Resistor RLR (MIL-R-39017)

1.0 Scope

This section contains detailed information for fixed film resistors (style RLR).

2.0 Application

The following tables contain information about fixed film (thick), resistors to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1120-1 Derating

Device Type	Parameter	Derating Factor	Comments
ALL	Steady State Power Peak Power	0.5 of rated 0.7	Derate linearly above 60C to zero at 100C Derate linearly above 70C to zero at 125C
RLR 05	Maximum continuous W V DC 200V	0.80 of the maximum continuous working voltages	
RLR 07	Maximum continuous W V DC 250V	0.80 of the maximum continuous working voltages	
RLR 20	Maximum continuous W V DC 350V	0.80 of the maximum continuous working voltages	
RLR 32	Maximum continuous W V DC 500V	0.80 of the maximum continuous working voltages	

TABLE 1120-2 End-of Life Design Limits

Resistance	Resistance
± 2 % for approved application	± 3 % for worst case application

TABLE 1120-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
RLR		Peak Power (Watt-seconds) should be limited to: RLR 05 1 RLR 07 3 RLR 20 15 RLR 32 40	
		Outgassing The resistor encapsulation is organic materials	The application must be tolerant of moisture and outgassing.
		These devices are susceptible to ESD damage.	Precautions against ESD should be used in packaging, handling, storage and kitting.

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Resistors designed and qualified to MIL-R-39017, failure level "S".

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1120-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Thin metal film	Devices constructed with a deposited thin metal film over solid core that do not have protective undercoating between the metal film and the outer jacket should not be used.
ESD Damage	Resistors not protected from electrostatic discharge during shipping and handling may experience permanent damage.
Corrosion	Resistors using aluminum terminations are susceptible to corrosion due to moisture penetration. These parts should not be used or procured, unless with protective undercoating.

3.3 Produceability and Baseline Controls A product baseline should be established for all fixed film resistors. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1120-5 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-R-39017
Process Controls Verification & Validation	Refer to MIL- R-39017
Screening Tests (100%)	Refer to MIL-R-39017 and table 1120-7 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-R-39017
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-R-39017

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-39017 unless other wise specified.

Table 1120-6 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-R-39017 Group A and Table 1120-7, in this handbook.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-R-39017 Group B tests	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to the requirements of MIL-R-39017	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

Table 1120-7 Screening Table

MIL-R-39017	Additions to the Methods and Criteria of MIL-R-39017
Subgroup 1 100% Thermal Shock	
DC Resistance	Read and record
Overload	24 hours min. @ 25°C ± 5°C with 1.5 X rated power
Power conditioning	96 hours min. @ max. rated temperature with full rated power; do not exceed max. voltage specified in the spec.
DC Resistance (after Power Conditioning)	a) Change in DC resistance should not exceed 0.5 % +0.05Ω or ± 3 standard deviation, whichever is less, for the combined overload and power conditioning tests b) DC resistance should be within initially specified tolerance limits; lots having more than 10% out-of-tolerance rejects should not be used
Subgroup 2 100% Resistance Noise	(Optional for applications that are not noise-sensitive) Procedure and accept/reject criteria should be per MIL-R-87252
Subgroup 3 Solderability	
Subgroup 4 Visual and Mechanical Examination	

SECTION 1125 Fixed Film Resistor Chips RM (MIL-R-55342)

1.0 Scope

This section contains detailed information for fixed film resistor chips.

2.0 Application

The following tables contain information about fixed, film resistor chips to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1125-1 Derating

Parameter	Derating Factor	Comments
Power	Nominal < 70°C 50% of rated power Worst Case < 70°C 75% of rated power	70 to 125°C linearly derate to zero power 70 to 125°C linearly derate to zero power
Voltage	Should be limited to 0.8 times maximum voltage values shown in MIL-R-55342	Steady-state voltage applied to resistors

TABLE 1125-2 End-of Life Design Limits

Resistance	Resistance
± 4 % for approved application	± 7% for worst case application

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Fixed film resistor chips, which meet the design and construction requirements of MIL-R-55342, and have had the additional testing in table 1125-7 herein.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

3.3 Produceability and Baseline Controls A product baseline should be established for all fixed film resistor chips. Areas which need to be specified and controlled in the drawing and baseline are:

TABLE 1125-3 Design Applications

Typical Applications	Application Considerations	Possible Mitigation
High Frequency	> 200Mhz, effective resistance is reduced as a result of shunt capacity between resistance elements and controlling circuits.	Perform design analysis before use in this application.
Operation under humid conditions	Chip resistors using nichrome films are susceptible to large increases in resistance values, or open failures, when operated under humid conditions.	For such environments, use tantalum nitride thin film with low ohms/square sheet resistance or ruthenium oxide thick films. Additionally, performing the laser trimming prior to passivation minimizes exposure of the metal film to moisture.
	The terminations of these chips (usually platinum or gold) are subject to leaching when exposed to molten solder at high temperatures.	Mounting Pre-tinning is recommended.
	Under low humidity conditions fixed film chip resistors, particularly those of smaller case sizes manufactured with high sheet resistance films, are subject to ESD damage and sudden shifts in resistance and the temperature coefficient of resistance.	Precautions against ESD should be used in packaging, handling, storage and kitting. These devices are not recommended for designs intolerant of sudden shifts in resistance and temperature coefficient of resistance under low humidity.

Table 1125-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Resistance to solder leaching	Silver and palladium terminations should not be used unless leach resistance barriers such as nickel or copper are utilized between the termination and the solder.
Thin Film Resistors	Designs requiring film thickness of 350 angstroms or less are reliability suspect due to increased susceptibility of these parts to: a) Mechanical handling damage b) Opens resulting from "hot spots" at surface defects c) Other anomalies
Copper or Nickel film	Fixed film resistor chips with copper or nickel conductor film is a prohibited part in MIL-STD-1547.

Table 1125-5 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to MIL-R-55342
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-R-55342
Process Controls Verification & Validation	Refer to MIL-R-55342
Screening Tests (100%)	Refer to MIL-R-55342 and Table 1125-7 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-R-55342
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-R-55342

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-55342 unless other wise specified.

Table 1125-6 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-R-55342 Group A and Table 1125-8, in this handbook.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-R-55342 Group B tests	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to the requirements of MIL-R-55342	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

Table 1125-7 Screening Table

MIL-R-55342	Additions to the Methods and Criteria of MIL-R-55342
Subgroup 1 1/ Pre-glassivation visual inspection	Paragraph 3.19 of MIL-R-55342
DC Resistance	Read and record
Thermal Shock	
Power conditioning	a) 96 hours +4 -0, full rated power @ 70°C applied 90 minutes on, 30 minutes off b) Delta DC resistance should not exceed the limits specified for thermal shock test.
Subgroup 2 Solderability	When applicable
Subgroup 3 Visual and Mechanical Examination	Paragraphs 3.19 and 4.7.1 of MIL-R-55342

1/ Lots having more than 3% PDA for Subgroup 1 screening due to exceeding the resistance change limits should not be used.

SECTION 1130 Fixed Metal Film Resistor RSC (MIL-R-87254)

1.0 Scope

This section contains detailed information for fixed metal film resistors (style RSC).

2.0 Application

The following tables contain information about fixed metal film resistors to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1130-1 Derating

Device Type	Parameter	Derating Factor	Comments
RSC	Steady State Power Peak Power	0.5 0.7	Derate linearly above 70C to zero at 120C Derate linearly above 70C to zero at 140C
	Voltage	Steady-state voltage applied to RSC resistors should be limited to 0.80 of the maximum allowable voltage rating in MIL-R-87254	Applications at 71°C to 125°C
	Voltage	Steady-state voltage applied to RSC resistors should be limited to 0.80 voltage rating in MIL-R-87254	Applications at 70°C and below

TABLE 1130-2 End-of Life Design Limits

Resistance	Resistance
± 1 % for approved application	± 1.5% for worst case application

TABLE 1130-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
RSC		Temperature Coefficient MIL-R-87254 specifies resistance changes if ±5 or ±25 ppm/°C (relative to 25°C resistance reading) over the operating temperature range. It should be noted that the TC is established relative to resistor temperature not the environment. The temperature coefficient is nonlinear but can be approximated by as straight line for small temperature changes.	Use in applications tolerant of TC changes. Verify the resistor temperature in the application then use derating.
		These devices are susceptible to ESD damage.	Precautions against ESD should be used in packaging, handling, storage and kitting.

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Resistors designed and qualified to MIL-R-87254.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1130-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Non-hermetic	Non-hermetic resistors using thin film metallization without a corrosion-resistant precoat over the metal film.
ESD Damage	Resistors not protected from electrostatic discharge during shipping and handling may experience permanent damage.
Corrosion	Resistors using aluminum terminations are susceptible to corrosion due to moisture penetration. These parts should not be used or procured, unless with protective undercoating.
Hollow core	Non-hermetic hollow-core types are prohibited
Hollow core corrosion	Hermetic hollow-core types with internal (inside surface of the core) metallization (susceptible to film corrosion due to contamination from the manufacturing process). This is a prohibited part in MIL-STD-1547.

3.3 Produceability and Baseline Controls A product baseline should be established for all custom resistors. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1130-5 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 4
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-R-87254
Process Controls Verification & Validation	Refer to MIL-R-87254
Screening Tests (100%)	Refer to MIL-R-87254
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-R-87254
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-R-87254

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-87254 unless other wise specified.

Table 1130-6 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Incoming Inspection: Verification of resistor received on a sample basis.	Review incoming data for accuracy of test.
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

SECTION 1140 Variable, Nonwire-wound and Wire-wound Resistors RJR, RTR (MIL-R-39035, MIL-R-39015)

1.0 Scope

This section contains detailed information for two (2) resistors types, variable, nonwire-wound and wire-wound resistors. Where the requirements or information differ the resistor style will be noted.

2.0 Application

The following tables contain information about variable, non-wire wound and wire-wound resistors to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1140-1 Derating

Device Type	Parameter	Derating Factor	Comments	
RJR (MIL-R-39035)	Steady State Power	0.5	Derate linearly above 50C to zero at 90C	
	Peak Power	0.6	Derate linearly above 60C to zero at 110C	
	Steady state applied voltage	0.80 of the values shown in Paragraph 3.3 of Section 402 of MIL-STD-199		
RTR (MIL-R-39015)	Steady State Power	0.5	Derate linearly above 25C to zero at 100C	
	Peak Power	0.7	Derate linearly above 25C to zero at 125C	
	Steady state applied voltage	0.80 of the values shown	Nominal Resistance	Maximum Rated Voltage Volts AC (rms) or DC
			10	2.7
			20	3.8
			50	6.1
			100	8.7
			200	12.3
			500	19.4
			1000	27.4
			2000	38.7
			5000	61.3
			10000	86.7

TABLE 1140-2 End-of Life Design Limits

Style	Resistance	Resistance
RJR	± 22 % for approved applications	± 30 % for worst case applications
RTR	± 10 % for approved applications	± 20 % for worst case applications

TABLE 1140-3 Design Applications

Style	Application Considerations	Possible Mitigation
RJR, RTR	These are non-hermetic resistors, which are susceptible to degrade performance due to ingress of solder flux, cleaning solvents, and conformal coatings during equipment fabrication. These parts are subject to resistance change during shock and vibration. Mounting brackets should be used.	Use in designs tolerant to resistance change while under vibration and shock
RTR	These parts are subject to resistance change during aging Pulse Power limitations of Wire wound resistors (See SECTION 1170) apply.	Use in designs tolerant to resistance chnage. Or in applications which will not age before use. Only if Wiper position is not less than 70 % of the maximum settings

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Variable resistors should be avoided whenever possible. They are not recommended for space use. If used variable, non-wire wound resistors, which meet the design and construction requirements of MIL-R-39035 for RJR types or wire-wound resistors in accordance with MIL-R-39015 for RTR types and the additional controls and testing herein.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1140-4 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Variable resistors	All variable resistors were documented as reliability suspect devices in MIL-STD-1547
Wire diameter	A minimum wire diameter of 25.4 micrometers (0.001”) zero negative tolerance should be used for RTR resistors
Internal connections	All internal connections should be welded for RTR resistors

3.3 Produceability and Baseline Controls A product baseline should be established for all variable, nonwire-wound and wire-wound resistors. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1140-5 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 4
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-R-39035 for RJR, MIL-R-39015 for RTR
Process Controls Verification & Validation	**Refer to MIL- R-39035 and the following for RJR type:** Perform 100% Internal visual, using a binocular microscope at minimum 30x. Any resistor exhibiting any of the following defects should be marked and rejected: a) Foreign material b) Chips, spalls, cracks, or scratches in the resistor element c) Element misalignment or improper seating d) Incorrect or missing element stops e) Incorrect seating or damage to wiper arm f) Faulty termination of element or pins Reject lot if the number of rejects at internal visual exceeds 7.0 % of the lot. **Refer to MIL- R-39015 and the following for RTR type**: Perform 100% Internal visual, using a binocular microscope at minimum 30x. Any resistor exhibiting any of the following defects should be marked and rejected: a) Damage to resistance wire reducing its diameter by 1/3 or more b) Nonwelded internal connections c) Loose windings on active portion of resistor d) Loose wire ends or wraps capable of touching other conductive parts or each other e) Any lubricant on resistance element f) Resistance element not secure to resistor body g) Body and wiper stops cracked, damaged, or distorted h) Loose welds i) Burning at weld greater than ½ of tab width j) Cracks or fractures in welds k) Loose terminals l) Foreign material such as weld splatter, flux residue, or metallic particles The entire lot should be rejected if the number of rejects at internal visual exceeds 7.0 % of the lot.
Screening Tests (100%)	Refer to MIL- R-39035 and table 1140-7-1 herein for RJR and MIL-R-39015 and table 1140-7-2 herein for RTR.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL- R-39035 for RJR or MIL-R-39015 for RTR.
Qualification Tests (Destructive & Non-	Refer to MIL-R-39035 for RJR or MIL-R-39015 for RTR.

destructive tests)	

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-39035 for RJR types or MIL-R-39015 for RTR types unless other wise specified.

Table 1140-6 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Refer to MIL-R-39035 and the following for RJR types: 100% Internal visual, using a binocular microscope at minimum 30x and an integral light source should be performed. Any resistor exhibiting any of the following defects should be marked and rejected: a) Foreign material b) Chips, spalls, cracks, or scratches in the resistor element c) Element misalignment or improper seating d) Incorrect or missing element stops e) Incorrect seating or damage to wiper arm f) Faulty termination of element or pins The entire lot should be rejected if the number of rejects at internal visual exceeds 7.0 % of the lot. Refer to MIL- R-39015 and the following for RTR type: 100% Internal visual, using a binocular microscope at minimum 30x and an integral light source should be performed. Any resistor exhibiting any of the following defects should be marked and rejected: a) Damage to resistance wire reducing its diameter by 1/3 or more b) Nonwelded internal connections c) Loose windings on active portion of

	resistor d) Loose wire ends or wraps capable of touching other conductive parts or each other e) Any lubricant on resistance element f) Resistance element not secure to resistor body g) Body and wiper stops cracked, damaged, or distorted h) Loose welds i) Burning at weld greater than ½ of tab width j) Cracks or fractures in welds k) Loose terminals l) Foreign material such as weld splatter, flux residue, or metallic particles The entire lot should be rejected if the number of rejects at internal visual exceeds 7.0 % of the lot. Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-R-39035 Group A and Table 1140-7-1 herein for RJR type, or MIL-R-39015 Group A and Table 1140-7-2 herein for RTR type.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-R-39035 Group B tests for RJR type or MIL-R-39015 Group B tests for RTR type	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to the requirements of MIL-R-39035 for RJR type or MIL-R-39015 for RTR type	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

Table 1140-7-1 Screening Table for RJR Type

MIL-R-39035	Additions to the Methods and Criteria of MIL-R-39035
Subgroup 1 100% 1/ Thermal Shock Conditioning Contact Resistance Variation Immersion	 168 hours minimum @ +85°C ± 5°C
Subgroup 2 Vibration, random	a) 12 samples (6 highest, 6 lowest in resistance value) accept on 0 failures b) MIL-STD-202, Method 214, Test Condition IIK (or to the requirements of the application) c) Two cycles of 10 minutes each in two (2) orthogonal planes d) Post vibration measurements should meet specification limits.
Subgroup 3 Visual and Mechanical Examination	

1/ Lots having more than 5% PDA for Subgroup 1 screening should not be used.

Table 1140-7-2 Screening Table for RTR Type

MIL-R-39015	Additions to the Methods and Criteria of MIL-R-39015
Subgroup 1 100% 1/ Thermal Shock Conditioning Peak Noise Total Resistance Immersion	 168 hours minimum @ +85°C ± 5°C
Subgroup 2 Vibration, random	a) 12 samples (6 highest, 6 lowest in resistance value) accept on 0 failures b) MIL-STD-202, Method 214, Test Condition IIK (or to the requirements of the application) c) Two cycles of 10 minutes each in two (2) orthogonal planes d) Measurements before, during and after test should be in accordance with MIL-R-39015 e) Change in total resistance and setting stability should meet specification limits.

Subgroup 3 Continuity Absolute Minimum Resistance End Resistance Actual Effective Electric Travel DWV IR Torque	
Subgroup 4 Visual and Mechanical Examination	

1/ Lots having more than 5% PDA for Subgroup 1 screening should not be used.

SECTION 1160 Wire-Wound, Accurate Resistors RBR (MIL-R-39005)

1.0 Scope

This section contains detailed information for fixed wire-wound (accurate) resistors

2.0 Application

The following tables contain information about fixed wire-wound (accurate) resistors to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1160-1 Derating

Device Type	Parameter	Derating Factor	Comments
RBR All Values	Power	 0.40 0.40 0.40 0.80	Resistance Tolerance 0.01% 0.05% 0.1% 1.0%
All Values	Voltage	0.80	Of the max voltages in Table 303-II of MIL-STD-199

TABLE 1160-2 End-of Life Design Limits

STRESS LEVEL	Resistance Tolerance
70% Power up to 125C	±1.00% plus initial tolerance
50% Power up to 125C	±0.51% plus initial tolerance
30% Power up to 125C	±0.30% plus initial tolerance
10% power up to 80C	±0.03% plus initial tolerance

TABLE 1160-3 Design Applications

Style	Application Considerations	Possible Mitigation
RBR	These resistors are susceptible to absorption of water vapor and can exhibit a positive or negative (usually positive) shift of resistance of 30 to 70 PPM. The shift in resistance is influenced by the relative humidity, temperature, and the time exposed.	The process is completely reversible by baking at a moderate temperature. (Consult with the manufacturer for temperature and duration.)

3.0 Design and Construction

3.2 Recommended Design for Space and Launch Vehicles Wire-wound, accurate resistors, which meet the design and construction requirements of MIL-R-39005 and the additional controls and testing herein.

Table 1160-4 Recommended Design Characteristics

Construction Item	Description of Construction
Wire	Wire diameter of 25.4 micrometers (0.001") zero negative tolerance
Internal Connections	Welded internal connections

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1160-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Internal connections	All designs using solder or crimped internal connections.
Wire diameter	Designs using a wire diameter of less than 25.4 micrometers (0.001") zero negative tolerance.

3.3 Produceability and Baseline Controls A product baseline should be established for all wire-wound, accurate resistors. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1160-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-R-39005
Process Controls Verification & Validation	Refer to MIL- R-39005 and the following: 100% Internal visual, of all exposed inner surfaces at minimum 10x should be performed. Any resistor exhibiting any of the following defects should be marked and rejected: a) Less than 0.025" gap between leads b) Absence of a soft cushion coating over wire winding c) Burning at weld greater than 1/2 tab width d) Lack if indication weld tip indention at welds e) Cracks, breaks, or partial fracture at welds
Screening Tests (100%)	Refer to MIL- R-39005 Group A tests and table 1160-8 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL- R-39005 Group B tests.
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-R-39005.

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-39005 unless other wise specified.

Table 1160-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation 100% Internal visual, of all exposed inner surfaces at minimum 10x should be performed. Any resistor exhibiting any of the following defects should be marked and rejected: a) Less than 0.025" gap between

	leads b) Absence of a soft cushion coating over wire winding c) Burning at weld greater than 1/2 tab width d) Lack if indication weld tip indention at welds e) Cracks, breaks, or partial fracture at welds Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-R-39005 Group A and Table 1160-8 herein.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-R-39005 Group B tests.	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to the requirements of MIL-R-39005.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

Table 1160-8 Screening Table

MIL-R-39005	Additions to the Methods and Criteria of MIL-R-39005
Thermal Shock	
DC Resistance	
Conditioning	168 hours minimum
Short Time Overload	
Delta DC Resistance	R $\pm$ (0.01% +0.01Ω)
Radiographic Inspection	Per MSFC-STD-355; 2 views 90° apart by x-ray, or 360° view by using real-time x-ray systems capable of viewing through 360° rotation. (Test may be waived if in-process inspection is performed)
External Visual and Mechanical Examination	a) Marking and identification b) Defects and damage; i.e., body finish, lead finish, misalignment, cracks.

SECTION 1170 Wire-Wound, Power-Type, Chassis-Mounted Resistors RWR (MIL-R-39007), RER (MIL-R-39009)

1.0 Scope

This section contains detailed information for two (2) types of resistors, fixed wire-wound power-type (RWR) and chassis-mounted (RER) resistors. Where the requirements or information differ the resistor style will be noted.

2.0 Application

The following tables contain information about fixed wire-wound (power-type) (RWR) and chassis-mounted (RER) resistors to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1170-1 Derating

Device Type	Parameter	Derating Factor	Comments
RWR,RER	Steady State Power Peak Power	0.47 0.60	Derate linearly above 25C to 0 at 140C Derate linearly above 25C to 0 at 170C
	N/A		RWR resistors are relatively low ohmic devices, and voltage derating is normally not required.

TABLE 1170-2 End-of Life Design Limits

Style	Resistance	Resistance
RWR, RER	± 1% for approved application	± 5% for worst case application

TABLE 1170-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
RWR, RER		The temperature coefficient of resistance (due to wire variations) may be either negative or positive	The values for each style of RWR resistors are listed in the applicable MIL-R-39007 slash sheet. Follow application derating rules.
	High-Frequency	These resistors are not designed for high-frequency circuits where their ac characteristics are important	For high-frequency applications were ac characteristics are not important.
	Noise	The only source of noise is thermal agitation which can be neglected in most circuit applications	Assure circuit design is tolerant of noise from thermal agitation
		Voltage coefficient of resistance is not specified for wire-wound resistors.	

3.0 Design and Construction

3.3 Recommended Design for Space and Launch Vehicles Wire-wound, power-type and chassis-mounted resistors, which meet the design and construction requirements of MIL-R-39007 (RWR), MIL-R-39009 (RER) as applicable and the additional controls and testing herein.

Table 1170-4 Recommended Design Characteristics

Construction Item	Description of Construction
Wire	Wire diameter of 25.4 micrometers (0.001") zero negative tolerance
Internal Connections	Welded internal connections

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1170-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Internal connections	All designs using solder or crimped internal connections.
Wire diameter	Designs using a wire diameter of less than 25.4 micrometers (0.001") zero negative tolerance.

3.3 Produceability and Baseline Controls A product baseline should be established for all. fixed wire-wound (power-type) (RWR) and chassis-mounted (RER) resistors. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1140-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 200
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-R-39007 for RWR and MIL-R-39009 for RER types
Process Controls Verification & Validation	Refer to MIL- R-39007 for RWR or MIL-R-39009 for RER and the following: 100% Internal visual, of all exposed inner surfaces at minimum 10x should be performed. Any resistor exhibiting any of the following defects should be marked and rejected: a) RWR, End cap misalignment greater than 5° b) RER, End cap misalignment greater than 10° c) Cracks, excessive bends, incomplete wire weld, or loose wire at end cap d) Split, distorted, or cracked end caps e) Space between wire turns more than 5 times the wire diameter, except for values less than 1.0 ohms or for fusible resistors (High resistance values require insulated wire and the wire turns may touch) f) Cracks or surface holes in core which exceed 0.025" in greatest dimension
Screening Tests (100%)	Refer to MIL- R-39007 Group A tests for RWR types or MIL-R-39009 Group A tests for RER types and table 1170-8 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL- R-39007 Group B tests for RWR types or MIL-R-39009 Group A tests for RER types
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-R-39007 for RWR types or MIL-R-39009 for RER types.

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-39007 for RWR types or MIL-R-39009 for RER types unless other wise specified.

Table 1170-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Perform 100% Internal visual, of all exposed inner surfaces at minimum 10x. Any resistor exhibiting any of the following defects should be marked and rejected: a) RWR, End cap misalignment greater than 5° b) RER, End cap misalignment greater than 10° c) Cracks, excessive bends, incomplete wire weld, or loose wire at end cap d) Split, distorted, or cracked end caps e) Space between wire turns more than 5 times the wire diameter, except for values less than 1.0 ohms or for fusible resistors (High resistance values require insulated wire and the wire turns may touch) f) Cracks or surface holes in core which exceed 0.025" in greatest dimension Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-R-39007 Group A for RWR types or MIL-R-39009 Group A for RER types and Table 1170-8 herein.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-R-39007 Group B tests for RWR types or MIL-R-39009 Group B tests for RER types.	Review lot conformance data (Attributes & Variables).
Qualification Testing: See MIL-R-39007 for RWR types or MIL-R-39009 for RER types.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Verify materials and construction upon receipt of each lot of devices, through DPA per MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of this	Maintain samples and data for further use.

handbook.	

Table 1170-8 Screening Table

MIL-R-39007, MIL-R-39009	Additions to the Methods and Criteria of MIL-R-39007 or MIL-R-39009
Subgroup 1 (100%) 1/ RWR, Thermal Shock RER, Thermal Shock	Test conditions and measurements after test should be per MIL-R-39007
Conditioning	
Short Time Overload	
Dielectric Withstanding Voltage	
DC Resistance	DC resistance should be within initially specified tolerance limits; lots having more than 10% out-of-tolerance rejects should not be used.
Subgroup 2 (100%) Radiographic Inspection	
Subgroup 3 Visual and Mechanical Examination	

1/ PDA for Subgroup1 tests is 5%, or one resistor, for rejects due to exceeding resistance change limits and DWV failures

SECTION 1190 Fixed Film Resistor Networks RZR (MIL-R-874)

1.0 Scope

This section contains detailed information for fixed film resistor networks.

2.0 Application

The following tables contain information about fixed film resistor networks to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1190-1 Derating

Device Type	Parameter	Derating Factor	Comments
RZR	Power, Approved Applications	0.50 of the power ratings values shown in Table 1190-2	Temperature below +70°C, power applied is linearly reduced to zero power from +70°C to +125°C
	Power, Worst Case	0.75 of the power ratings values	Temperature below +70°C, power applied is linearly reduced to zero power from +70°C

	Applications	shown in Table 1190-2	to +125°C
	Steady-State Voltage	0.80 of the maximum voltage values shown in Table 1190-2	

Table 1190-2 Manufacturer's Element Power, Network Power and Voltage Ratings

Style	Schematic Type*	Element Power Rating @ +70°C in watts	Network Power Rating @ +70°C in watts	Maximum Voltage DC or AC (RMS)
RZR 010	A	0.2	1.4	100
RZR 010	B	0.1	1.3	100
RZR 020	A	0.2	1.6	100
RZR 020	B	0.1	1.5	100
RZR 030	A	0.05	0.35	50
RZR 030**	B	0.025	0.325	50
RZR 030**	A	0.2	1.0	50
RZR 030	B	0.1	1.0	50
RZR 040	C	0.2	1.8	50
RZR 040	G	0.2	1.0	50
RZR 050	C	0.2	1.8	50
RZR 050	G	0.2	1.0	50
RZR 060	C	0.2	1.8	50
RZR 060	G	0.2	1.0	50
RZR 070	C	0.12	0.6	50
RZR 070	G	0.12	0.36	50
RZR 080	C	0.12	0.84	50
RZR 080	G	0.12	0.48	50
RZR 090	C	0.12	1.08	50
RZR 090	G	0.12	0.6	50
* Schematics are shown in detail specification of MIL-R-874				
** RZR 030 ratings are based on case temperature (heat sinked) up to +50°C for total network and up to +90°C per element. Rating shown here is for thick film.				

TABLE 1190-3 End-of Life Design Limits

Style	Resistance	Resistance
RZR	± 1% for approved application	± 2% for worst case application

TABLE 1190-4 Design Applications

Style	Application Considerations	Possible Mitigation
RZR	The resistance temperature coefficient (TC) can be either characteristic H (± 50 ppm per deg. C) or characteristic K (± 100 ppm per deg. C). Since all resistors in a network are manufactured from the same batch at the same time, the TCs should be matched within ±5 ppm.	

3.0 Design and Construction

3.4 Recommended Design for Space and Launch Vehicles Fixed film network resistors, which meet the design and construction requirements of MIL-R-874 and the additional controls and testing herein. The resistance temperature coefficient (TC) should be either characteristic H (+ 50 ppm per deg. C) or characteristic K (+ 100 ppm per deg. C). All resistors in a network should be manufactured from the same batch at the same time.

Table 1190-5 Recommended Design Characteristics

Construction Item	Description of Construction
Film	Tantalum nitride, deposited onto substrate, and protected by tantalum pentoxide passivation.
Surface	The surface should be anodized for moisture protection or laser-trimmed and subsequently glassivated.
Internal Connections	Welded internal connections.
Hermeticity	Hermetically sealed units.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1190-6 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Thick film designs	Resistor networks manufactured by thick film technology with internal solder connections.
Nichrome	Thin film resistors manufactured with nichrome as the resistive element are prone to potential opening of nichrome traces in the presence of moisture and bias, even in hermetically sealed packages.
Excessively thin tantalum nitride	Designs requiring tantalum nitride thickness' below 35 nanometers have increased susceptibility to (a) mechanical handling damage, (b) opens resulting from "hot spots" at surface defects and (c) nonohmic behavior at low voltages.
Nonhermetically sealed packages	Parts in nonhermetically sealed packages are reliability suspect.

3.3 Produceability and Baseline Controls A product baseline should be established for all fixed film resistor networks. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1190-7 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 4
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-R- 874 and MIL-R-83401.
Process Controls Verification & Validation	Refer to MIL- R-83401 and Precap visual specified in Table 1190-9 herein.
Screening Tests (100%)	Refer to MIL- R-874 Group A tests and Table 1190-9 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL- R-874 Group B tests.
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-R-874.

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-R-874 unless other wise specified.

Table 1190-8 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity, Production Lot, Serialization Traceability Control for Parts, Materials, & Processes, Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests and Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-R-874 Group A and Table 1190-9 herein.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-R-874 Group B tests.	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to the requirements of MIL-R-874.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

Table 1190-9 Screening Table

MIL-R-83401 1/	100% Additions to the Methods and Criteria of MIL-R-874
Precap Visual Inspection	A binocular microscope with at least 100X mag. And a coaxial illuminated or fiber optic light ring should be used. The resistor side visual inspection should be performed at 100X min. mag. Perpendicular to the die surface, with illumination normal to the die surface. Any die exhibiting one or more of the following defects should be marked and rejected: 1) **Metallic Particles** a) Unattached There should be no more than 3 unattached metallic particles. Unattached particles should be less than 0.005" or the width of the spiral cut in dimension, whichever is less. Particles should not be joined. b) Attached Attached metallic particles should not exceed 0.005" in major dimension. Particles should not touch nor extend over the metal film. Particles should be considered attached when they cannot be removed with 20 psig gas blow of dry nitrogen or dry, oil-free air. c) Residue There should be no residue from the spiral cutting operation at 100X mag. Within the enclosure. 2) **Nonmetallic Particles** Glass, fibers, and other nonmetallic materials within the enclosure should not exceed 0.005" in their major dimension. 3) **Metallization Defects** Any of the following anomalies in the active circuit metallization should be cause for rejection. a) Metallization Scratches 1. Any scratch in metallization through which the underlying resistor material also appears to be scratched. 2. Any scratch in the interconnecting metallization, which exposes resistive material or oxide anywhere along its length and reduces the width of the scratch-free metallization strip to less than 50% of its original width. 3. A scratch is defined as any tearing defect that disturbs the original surface of the metallization. b) Metallization Voids 1. Any void in the interconnecting metallization, which leaves less than 50% of the original width undisturbed. 2. A void is defined as any region in the interconnecting metallization where the underlying resistive material or oxide is visible which is not caused by scratch. c) Metallization Adherence Any evidence of metallization lifting, peeling or blistering. d) Metallization Probing Probe marks on the interconnecting metallization other than the bonding pads that violate the scratch or void criteria. e) Mettalization Bridging Bridged metallization defect that reduces the distance between any two metallization areas to less than 0.0003". Bridging between metallization and resistor pattern not intended by design that reduces the distance between the two to less than 0.0001". f) Metallization Alignment Any misalignment between the resistor

	pattern and the metallization such that more than 0.0005” of resistor on a side is exposed. g) Metallization Corrosion Any evidence of localized heavy stains, metallization corrosion, discoloration or mottled metallization. 4) **Resistor Defects** Any of the following anomalies within the active resistor area should be caused for rejection. The active area of resistor is that part of the resistance pattern, which remains in series connection between resistor terminals and is not, shorted by metallization. a) Resistor Scratches Any scratch within the active resistor area. b) Resistor Voids Any void or neckdown in the active resistor path which reduces the width of the stripe by more than 50% of the original width. Any void or necking down in the active resistor path for a line width design of less than 0.0002” which reduces its chain of voids in the resistor element at the gold termination. c) Resistor Adherence Any evidence of resistor film lifting, peeling or blistering. d) Probe Marks Any probe mark on the resistor material. e) Resistor Material Corrosion Any evidence of localized heavy stains or corrosion of resistor material in the active resistor path; however, discoloration of tantalum-based resistors due to thermal stabilization is not a cause for rejection. f) Resistor Bridging Defects Any conductive continuous bridging between active resistance strips. A partial bridging defect is that which reduces the distance between adjacent active resistance stripes to less than 0.1 mil or 50% of the design separation, whichever is less, when caused by smears, photolithographic defects or other causes. For a partial bridge within lines and spacing of 0.0001” design width, visual separation (evident @ 40X) is sufficient for acceptance. 5) **Laser Trim Faults** a) A partially cut or bridged coarse or mid-range trim link. b) The remaining width in fine-trim top hat area after laser cut is less than the width of the narrowest line within the same resistor pattern. Uncut material is remaining after a laser scribe due to “skipping” of laser beam. If laser cut is not straight lines, the narrowest remaining width should be equal to or greater than the width of the narrowest lines within the same resistor pattern. c) Laser cut scribed to indicate a reject chip when the scribe does not meet the requirements of the individual mask model lists. d) Oxide voids, cracking or similar damage caused to the SiO_2 underlayer by laser beam where such damage touches active interconnects or resistor path. e) Laser trim cut where edge of cut touches the active resistor path. f) Any discolorization or change in surface finish of a resistor stripe by the direct laser beam or by spurious reflections caused by optics of the system. Discoloration of tantalum-based resistors in and around laser kerf is not cause for rejection. 6) **Resistor Bonding Pad Defects** Any resistor containing one or more bonding pads with one or more of the following anomalies should be

	rejected. a) Globules A globule is defined as any material with a smooth perimeter extending out from the bonding pad onto the resistor or substrate material. Such globules are usually featureless and of low reflectivity and therefore difficult to focus upon. b) Missing Metallization Any indications of missing metallization whether at the perimeter or totally within the bonding pad. Resistor material may be visible in the areas of missing metallization. c) Metallization Corrosion Any evidence of localized heavy, diffuse stains, discolored material, or low-density material either on the pad's perimeter or totally within the bonding pad. Any evidence of stains or discoloration extending out onto the resistor or substrate material. 7) **Oxide Defects** Any resistor having excessive oxide defects or voids should rejected. An oxide void is a fault in the oxide evidenced by localized double or triple colored fringes at the edges of the defect visible at 100X. The following should be cause for rejection: a) Any oxide void that bridges any two resistor or metal areas not intended by design. b) Any oxide void under metallization or resistor geometry. c) Less then 0.0005" oxide visible between active metallization and edge of a die. Excluded from this are any inactive metallization lines. 8) **Scribing and Die Defects** Any resistor having the following scribing or die anomalies should be rejected: a) Any chipout or crack in the active resistor or metal area. b) Any crack that exceeds 0.005" in length or come closer than 0.001" to an active circuit area. c) Any crack in a die that exceeds 0.001" in length and points towards the active circuit area. d) A die having an attached portion of an adjacent die which contains metallization or resistor material. e) A crack or chip in the backside of a die that leaves less than 75% of area intact or a crack or chip under a bonding pad.
Thermal Shock	
Power Conditioning	a) The network should be mounted to attain the test temperature condition noted below. Leads should be mounted by means other than soldering or welding to avoid stress or damage to the leads. Networks should be so arranged that the temperature of one network can not appreciably affect the temperature of any other network. b) Operating conditions should be in accordance with MIL-R-83401. The supply voltage should be regulated and controlled to maintain a tolerance ±5% of the maximum voltage specified. c) With the dc voltage applied, the ambient temperature should be adjusted to obtain a case temperature of +70°C, +5°C, -0°C. d) Initial and final resistance should be At room ambient. e) Test duration should be 168 hours, min.
Short Time Overload	
Dielectric	

Withstanding Voltage	
Insulation Resistance	
DC Resistance	
Particle Impact Noise (PIND)	a) MIL-STD-202, Method 217 Detection b) The lot may be tested a max. of 5 times. 1. If less than 1% of the lot fails during any of the 5 runs, the lot may be accepted. 2. All defective devices should be removed after each run, no retesting of failed devices allowed. 3. Lots, which do not meet the 1% PDA on the fifth run, or cumulatively exceed 25% defectives, should be rejected. 4. Applicable to cavity devices only.
Visual and Mechanical Examination	a) Marking and identification. b) Defects and damage; i.e., body finish, lead finish, misalignment, cracks.

1/ Resistor networks that are out of resistance tolerance, or which exhibit a change in resistance greater than that permitted, should be removed from the lot. Lots having more than 5% total rejects due to resistance tolerance or resistance change should be rejected

SECTION 1195 Thermistors RTH (MIL-T-23648)

1.0 Scope

This section contains detailed information for thermistors, i.e. temperature-sensitive resistors. There are two classes of thermistors, one with positive temperature coefficients of resistance (PTC) and one with negative coefficients (NTC).

2.0 Application

The following tables contain information about thermistors both positive TC and negative TC to assist in the decision making process of selection and documentation for Design Engineers and Parts Engineers.

Table 1195-1 Derating

Device Type	Parameter	Derating Factor	Comments
PTC	Rated Power	50% at any given temperature as provided in the thermal derating curve of a given slash sheet.	Positive temperature coefficient thermistors are generally operated in the self-heat mode (heated as a result of current passing through).
NTC	Dissipation Constant		

TABLE 1195-2 End-of Life Design Limits (for 5 years)

Style	Resistance
Glass Bead NTC	$\pm$ 1.3% + initial tolerance
Bead Encapsulated PTC	$\pm$ 1.8% + initial tolerance
Disc PTC, NTC	$\pm$ 5% + initial tolerance
	EOL resistance factor is the total RSS (root sum square) design tolerance: $\text{Total Design Tolerance} = \left[(\text{Aging + initial tolerance})^2 + (\text{environments})^2 \right]^{1/2}$

TABLE 1195-3 Design Applications

Style	Typical Applications	Application Considerations	Possible Mitigation
NTC		Use current limiting resistor or a series circuit design when using a fixed voltage source to prevent the negative coefficient type thermistor from going into thermal runway.	
RTH		Never exceed the maximum current or power rating, even for short time periods.	
		Never move a thermistor (used in the self-heat mode) into a medium of lower thermal conductivity without careful analysis in order to prevent thermal runway.	
		Accurate thermistors (+ 1%) are calibrated for specific temperature test points; operation beyond the test points could result in permanent tolerance changes greater than those allowed for in the calibration.	
		Mounting considerations: The dissipation constant is specified in still air with the thermistor suspended by its leads. Any thermal or mechanical contact with an item acting as a heat sink, or change in surrounding media, changes resistance of the thermistor.	
		Handling during assembly: Heat sinks should be used when soldering to thermistor leads.	

3.0 Design and Construction

3.5 Recommended Design for Space and Launch Vehicles Thermistors, which meet the design and construction requirements of MIL-T-23648 and the additional controls and testing herein.

Table 1195-4 Recommended Design Characteristics

Construction Item	Description of Construction
Style	Glass bead style
Hermeticity	Hermetically sealed where appropriate. (The only hermetically sealed thermistor available in MIL-T-23648 is the -/19, a PTC device type.)

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1195-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Moisture	Some disc-type thermistors should be avoided because they can absorb water.
Fragility	Some thermistors are mechanical fragile and can easily be broken.
Tin slivers	Tin coated case or leads

3.3 Produceability and Baseline Controls A product baseline should be established for all thermistors. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1195-6 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 4
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-T-23648.
Process Controls Verification & Validation	Refer to MIL-T-23648
Screening Tests (100%)	Refer to MIL-T-23648 Group A tests and Table 1195-8 herein.
Lot conformance Tests (Destructive & Non-destructive tests)	Refer to MIL-T-23648 Group B tests.
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-T-23648.

4.0 Quality Assurance Provisions

Quality Assurance provisions should be in accordance with the requirements of MIL-T-23648 unless other wise specified.

Table 1195-7 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity Production Lot Serialization Traceability Control for Parts, Materials, & Processes Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)
Screening (100 percent): Refer to MIL-T-23648 Group A and Table 1195-8 herein.	Review screening data (Attributes & Variables).
Lot Conformance: Refer to MIL-T-23648 Group B and Table 1195-8 herein.	Review lot conformance data (Attributes & Variables).
Qualification Testing: Refer to the requirements of MIL-T-23648.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: Materials and construction is verified upon receipt of each lot of devices, by performing DPA in accordance with MIL-STD-1580.	Review incoming DPA and compare to historical DPA data.
Sample and Data Retention: Data retention information is found in Section 4 of this handbook.	Maintain samples and data for further use.

Table 1195-8 Screening Table

MIL-T-23648	Additions to the Methods and Criteria of MIL-T-23648
Zero Power Resistance (Initial)	At + 25°C
Thermal Shock	NTC devices only – Max. of 1.0% change.
Bake (High temperature exposure)	100 hours at max. specified operating temperature.
Burn-in	PTC devices only – 168 hours @ +25°C with 1.5 times rated power.
Zero Power Resistance	
Resistance Ratio Characteristic	
Insulation Resistance	Min. of 500 megohms
External Visual and Mechanical	a) Marking and identification

Examination	b) Defects and damage; i.e., body finish, lead finish, misalignment, cracks.

Table 1195-9 Lot Conformance Table

MIL-T-23648	Additions to the Methods and Criteria of MIL-T-23648
Short Time Load	Max. delta Zero Power Resistance: 1%
Dielectric Withstanding Voltage	
Low Temperature Storage	Max. delta Zero Power Resistance: 1%
Dissipation Constant	
Terminal Strength	a) Min. 1.0 lb. Strength b) Max. delta Zero Power Resistance: 0.5%

SECTION 1200 SWITCHES (Sensitive & push) MIL-S-8805, (Thermostatic) MIL-S-24236, (Pressure) MIL-S-9395

1.0 Scope This section contains multiple types of switches, where the switch information is not common the type of switch will be indicated. The military specifications and the type of switches are presented in the following table:

Table 1200-1 Switch Types

Switch Type	Military Specification	Comments
Sensitive and Push	MIL-S-8805	Snap action
Thermal	MIL-S-24236	
Pressure	MIL-S-9395	

2.0 Application For the selection and use of switches and associated hardware MIL-STD-1132 and requirements contained herein are recommended for use. Contact data such as loads, protection, arc suppression, and noise suppression are similar to those for relay contacts of the equivalent type. See Section 1000 of this Handbook for applicable information.

Table 1200-2 Derating

Switch Type	Parameter	Derating Factor	Comments
All	Contacts	See Section 1000	Operation at ambient temperatures
Typical	Current		

TABLE 1200-3 Design Applications

Type	Application Considerations	Possible Mitigation
All	Contact Current: Current during make, break, and continuous duty is to be carefully considered. Rating of contacts are usually given for room temperature. As the ambient temperature increases, switching current rating are reduced.	Observe established derating criteria.
	Manually Operated Switch: Manually operated switches that are not toggle or snap action can have the contacts damaged or seriously reduce their load handling capabilities when the switch is deliberately operated in slow motion.	Highlight this operational caution in testing and operational manuals or documents when using Thermal or Pressure switches.
	Load Considerations: For inductive loads, low level loads, intermediate range loads, parallel contacts,	Refer to MIL-STD-1132 and MIL-STD-1346 as applicable to determine these load considerations.

	series contacts, dry switching, transformer switching, transient suppression, and dynamic contact resistance.	
	<u>Environmental Conditions</u>: The environmental conditions need to be considered when using the leaf type actuator. Uncontrolled forces due to shock, vibration and acceleration can result in inadvertent plunger actuation.	Verify construction features during the selection process. Establish controls for shock, vibration and acceleration within the design.
	<u>Cold environment applications.</u>: Slow working contacts.	The use of high contact pressures is recommended
Sensitive and Push	This style is recommended for space applications.	
Thermal	These switches have the advantage of being lightweight, sturdy (withstands high shocks of 750 g & vibration of 60 g rms random), and require no external power.	Bimetallic disc (BMD) thermal switches.
	These switches can exhibit anomalous switch behaviors in both the upper and lower switching temperatures. These anomalies are known as “creepage” or “dithering” and have been used interchangeably to describe either of the following two conditions: a. The failure of an assembled unit to respond to temperature changes with immediate positive snap action of the disc. b. A deviation of the switching temperatures of a unit in service from its original set-temperatures, resulting in a very narrow switching band	This failure anomaly usually occurs during acceptance tests. See mitigation. This anomaly is far more consequential, since events are usually characterized by either a hesitant contact or a series of frequent openings and closings of the contacts and thus may induce excessive arcing or stress cycling, these effects often result in switch malfunction or shortened service life.
	Thermal switches should not be used for applications where the temperature rate of change is > 0.11°C per minute, or the thermal deadband is > +2.2°C	Mitigation - One possible mitigation to alleviate the possibly, is to require a 2.2°C min. for the thermal deadband (temperature separation between the thermal switch “on” position and the switch “off” position) and require a temperature rate of change < 0.11°C per minute. Switches exhibiting a contact current rating of 5 Amps. max.
		When the application exhibits these considerations Solid state temperature

		sensing and controls are preferred.
Pressure	See All	

3.0 Design and Construction

3.1 Recommended Design for Space and Launch Vehicles Design and construction are documented in the applicable specifications and this handbook.

Table 1200-4 Design and Construction Considerations

Construction	Information
Corrosion resistant material	It is recommended the switch shaft and housing be made of corrosion resistant material.
Positive break	Recommended for Space applications
Hermetically sealed package	Hermetically sealed packages are highly recommended to reduce contact failure from oxidation caused by moisture.
Panel seal	Recommended for Space applications
Thermal switches	Recommended for Space application - Snap action, switches with current rating of 5 Amps max., temperature rate of change accommodated, 0.11°C per minute min., deadband +2.2°C min.

3.2 Known Reliability Suspect Designs The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product and known manufacturing controls needed.

Table 1200-5 Known Reliability Suspect Designs

Problem	Description of Product that is Reliability Suspect
Particles greater than 25.4 micrometers (0.001") in maximum dimension.	1. Switches during assembly processing and before package closure which are not stored in a dust free atmosphere. 2. Switches being worked on following final cleaning and assembly in an environment which exceeds Class 100 per FED-STD-209. 3. Switches which are not millipore cleaned at pre-closure. (refer to Section 1000 of this handbook for millipore clean information)
Nonhermetic units	Switches designed using materials for encapsulation which allow moisture and atmosphere to enter the device body after closure. Documented in MIL-STD-1547B as a Registered PMP.
Slide devices	Documented in MIL-STD-1547B as a Registered PMP.
Thermal Switches	The application considerations of these switches cause these switches to be reliability suspect unless totally mitigated in the design.

3.3 Known Material Hazards_ The following table describes design and manufacturing problems which have been identified as the cause of reliability problems. This information was taken from MIL-STD-1547 as reliability suspect and prohibited product.

Table 1200-6 Known Material Hazards

Material	Precaution
Noncorrosion resistant material	The use of materials which are non corrosion resistant causes oxidation which will cause switch failure.
100% tin	100% tin causes tin whiskers to grow which can short a switch out internally or when mounted. It is recommended that another metal be added to the tin, at least 10% making a tin alloy.
Snap-action - thermoplastic dielectric or packaging.	Documented in MIL-STD-1547B as reliability suspect parts.

3.4 Produceability and Baseline Controls A product baseline should be established for all switches not purchased as a QPL MIL-S-8805 Sensitive and push style, MIL-S-24236 Thermostatic style and MIL-S-9295 style device. Areas which need to be specified and controlled in the drawing and baseline are:

Table 1200-7 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to Section 4
Production Lot	Refer to Section 4
Serialization	Refer to Section 4
Traceability Control (Parts, Materials, & Processes)	Refer to Section 4
Rework Provisions	Refer to MIL-S-8805, MIL-S-24236 and MIL-S-9395
Process Controls Verification & Validation All	Refer to MIL- S-8805, MIL-S-24236 and MIL-S-9395 and the following: a. Storage of switches during assembly and inspection prior to closure is a clean dust-free environment. b. Subsequent to final cleaning and assembly, all open switches should be worked on under a Class 100 environment per FED-STD-209. c. Pre-closure wash (millipore) should be accomplished per Section 1000. Description of Millipore clean - Obtain freon from pre-filtered supply. Assembly pre-cleaned 1000 milliliter flask, vacuum pump, filter holder, pre-cleaned 0.080-micrometer filter, and pre-cleaned funnel. Fill funnel with pre-filtered freon and turn vacuum pump on. Repeat until flask is filled. Fill a pressurized container with cleaned freon. Clean filter by blowing both surfaces with ionized air. Using the pressurized container, wash both sides of the filter with clean filtered freon. Observe filter under 30X mag., if any particles are observed, repeat the cleaning process until satisfactory results are obtained. Place the filter holder and cleaned filter on a clean empty 1000-milliliter flask under funnel. Air blow all parts to be millipore-cleaned using ionized air. Place parts in funnel. Using 1000-milliliter flask of filtered freon, pour the freon into the funnel, covering the parts to be cleaned. Cover funnel. Turn on vacuum pump. When all freon has passed through the filter, turn off vacuum pumps. Remove filter and examine under 30X mag. If one or more particles 2.5 micrometers (0.001”) or larger are

	present, or three or more visible particles under 2.5 micrometers (0.001") are present on the filter repeat the process until this condition is corrected. Place cleaned parts in cleaned covered trays in preparation for sealing and storage in a class 100 environment. d. 100% Internal visual inspection at 10X min. under a laminar flow hood, for the following : 1. Particles greater than 25.4 micrometers (0.001 inch) in maximum dimension 2. Solder and weld joints. 3. Proper alignment 4. Feedthroughs with contamination, debris damage or misalignment. 5. Each switch should have its contact closure or opening force setting checked. 6. Check critical internal dimensions for correctness 100%. 7. All switches that utilize different materials for movable and stationary contacts should have the contacts identified as + and -, and the life verified by tests with voltage applied in the polarity specified. 8. No plating defects such as flaking or blistering. e. The following additional controls apply: 1. Inspect seals and encapsulation 100% at 10 X minimum for cracks. 2. Leads and terminals are clean, straight, and free of tin.
Snap-action	Refer to MIL-S-8805 for in-process controls and this handbook the following defects should be removed from space level switches: a. Switches which have adhering conductive or nonconductive particles visible at 10X min. (metal burrs or flashing. b. Switches with incomplete swaging or staking of assembly components (not 360°). c. Scratches or nicks on the contact surface areas.
Thermal switches	Refer to MIL-S-24236 and the following: 100% internal (Pre-cap)visual for the following defects: a. No loose oxide film on surface of bimetallic disc. b. No organic compounds or films on contacts or header base. c. Actuator tips free of sharp peaks, cracks, chips, and flakes. d. No radial cracks in the glass seal extending greater than ½ the distance from the center post to outside edge.
Screening Tests (100%) - All Snap-action Thermal Switches Pressure	Refer to MIL- S-8805, MIL-S-24236 and MIL-S-9395 and the following: 1. 500 cycles of run-in testing with contacts monitored for misses at 6 volts dc, 100 μA maximum. Refer to table 1200-9 of this handbook. Refer to table 1200-10 of this handbook. Refer to table 1200-11 of this handbook.
Lot conformance Tests (Destructive & Non-destructive	Group B of these applicable documents MIL- S-8805.

tests) Thermal Switches Pressure Switches	MIL-S-24236, Group B tests not required on each lot are as follows: Subgroup 1 - Moisture Resistance Flame Response Short Circuit Subgroup 3 - All Subgroup 4 - Sensitivity Response Temperature Anticipation Refer to MIL-S-9395 and Table 1200-12 in this handbook.
Qualification Tests (Destructive & Non-destructive tests)	Qualification of these applicable documents MIL- S-8805, MIL-S-24236 and MIL-S-9395 and the application requirements.

Note: A manufacturing baseline should be developed and maintained by the manufacturer and controlled and verified by the procuring organization for (company unique drawings), for QPL reliability level S the manufacturing baseline should be verified by the procuring organization.

4.0 Quality Assurance Provisions

4.1 The following table outlines the minimum areas which should be considered and verified when purchasing QPL MIL- S-8805, MIL-S-24236 and MIL-S-9395 and company specific switch drawings.

Table 1200-8 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
In-Process Controls: should be in accordance with the requirements of the applicable manufacturing baseline.	Homogeneity, Production Lot, Serialization Traceability Control for Parts, Materials, & Processes, Rework Provisions Process Controls verification & validation Screening Tests (100%) Lot conformance Tests (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests) Specifically the following verifications are essential for this product: a. Storage of switches during assembly and inspection prior to closure is a clean dust-free environment. b. Subsequent to final cleaning and assembly, all open switches should be worked on under a Class 100 environment per FED-STD-209. c. Verify Pre-closure wash (millipore-clean) was performed per Section 1000. d. 100% Internal visual inspection at 10X

	min. for the following : 1. Particles greater than 25.4 micrometers (0.001 inch) in maximum dimension 2. Solder and weld joints. 3. Proper alignment 4. Feedthroughs with contamination, debris damage or misalignment. 5. Normal contacts. 6. Check critical internal dimensions for correctness 100%. e. The following additional controls apply: 1. Inspect seals and encapsulation 100% at 10 X minimum for cracks. 2. Leads and terminals are clean, straight, and free of tin.
Screening (100 percent): refer to the requirements of the company unique drawing and MIL- S-8805, MIL-S-24236 and MIL-S-9395	Review screening data (Attributes & Variables).
Lot Conformance: refer to the requirements of the company unique drawing and MIL- S-8805, MIL-S-24236 and MIL-S-9395	Review lot conformance data (Attributes & Variables).
Qualification Testing: refer to the requirements of company unique drawing and MIL- S-8805, MIL-S-24236 and MIL-S-9395	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier DPA.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

Table 1200-9 Screening Table Snap-Action type

MIL-S-8805	Additions and Exceptions to the Methods and Criteria of MIL-S-8805
Operating Characteristics	
Dielectric Withstanding Voltage	
Contact Resistance	
Vibration (Random)	a. MIL-STD-202, Method 214, Test Condition II, K (switch in critical systems position and test to the requirements of the application). b. 3 orthogonal planes, 1 minute each. c. Mounting fixture should not add or remove energy from the switch under test. d. Monitor for chatter, 10 µsec max. per MIL-STD-202, Method 310, Circuit B. e. No contact transfer (monitor equipment must be capable of detecting closures <1µsec. f. If more than one critical system position exists, repeat steps a through e, with the switch in each critical position.
Thermal Shock	During last cycle (5th) measure contact resistance at temperature extremes.
Particle Impact Noise Detection (PIND)	MIL-STD-202, Method 217 Detection, Percent Defective Allowable (PDA) criteria: a. The lot may be tested a maximum of 5 runs, during testing of the 5 runs the lot exhibits > 1% failures the lot is acceptable at that point. b. Lots which do not meet the 1% PDA by the fifth run or exceed 25% defectives cumulative should be rejected. All defective devices should be removed after each run. (No device should be tested more than once.)
Insulation Resistance	
Mechanical Run-in	a. 500 cycles @ 10 cycles per minute @ +25°C. b. Monitor all make and break contacts at 6 VDC 100mA max.
Seal	
Dielectric Withstanding Voltage	
Insulation Resistance	
Operating Characteristics	
Radiographic Inspection	MSFC-STD-355, 2 views 90° apart by x-ray, or 360° view by Real Time X-ray system capable of viewing through 360° rotation.
Visual & Mechanical Examination (External)	a. Inspect seals and encapsulation 100% at 10 X minimum for cracks. b. Leads and terminals are clean, straight, and free of tin. c. Marking and identification d. Defects and damage, i.e., body finish, lead finish, misalignment, cracks.

Table 1200-10 Screening Table Thermal Switches

MIL-S-24236	Additions and Exceptions to the Methods and Criteria of MIL-S-24236
Vibration (Sine) 1/	a. MIL-STD-202, Method 204, @ 30g, 10-2,000Hz (switch in critical system position). b. Electrical load of 110 MA max. @ 6 Vdc. c. Monitored for contact chatter 10μsecs. Max. per MIL-STD-202, Method 310, Circuit B. d. No contact transfer (monitor equipment should be capable of detecting closures greater than 1 μsec. e. Duration of 1 frequency sweep per contact position.
Vibration (Random) 1/	a. MIL-STD-202, Method 214, except use the following spectrum: 1. 20 Hz. $0.01g^2$ per Hz. 2. 20 - 90 Hz +9db per Octave 3. 90 - 350 Hz $0.9g^2$ per Hz. 4. 350 - 2,000 Hz -6db per Octave b. 3 Orthogonal planes. c. Duration should be 1 minute per axis per contact position. d. Monitored for contact chatter, 10μsecs. Max. per MIL-STD-202, Method 310, with 110 μA max. at 6 Vdc. e. No contact transfer (monitor equipment greater than 1 μsec.)
Calibration	
Mechanical Run-in	a 500 cycles. b. Monitor all make and break contacts @ 6 Vdc 100 mA max. c. Miss test monitoring equipment to measure contact resistance required
Particle Impact Noise (PIND)	MIL-STD-202, Method 217 Detection, Percent Defective Allowable (PDA) criteria: a. The lot may be tested a maximum of 5 runs, during testing of the 5 runs the lot exhibits > 1% failures the lot is acceptable at that point. b. Lots which do not meet the 1% PDA by the fifth run or exceed 25% defectives cumulative should be rejected. All defective devices should be removed after each run. (No device should be tested more than once.)
Creepage	a. Temperature rate of change should be 0.11°C per minute min. b. Three runs. c. Arc duration of 5 μsec. Max. @ 500 - 600 Vdc with current limited to 1μA max.
Seal	Per MIL-S-24236 for hermetic switches.
Dielectric Withstanding Voltage	
Insulation Resistance	
Contact Resistance	
Radiographic Inspection	MSFC-STD-355, 2 views 90° apart by x-ray, or 360° view by Real Time X-ray system capable of viewing through 360° rotation
Visual & Mechanical Examination (External)	a. Marking and identification. b. Defects and damage, i.e., body finish, lead finish, misalignment, cracks.

NOTES: 1/ Vibration method used should be based on the application.

Table 1200-11 Screening Table Pressure Switches

MIL-S-9395	Additions and Exceptions to the Methods and Criteria of MIL-S-9395
Contact Resistance	
Dielectric Withstanding Voltage	
Seal	
Radiographic Inspection	MSFC-STD-355, 2 views 90° apart by x-ray, or 360° view by Real Time X-ray system capable of viewing through 360° rotation
Visual & Mechanical Examination (External)	a. Marking and identification. b. Defects and damage, i.e., body finish, lead finish, misalignment, cracks.

Table 1200-12 Lot Conformance Table Pressure Switches

MIL-S-9395	Additions and Exceptions to the Methods and Criteria of MIL-S-9395
Group I Solderability Shock Moisture Resistance Overload Cycling Seal	a. 3 Samples. Note: Because this sampling plan is different that MIL-S-9395, the group samples must be unique and can not be used in more than 1 group test. If applicable.
Group II Mechanical Endurance Electrical Endurance Contact Resistance Seal Dielectric Withstanding Voltage	a. 3 Samples
Group III Burst Pressure Explosion	b. 2 Samples If applicable

SECTION 1400: TRANSISTORS

1 Organization:

This section covers the following device types: Unijunction, Switching, Power, General Purpose, Field Effect (FET), Metal Oxide Field Effect (MOSFET), and Injection Gate Bipolar Junction (IGBT).

2 APPLICATION: .

It is recommended that the locus of the I-V operating point for applications such as in line or relay drivers, power inverters, converters, or amplifiers, and other circuits involving reactive loads should fall within the safe operating (including secondary breakdown) area with a safety margin not less than 20 percent for worst-case circuit operating condition. Table 1400-1 provides the recommended derating criteria for transistors in space applications and Table 1400-2 provides the recommended end of life design limits.

TABLE 1400-1 - TRANSISTOR DEVICES DERATING

DEVICE TYPE	PARAMETER	DERATING FACTOR	COMENTS
Small Signal, Switching and General Purpose Transistors	P_D BVCBO BVCEO BVEBO IC Tj	.50 .70 .70 .75 .75 80% of Tj Max	Based on the SOA at operatir point Not to exceed .75 of SOA IC limit the specified operating conditions. Not to exceed 105°C
POWER TRANSISTORS	P_D BVCBO BVCEO BVEBO IC Tj	.50 .70 .70 .75 .75 80% of Tj Max	Based on the SOA at operatir point Not to exceed .75 of SOA IC limit the specified operating conditions. Not to exceed 105°C
FETS	P_D VDS Tj	.50 .75 80% of Tj Max	Not to exceed 105°C
MOSFETS	P_D BVDSS BVGSS ID Tj	.50 .75 .50 .75 80% of Tj Max	Not to exceed 105°C
RF TRANSISTORS	P_D BVCBO BVCEO IC f_T Tj	.50 .70 .70 .75 .75 80% of Tj Max	Not to exceed 105°C
OPTICALY COUPLED ISOLATORS	IO BVCBO BVCEO Tj	.50% .70 .70 80% of Tj Max	Not to exceed 105°C
IGBTS	P_D Brkdown Voltage IC Tj	.50 .70 .75 80% of Tj Max	Not to exceed 105°C

Table 1400-2 End-of Life Design Limits

Device Type	Parameter	Parameter Design Value
Small Signal, Switching and General Purpose Transistors	I_{CBO} h_{FE} V_{BE}(sat) V_{CE}(sat) I_{EBO}	10% of initial maximum limit 25% of initial maximum limit 50mV from initial maximum limit 50mV from initial maximum limit 10% of initial maximum limit
POWER TRANSISTORS	I_{CBO} I_{CEO} h_{FE} V_{BE}(sat) V_{CE}(sat) I_{EBO}	10% of initial maximum limit 10% of initial maximum limit 25% of initial maximum limit 50mV from initial maximum limit 50mV from initial maximum limit 10% of initial maximum limit
FETS	I_{DS} I_{GSS} V_{GS}(off)	15% of initial maximum limit 10% of initial maximum limit 100mV from the original maximum limit
MOSFETS and IGBTS	I_{DSS} I_{GSS} V_{GS}(th) R_{DS}(on) g_{FS}	10% of initial maximum limit 10% of initial maximum limit 100mV from the original maximum limit 25% of the initial maximum limit 25% of the initial maximum limit
OPTICALY COUPLED ISOLATORS	I_{CBO} h_{FE} V_{BE}(sat) V_{CE}(sat) I_{EBO} I_O	10% of initial maximum limit 25% of initial maximum limit 50mV from initial maximum limit 50mV from initial maximum limit 10% of initial maximum limit 25% of initial maximum limit
RF Transistors (bipolar & FETS)	Apply all parameters for the Bipolar or FET as applicable and the following. D $I_{DS'}$ D Gm Transductance D Pout NF D C_{obo}	Apply all parameters for the Bipolar or FET as applicable and the following ± 15% of specified value ± 10% of specified value ± 0.5 dB output power ± 10 percent where appropriate ± 25% of specified value

Electrical Parameters Deffinitions:

1. FET
   Drain to source current, source shorted to gate, I_{DSS}
   Small signal forward transadmittance, y_{fs}
   On resistance, r_{on}
   Gate-to-source threshold voltage, $V_{GS\ (th)}$, or
   Gate-to-Source cutoff voltage, $V_{GS\ (off)}$, as applicable
   Gate-to-source leakage current, source shorted to drain, I_{GSS}
   Drain-to-source voltage (on-state), $V_{DS\ (on)}$

2. General Purposes Bipolar Junction Transistor
   Collector cutoff current, base shorted to emitter, I_{CES}
   Collector cutoff current, emitter open, I_{CBO}
   Emitter cutoff current, collector open, I_{EBO}
   Base-to-emitter saturation voltage, $V_{BE\ (sat)}$
   Static value of the forward current transfer ratio (common emitter), h_{FE}
   Breakdown voltage, collector to base, emitter open,$V_{(BR)CEO}$
   Breakdown voltage, emitter to base, collector open, $V_{(BR)EBO}$

3 Unijunction
   Emitter to base two reverse current, I_{EB20}
   Interbase resistance, r_{BBO}
   Intrinsic standoff ratio, n

4. Power Bipolar Junction Transistors
   Same as General Purposes (see Note 2)

5. Switching
   Same as General Purposes (see Note 2)

6. MOSFET
   Same as FET above (see Note 1) plus
   Forward transconductance g_{FS}
   Forward body drain - to- source diode voltage drop V_{SD}

3. DESIGN AND CONSTRUCTION

BACKGROUND: Semiconductor devices Design and Construction has traditionally been maintained in accordance with the requirements of the applicable specifications (MIL-S-19500 and its Slash Sheets). The JANS design rules within the specifications were applied where available. With the push for the use of plastic encapsulated devices, and replacement of traditional JANS controls with the more cost effective high volume production line process controls the designer has to evaluate the acceptability of the proposed design and construction for the application. In addition, some of the old Bipolar junction and Unijunction technologies were never designed to meet the high reliability applications needs and application of the JANS rules was often limited to just screening the quality in. Other new technologies such as MOSFET and IGBT require a high degree of process controls and advanced equipment and facilities for their manufacture.

The new approaches such as Surface Mount package, Multi Chip Module (MCM) technology, and Power Module technology that are currently beginning to be employed in the space application designs are often based on old technology, either old die designs, old package types etc., that are modified and supplied as Surface Mount, MCM, and Power Modules. As such the modifications are often performed after the discrete devices were screened and the final product is rarely verified and validated for the intended application. Therefore, the designer or the component engineer needs to ensure that the supplied components meet the application requirements. Table 1400-3 provides some of the known Design and Construction Considerations.

Table 1400-3 Design and Construction Considerations

Device Type	Design & Construction Considerations	Possible Mitigation
Small Signal, Switching and General Purpose Transistors, & FETS	Gold wire bonds on Aluminum die metalization.	Qualify wire bond process to survive 300°C without Au-Al intermetalic formation.
	Electron Irradiation post wafer fabrication for gain targeting.	Establish time & temperature needed to stabilize die characteristics and prevent annealing.
	Use of Unglassivated die.	Validate assembly cleaning and vacuum bake processes to minimize contamination.
	Silver filed Epoxy or Silver glass die attach mediums.	Maintain under 5000 ppm moisture, perform Transient Thermal Response and qualify process to 1000hrs. Power Burn-In.
POWER TRANSISTORS, MOSFETS, & IGBTS	Lead solder based compounds used for die attach medium.	Maintain the moisture levels below 5000ppm to prevent solder decomposition.
	Organic passivating or conformal coating materials.	Qualify process to 1000 hr HTRB, perform extended vacuum bake prior to device sealing, maintain low moisture levels.
	Aluminum wire on gold substrates.	Qualify wire bond process to survive 300°C without Au-Al intermetalic formation.
	Aluminum wire bonds on Ni plated Au flash posts.	Qualify process to survive an acceptable number (to the design application) of Intermittent Operating Life Cycles followed by wire pull test without any wire lifts.
	Au flash on Ni plated posts.	Maintain gold to 5 - 10µin over Ni plating on posts.

Table 1400-3 Design and Construction Considerations (cont.)

Packaging	Design & Construction Considerations	Possible Mitigation
Gallium Arsenide Transistors	Potential for thermo-mechanical stress induced cracking.	Adequate heat sinking and monitored Temperature Cycling.
Optically Coupled Isolators	Open circuit and high transfer loss due to optical couple material shape and processing.	Monitored Temperature Cycling, and qualification of process through extended Life tests (1000 hrs. min)
Hot Welded Cans	A high potential for loose conductive particles inside the cans.	Monitored cap welding and PIND test. Use of alternate materials for packages such as Ni caps etc.
Solder Sealed packages	A high potential for loose conductive particles inside the cans, loss of inert atmospheric content and of hermetic seal.	Validate the sealing process through extended temperature cycles, liquid to liquid temperature shock, PIND tests, RGA, and Hermetic Seal.
Electrically Isolated packages	Use of Beryllium Oxide materials for package isolation	Handle with caution; BeO is a carcinogenic material.
	Loss of isolation due to subsequent processes and thermal mismatch caused cracks during device operation.	Perform package isolation tests after Solder Dip, qualify attachment process to minimize header to substrate voiding.
Glass to metal seals materials	Use of glass seals on Kovar and Stainless Steel headers.	Qualify packages through extended temperature cycling and liquid-to-liquid thermal shock.
	High probability of developing glass cracks during testing and handling of devices.	Qualify packages to survive acceptable number of Temperature Cycles for the proposed application followed by die penetrant.

Produceability and Baseline Controls A product baseline should be established for all devices not purchased as a MIL-PERF-19500 QPL device. Areas which need to be specified and controlled in the drawing and baseline are provided in Table 1400-4.

Table 1400-4 Produceability & Baseline Controls

Produceability Controls	References
Homogeneity	Refer to MIL-PERF-19500 for JANS
Wafer Lot	Refer to MIL-PERF-19500 for JANS
Wafer Lot Acceptance	Refer to MIL-PERF-19500 for JANS
Radiation Hardening Performance	Refer to MIL-PERF-19500 for JANS
Assembly Lot accumulation period	Refer to MIL-PERF-19500 for JANS
Manufacturing Location	Refer to MIL-PERF-19500 for JANS
Assembly processes and their verification	Refer to MIL-PERF-19500 for JANS
Inspection Lot formation	Refer to MIL-PERF-19500 for JANS
Test equipment validation	Refer to MIL-PERF-19500 for JANS
Serialization	Refer to MIL-PERF-19500 for JANS
Traceability Control (Parts, Materials, & Processes)	Refer to MIL-PERF-19500 for JANS
Rework Provisions	Refer to MIL-PERF-19500 for JANS
Process Controls verification & validation	Refer to MIL-PERF-19500 for JANS
MRB and Change Control Authority	As agreed with Contracting Activity
Screening Tests (100%)	Refer to MIL-PERF-19500 Table II and Detail Specification as applicable
Quality Conformance Inspection (Destructive & Non-destructive tests)	Refer to MIL-PERF-19500 for Tables III, IVa, V, and Detail Specification as applicable
Qualification Tests (Destructive & Non-destructive tests)	Refer to MIL-PERF-19500 for Table VI and Detail Specification as applicable

Note: A manufacturing baseline should be developed and maintained by the manufacturer in accordance with MIL-PERF-19500, and controlled and verified by the procuring organization.

4. QUALITY ASSURANCE There are four major areas to be covered under the Quality Assurance provisions. These are the Wafer Fabrication, Assembly, 100% Test or Screening, and Quality Conformance Inspection and Qualification. MIL-S-19500 has provided guidance for both the device manufacturers and designers in all of the four areas. The designer and component engineer has to understand the device application, the need for and application tolerance of device to device performance variation and how the device manufacturer controls in each of the four areas impact the performance. Table 1400-5 provides a summary of the recommended controls for space level devices.

Table 1400-5 Quality Assurance

Quality Assurance Consideration	Recommended Verifications and Validations
Wafer Fabrication: In process controls should be per MIL-PERF-19500 Appendix D.	Wafer Lot formation Wafer Fab rework Wafer Lot Acceptance Wafer Fab Location
Assembly: In process controls should be per MIL-PERF-19500 Appendix D	Lot Homogeneity Production Lot formation Traceability Control Rework Provisions I.A.W. approved procedures Process Controls, their verification & validation elements Assembly Location
Screening Tests (100%): Screening should follow the MIL-PERF-19500 Table II and detailed specification. Quality Conformance Inspection (Destructive & Non-destructive tests) Qualification Tests (Destructive & Non-destructive tests)	Electrical parameters and performance specified meets application. Screening Temperature Range, QCI and Qualification specified meet application Test equipment accuracy and repeatability Accept and Reject criteria Failure Analysis and Corrective action.
Screening (100 percent): refer to the requirements of MIL-PERF-19500 for JANS and the detailed specification.	Review screening data (Attributes & Variables). Verify test equipment correlation, repeatability, test windows were met, test conditions, and PDA compliance.

Table 1400-5 Quality Assurance (cont.)

Quality Assurance Consideration	Recommended Verifications and Validations
Quality Conformance Inspection: refer to the requirements of MIL-PERF-19500 for JANS and the detailed specification.	Review lot conformance data (Attributes & Variables), sampling techniques, and stress levels.
Qualification Testing: refer to the requirements of MIL-PERF-19500 and the detailed specification.	Review qualification data (Attributes & Variables).
Incoming Inspection DPA: should be in accordance with MIL-STD-1580.	Review incoming DPA and compare to supplier documentation.
Sample and Data Retention: Data retention information is found in Section 4 of the this handbook.	Maintain samples and data for further use.

5.0 Lessons Learned

Wafer Fabrication: This is probably the most critical area that determines the device reliability and performance. Traditionally this area has been downplayed in its importance to the reliability of the end product and consequently controlled by OEMs through a flow chart at best. With the change from "screening of devices to meet quality requirements" to "building of quality into devices" this area becomes the only area that builds quality into the die. Table 1400-6 outlines some of the areas that need specific attention.

NOTE: For most of the older semiconductor device technologies the wafer fabrication process is typically designed to a nominal level that would produce a range of device types and device families on the same line and may not be cost effective target the process for only one device type.

Assembly: This is area where the die or chips, processed through wafer fabrication, are put in packages or assembled so that they can used in systems. These packages and assembly materials used determine in most cases, where the die ratings outperform the package ratings, the final device ratings such as Power Dissipation, Operating and Storage Temperature Ranges, Output Steady State Current, and Thermal Resistance. It is very important that the assembly processes are closely monitored and controlled so that defects are not introduced. MIL-S-19500 Appendix D has traditionally provided the guidelines for process controls for semiconductor devices. Table 1400-7 outlines some of the areas that need specific attention.

Screening: This area covers the 100% testing (electrical, mechanical, and environmental) that are applied to devices in order to eliminate the defects associated with infant mortality portion of the "Bathtub" reliability curve (see Figure 1400-9). The Percent Defect Allowable (PDA), test windows post HTRB and Burn-In, and other controls determine the number of random defects expected when using the lot of devices. The implementation of effective process controls in the front areas, wafer fabrication and assembly, makes device to device performance variability more consistent, and therefore, could allow lots to be evaluated on a sample basis rather than screened on 100% basis. The intended design application requirements provide the basis for device performance valuation. Table 1400-8 outlines some of the areas that need specific attention.

Quality Conformance Inspection (QCI): This area covers the sample verification of the lot integrity to be used in the application. The stress levels applied traditionally have been at the levels established, for the particular technology and product type, to simulate the end of life characteristics under accelerated conditions. Table 1400-10 outlines some of the areas that need specific attention.

Table 1400-6 - Wafer Fabrication

Area of Concern	Effect on Performance	Potential Remedy
Wafer Lot formation	Determines die lot performance homogeneity	Use wafers from single batches and manufacturers.
Wide resistivity and thickness, epi and epi thickness specifications	Allows wide range of electrical characteristics which lead to new device types and or product downgrading.	Use only the devices for which the target specifications of the raw wafers were designed and not the downgraded by products.
High defect count per cm^2.	Increase of device to device variation, risk of premature device failure, lower yields.	Lower the acceptable number of defects per cm on the incoming wafers.
Wafer Fab. Processing	Determines the device performance	
Particle size and count allowable in the clean room.	Depending on the device type, geometry, and technology may impact device reliability and electrical performance. Ionic contamination.	Use positive air flow interlocks and entries, air filters, process only devices for which the clean room characteristics were proven to be acceptable.
Water purity and Diffusion cleanness	Potential for ionic contamination.	Use water filters, test for bacteria, C-V plots.
Rework	Increase of device to device variation, risk of premature device failure, lower yields.	If allowed, verify that the rework did not have adverse effects on device performance in the intended application.
Wafer Fab Location	Use of foundries and other manufacturer's die leads to loss of visibility into wafer fab processing and controls may impact device performance.	Verify the supplier of devices has visibility and control over the wafer fabrication processes, changes, and implementation.
Wafer Lot Acceptance	Data provided does not correlate or tie into the wafer fab process controls for oxide, die, metalization, and passivation layer thickness. Sampling may not be valid.	Ensure wafer lot acceptance provides meaningful data to ascertain the wafer fabrication process and controls.
Radiation Tolerance	Wafer fab design and processing are not conducive to rad hard characteristics.	Provide circuit design solutions to prevent system failure.

Table 1400-7 - Assembly

Area of Concern	Effect on Performance	Potential Remedy
Die attach is not consistent	Devices fail prematurely due to voids which cause over heating and or current crowding effects	Implement die attach monitors such as Transient Thermal Response, ΔVBE, SOA, and die shear.
Attach materials are not optimized for the package and design application.	Devices fail prematurely due to die attach degradation when operated under simulated and accelerated application conditions.	Qualify and validate the attach process and materials for the intended design application.
Use of Organic material coatings and desiccants.	Devices may intermittently open during temperature transitions while under operation.	Validate and monitor the process through Monitored Temp Cycle and extended life tests.
Multiple Lots formation and loss of Lot Traceability	Increase potential for lot failure due to loss of traceability to individual lots.	Maintain traceability to individual lots.
Rework Provisions	Allowing rework on the production line may not enforce corrective action implementation and promote loose process controls.	If rework was allowed maintain traceability to the reworked portion of the lot for future valuation of adverse rework effects.
Purple Plague (Au wire on Al metalization)	Open circuit.	Validate process through extensive High temperature storage; subject lot to 300°C.
Purple Plague (Al wire on Au metalization	No impact if Gold is thin and the bonding is to the Ni under plate. Otherwise will lead to open circuit.	Validate process through Temperature and Operating Cycles; peel wire to verify bond.
Al wire bonds on Ag metalization.	Open circuit due to operating and Thermal cycles.	Validate process through Temperature and Operating Cycles;
Particles inside cavity	Potential short due to conductive particle such as Die attach slag, weld splash, etc.	Validate the processes to ensure loose particles are not introduced. Institute PIND.
Irradiation of device	Targets h_{FE} and V(sats) selection; Devices may return to original values if not annealed properly.	Validate the annealing process and monitor the hFE and V(sats) drift over HTRB, Power Burn-In, and Life tests.

Table 1400-8 - 100% Screening

Screening Test (MIL-S-19500 Table II)	Effect on Performance	Rationale for Test Conditions
Pre-Cap Visual Inspection	Ensures the devices are free of defects prior to encapsulation	Depending on the manufacturer's process controls this may be done on a sample basis.
High Temperature Storage	Some device technologies require this to stabilize the junction characteristics.	Select the max. device rated temperature storage.
Temperature Cycling	Intended to screen out infant mortality defects due to die attach and other package mismatch defects.	20 cycles were initially established as sufficient to pass the infant mortality stage. Devices should reach temperature extremes.
Constant Acceleration	Test designed to stress the wire bonds and die attach areas.	The G-force level is determined by the package capability and should be above the application requirements.
Transient Thermal Response	Non-destructive die attach screen for voids outside the process capabilities.	Applicable only to devices with negative voltage temperature coefficient. Limits should track back to maximum $R_{\theta JC}$, P_D, and or Surge characteristics.
SOA1 (Low Voltage High Current)	Developed to screen out devices with die attach, junction, and or bulk silicon defects.	SOA should not exceed the max. designed capability of the die under DC conditions.
SOA2 (High Voltage -Low current)	Developed to screen out devices with junction, and or bulk silicon defects	SOA should not exceed the max. designed capability of the die under DC conditions.
PIND	Developed to screen out devices with loose particles inside the cavity.	Set-up sensitivity, location and tester mounting, shock/ co-shock and vibration levels, and transducer couple medium are important to effective PIND screening.

Table 1400-8 - 100% Screening (cont.)

Screening Test (MIL-S-19500 Table II)	Effect on Performance	Rationale for Test Conditions
Pre-HTRB electrical tests	Electrical parameters (at T_A=25°C) established for each technology and device type to be indicative of a good device.	Parameters most likely to change if ionic contamination is present such as Leakage currents, DC gains, Breakdown Voltages
HTRB	Stress test designed to screen out ionic contaminated devices using DC Bias Voltage and Temperature to accelerate the effects. Ions are made mobile through Temperature exposure while the DC Bias Voltage acts as dipole magnet attracting the ions on each positive and negative side of the power supply.	The applied Temperature should be that of the Max. Operating Ambient without heat sink, and the applied voltage should be 80% of the rated breakdown voltage of the stressed junction. The magnitude of the exposing temperature and applied bias directly affect the result. Applying AC Voltage or removal of the bias before devices reached approx. 35°C will negate the test.
Post-HTRB electrical tests	Repeat of Pre-HTRB electrical tests to validate devices did not drift outside the established limits. Test should be performed within 16 hrs of bias removal.	Ionic contamination, if free to move around will cause a change in the device electrical characteristic. Depending on the contaminant type and level the ions will eventually return to original state.
Percent Defective Allowable (PDA)	Establishes the random failure rate expected during the useful life of the devices.	Typical PDA is 5% max. with a one time resubmission if Percent Defective (PD) < 20%. Lots failing this criteria are should be considered reliability suspect.
Power Burn-In	Test designed to screen out assembly defects.	Test conditions are typically established such that device junction temperature approaches that of the maximum Operating Junction Temperature Ratings.

Table 1400-8 - 100% Screening (cont.)

Screening Test (MIL-S-19500 Table II)	Effect on Performance	Rationale for Test Conditions
Post Power Burn-In electrical tests	Verify that devices still meet the established electrical characteristics.	Repeat the Post HTRB (Pre Burn-In) electrical tests plus the rest of the DC characteristics including those at high and low temperatures.
Percent Defective Allowable (PDA)	Establishes the random failure rate expected during the useful life of the devices.	Typical PDA is 5% max. with a one time resubmission if Percent Defective (PD) < 20%. Lots failing this criteria are should be considered reliability suspect.
X-Ray	Test was developed for workmanship verification (it does not replace Pre-Cap Visual Inspection).	Criteria and level of inspection is based on the package and defect type.

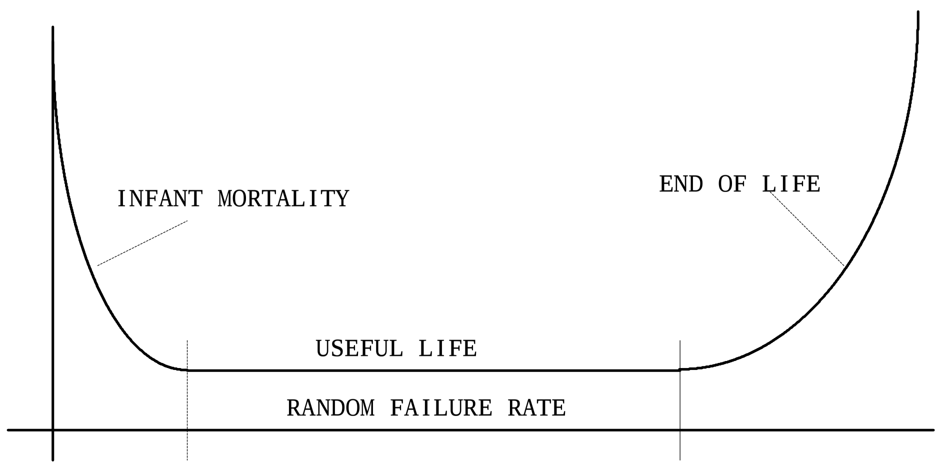


Figure 1400-9: Reliability Bath Tub Curve

Table 1400-10 - Quality Conformance Inspection

Test Name	Effect on Performance	Test Rationale
Group A	Verifies device electrical performance under DC, AC or transient conditions, and over the Rated temperature range.	Validates device capability to meet its electrical characteristics. Usually performed on each lot on a sample basis after 100% screening was completed.
Group B	Verifies device operational performance within the useful life portion of the bath tub curve. This includes package design integrity verification (Temperature Cycling, Intermittent Operating Life, and Thermal Resistance Subgroups), device operational performance (Accelerated Life Test).	Validates lot homogeneity and process/design operational performance capability on a lot by lot basis. Validates screening was performed correctly and no defects were introduced.
Group C	Verifies device mechanical performance and operational performance up to 1000 hrs. Operational Life or 6000 Intermittent Operation Cycles.	Validates the processing and device design provide up to 1000 hrs. and or 6000 cycles of useful life under accelerated conditions. Most military and space design applications reliability predictions use this as basis for predictions.
Group D	Verifies the die design capability to withstand the radiation effects that some applications may require to operate under.	Validates wafer fabrication device design and processing are capable to meet 100K Rads of total exposure and Single Event Upset capabilities.
Group E	Verifies end of life device design capability	Validates that the device processing and design end of life are outside the Thermo-Mechanical and Operational boundaries established for useful life.

Table 1400-11 Recommended Electrical Parameters

Device Type	Parameter	Measurement Point	Measurement Temperature (1)
Small Signal, Switching and General Purpose Transistors, Power Transistors	I_{CBO}	At 80% of rated BV_{CBO}	At room, hot, and cold.
	h_{FE}	At specified DC conditions	At room, hot, and cold.
	V_{BE}(sat)	At specified DC conditions	At room, hot, and cold.
	V_{CE}(sat)	At specified DC conditions	At room, hot, and cold.
	I_{EBO}	At 80% of rated BV_{CBO}	At room, hot, and cold.
	I_{CES}	At 80% of rated BV_{CEO}	At room, hot, and cold.
	BV_{CBO}	At 10x I_{CBO}	At room and cold
	BV_{CEO}	At 10x I_{CEO}	At room and cold
	BV_{EBO}	At 10x I_{EBO}	At room and cold
	ΔI_{CBO}, ΔI_{CES}, Δh_{FE}, ΔV_{BE}(sat), ΔV_{CE}(sat)	Post HTRB, Burn-In, Life Tests, Temperature Cycling, Operating Cycling.	Room Temperature
	SOA1 and SOA2	Peak Rated Current At rated DC SOA curve points	Room Temperature
	Junction Capacitance C_J	At specified Voltage and frequency	Room Temperature
	Switching Times	At specified V_{CB}, I_B, I_C, load resistance, and load capacitance.	Room Temperature
FETS	I_{GSS}	At ±80% of rated BV_{GSS}	At room, hot, and cold.
	Y_{FS}	At specified DC conditions	At room, hot, and cold.
	I_{DSS}	At 80% of rated BV_{CBO}	At room, hot, and cold.
	V_{GS}(off)	At specified current	At room, hot, and cold
	BV_{DSS}	At 10x I_{CBO}	At room and cold
	BV_{GSS}	At 10x I_{GSS}	At room and cold
	ΔI_{GSS}, ΔI_{DSS}, ΔY_{FS},	Post HTRB, Burn-In, Life Tests, Temperature Cycling, Operating Cycling.	Room Temperature
	SOA1 and SOA2	At rated DC SOA curve points	Room Temperature
	C_{ISS}, and C_{OSS},	At specified Voltage and frequency	Room Temperature
	Switching Times	At specified V_{GS}, I_D, load resistance, and load capacitance.	Room Temperature

Table 1400-11 Recommended Electrical Parameters (cont.)

Device Type	Parameter	Measurement Point	Measurement Temperature (1)
MOSFETS and IGBTS	I_{GSS}	At ±80% of rated BV_{GSS}	At room, hot, and cold.
	g_{FS}	At specified DC conditions	At room, hot, and cold.
	V_{SD}	At specified DC conditions	At room, hot, and cold.
	$r_{DS}(on)$	At specified DC conditions	At room, hot, and cold.
	I_{DSS}	At 80% of rated BV_{CBO}	At room, hot, and cold.
	BV_{DSS}	At 10x I_{CBO}	At room and cold
	BV_{GSS}	At 10x I_{GSS}	At room and cold
	ΔI_{GSS}, ΔI_{DSS}, Δg_{FS}, ΔV_{SD}, $\Delta r_{DS}(on)$	Post HTGB, HTRB, Burn-In, Life Tests, Temperature Cycling, Operating Cycling.	Room Temperature
	SOA1 and SOA2	At rated DC SOA curve points	Room Temperature
	C_{ISS}, C_{OSS}, C_{RSS} and or Gate Charges	At specified Voltage and frequency	Room Temperature
	Switching Times	At specified V_{GS}, I_D, V_{DS}, load resistance, and load.	Room Temperature
Optically Coupled Isolators	Forward Voltage (Vf)	At rated I_F	At room, hot, and cold.
	Leakage Current (I_R)	At 80% of rated B_{VR}	At room and hot temp.
	Power Output (P_O)	At specified DC conditions	Room Temperature
	ΔV_F, ΔI_R , and $\Delta P_{O,}$ ΔI_{CBO}, ΔI_{CES}, Δh_{FE}, $\Delta V_{BE}(sat)$, ΔV_{CE}(sat	Post HTRB, Burn-In, Life Tests, Temperature and Operating Cycling	Room Temperature
	I_{CBO}	At 80% of rated BV_{CBO}	At room, hot, and cold.
	h_{FE}	At specified DC conditions	At room, hot, and cold.
	$V_{BE}(sat)$	At specified DC conditions	At room, hot, and cold.
	$V_{CE}(sat)$	At specified DC conditions	At room, hot, and cold.
	I_{EBO}	At 80% of rated BV_{CBO}	At room, hot, and cold.
	I_{CES}	At 80% of rated BV_{CEO}	At room, hot, and cold.
	BV_{CBO}	At 10x I_{CBO}	At room and cold
	BV_{CEO}	At 10x I_{CEO}	At room and cold
	BV_{EBO}	At 10x I_{EBO}	At room and cold
	Junction Capacitance C_J	At specified Voltage and frequency	Room Temperature
	Switching Times	At specified V_{CB}, V_f, I_f, I_B, I_C, load resistance, and load	Room Temperature

Table 1400-11 Recommended Electrical Parameters (cont.)

Device Type	Parameter	Measurement Point	Measurement Temperature (1)
RF Transistors (Bipolar &FET)	Apply all parameters for the Bipolar or FET as applicable and the following.	Same as for Bipolar and FET as applicable.	Same as for Bipolar and FET as applicable
	D $I_{DS'}$, D Gm, D Pout, NF, D C_{obo}	Post HTRB, Burn-In, Life Tests, Temperature and Operating Cycling	Room temperature.

Table 1400-12: Reliability Suspect Parts.

Part Type	Potential Problem	Remedy
Hot welded cans	Short due to conductive particles	100% PIND and Weld monitors
Non-Glassivated Die	Short due to particles, moisture and contamination	Extended vacuum bake prior to seal, 100% PIND, RGA < 5000ppm moisture, 1000 hrs. Life test.
Bimetallic bonds at die	Open due to bond lift.	300C bake, bond pull post IOL and Life Test on samples.
Internal Organic materials	Open due to lifted bonds; Short due to moisture and contamination.	Extended vacuum bake prior to seal, monitored Temp. Cycling, 1000 hrs. Life test with wire pull.
Silver glass/ epoxy die attach.	Open and or short due to lack of die attach	Mechanical shock, transient thermal response post extended Temperature cycles, IOL, 1000 hrs. Life test.
Mesa Design	Old technology	Use in non-critical applications only.
Alloy junction	Old technology	Use in non-critical applications only.
Plastic encapsulated	Not proven reliable for applications outside commercial and industrial environments.	Conduct extensive qualification for the application prior to use.
Flip chips	Not recommended for high vibration/shock and power management applications.	Provide system level design solutions.
Beam leaded	Not recommended for high vibration/shock applications	Provide system level design solutions.
Third party assembled	Lower reliability	Qualify and validate all processing as necessary to ensure device reliability for the applications.
Chip on board	Not proven reliable for applications outside commercial and industrial environments.	Provide system level design solutions

SECTION 1500 - WIRE AND CABLE

1. SCOPE This section covers the common requirements which should be taken into account for wire and cables for use in space applications

2. APPLICATION

2.1 External. Use the requirements of MIL-W-83575 for external wiring to electronic enclosures

2.2 Internal. Use MIL-STD-454, Requirement 61 for wiring internal to the electronic enclosures.

2.3 Coaxial Cable. Use MIL-C-17 for all flexible and semi-rigid coaxial cables.

2.4 Derating. Derating factors and wire current should be based on the individual specification or MIL-W-5088 and should take into account the wire size, wire insulation, and the number of wires used in a cable or harness.

2.5 Electrical and Handling Considerations - Insulation. Use the characteristics of the insulation used on wire as an aid in the selection of the proper wire type for each application.

2.5.1 Ethylene Tetrafluoroethylene (Tefezel - ETFE). Tefezel, a Du Pont trade name, is a high temperature resin consisting of 75% TFE by weight and its balance or properties is well suited for space applications. It can withstand an unusual amount of physical abuse during and after the installation, has good electrical characteristics, good thermal and low temperature properties and chemical inertness. Its high flex life and exceptional impact strength are better than Kynar's. It has better service temperature, 150°C as compared with Kynar's 135°C and has no known solvent below 200C. Its embrittlement temperature is below -100°C. This insulation meets the outgassing requirements of NASA SP-A-0022. This wire insulation material is in MIL-W-22759/16, /17, /18, and /19. The equivalent cable specifications are MIL-C-27500 types TE, TF, TG, and TH.

2.5.2 Crosslinked ETFE. This material is a modified version of ETFE. The properties are higher service temperature, 200°C and better resistant to radiation effects. The flexibility, tensile strength, chemical inertness remain unchanged. This insulation material meets the outgassing requirements of NASA SP-A-0022. This wire insulation is in MIL-W-22759/32, /33, /34, /35, /41, /42, /43, /44, /45, and /46. The equivalent cable specifications are MIL-C-27500 types SB, SC, SD, SE, SM, SN, SP, SR, SS, and ST.

2.5.3 Polyvinylidene Fluoride (PVF_2, Kynar). Kynar, a Pennwalt Corporation trade name, is a crystalline, high molecular weight polymer of vinylidene fluoride with excellent abrasion and cut through resistance. Its electrical, thermal, chemical and radiation resistance properties are inferior to Tefezel. Its nominal service temperature is -65C to + 135C. Kynar is typically used as a jacket material over a soft insulation material such as polyalkene, rather than as a primary insulation. The high dielectric constant makes it undesirable as primary insulation. This insulation material is specified in MIL-C-27500 jacket symbol 08, 10, 58, and 60. **This material is a reliability suspect PMP item.**

2.5.4 Polyalkene. This is a dual extrusion of polyolefin and polyvinylidene fluoride (Kynar), with those materials crosslinked for increased heat resistance and greater mechanical strength. Combining these two insulating materials mutually offsets their individual disadvantages. This material exhibits good properties for thinner-walled, lighter weight wire construction. This insulation meets outgassing requirements of NASA SP-A-0022. This wire insulation material is in MIL-W-81044/6, /7, /9, /10, /12, and /13. The equivalent cable specifications are MIL-C-27500 types ME, MF, MH, MJ, ML, and MM. **This material is a reliability suspect PMP item.**

2.5.5 Aromatic polyimide (Kapton). Kapton, a Du Pont trade name, has excellent thermal (nominal service temperature is 200C with some up to 250C) and electric properties, and solvent resistance except when exposed to concentrated acids and alkalies. It is the lightest weight wire insulation material and meets outgassing requirements of NASA SP-A-0022 and flammability and toxicity requirements of MSFC-HDBK-527. The drawbacks are its inflexibility (stiffness), water absorption, lack of abrasion and cut through resistance. It is prone to both wet-arc and dry-arc tracking especially from abrasions and cuts in the insulation material exposing the conductors, and the failure results in an explosive (rapid) carbonization of the insulation materials. Naval Air Development tests have shown this insulation material to cause fires, explosions, and other damage to the host vehicle when the insulation fails. This insulation material is in MIL-W- 81381, all slash sheets. The equivalent cable specifications are MIL-C-27500 types MR, MS, MT, MV, MW, MY, NA, NB, NE, NF, NG, NH, NK, and NL. **This material is a reliability suspect PMP item**.

2.6 Electrical and Handling Considerations - Conductors. Use the characteristics of the conductors used on wire as an aid when selecting the proper wire for each application. Conductor strands should made of soft annealed copper, high strength copper alloy, or beryllium-copper alloy, and coated with either silver, nickel, or tin alloy.

2.6.1 Silver Coated Wire. Temperature range is above 150C to about 200C, and is good for high frequency applications due to its higher conductivity. Silver coated wire is susceptible to “red plague”, corrosion of the silver material, when exposed to high humidity. A minimum of 40 microinches of silver should be used. All beryllium - coper wire should be silver coated.

2.6.2 Nickel Coated Wire. Good for crimp applications (if the MIL-C-39029 crimp values are used) and has good finish up to 260C. For solder applications, solder does not wick under the insulation beyond the joint, leaving a good flexible area.

2.6.3 Tin Coated Wire. Tin or tin alloy is the least expensive, but is susceptible to oxide formation and corrosion when exposed to traces of clorine, oxides of nitrogen, or humidity. Tin whisker formation is possible but very rare due to alloying of the thin tin coating with the copper wire. Tin or tin alloy finish may be used with solder terminations, but they are not recommended with crimp terminations.

2.7 Stripping. Thermal stripping of the wire insulation is the preferred method for most wire insulation types. Mechanical stripping is acceptable if adequate workmanship precautions are taken to avoid quality problems such as nicks due to improper tools use.

3.0 DESIGN AND CONSTRUCTION

3.1 General Purpose Wire. Use Quality Conformance Inspection tests of MIL-W-22759 Table VI for all non military specification wire. Use Quality Conformance Inspection tests of MIL-C-27500 Table VII for all non military specification cable.

3.2 Reliability Suspect Parts.

a. MIL-W-22759 with only one layer of PTFE
b. Teflon insulated wire
c. MIL-W-76 wire
d. Aluminum wire
e. MIL-W-81381 wire
f. MIL-W-81044 wire
g. MIL-W-16878 wire types
h. All Polyvinyl chloride (PVC) insulated wire and cable.

3.3 Radiation Hardness Assurance. Verify that the selected insulation material can withstand greater than 105 rads(Si) total ionizing dose.

4 QUALITY ASSURANCE Follow the guidance of this handbook Section 4 and the applicable military specification.

SECTION 2000 - MATERIALS REQUIREMENTS

1. SCOPE This section covers the common requirements which should be taken into account for non-electronic materials. Materials fall into two main categories: Metals and Non-metals (which include Organics).

2. APPLICATION The selection of all materials used for space and launch vehicles should be made such that the system can operate in the specified environments without maintenance over the specified lifetime with an acceptable level of deterioration and degradation. Therefore, the selection of suitable materials, appropriate processing methods, and appropriate protective treatments should be made such that design allowables are adequate for the system's anticipated worst case environments.

3. SPECIAL CONSIDERATIONS All materials used should meet the requirements listed in Section 4.3.2 of this handbook.

4. PROHIBITED MATERIALS LIST FOR SPACE FLIGHT ITEMS

   a. Items with exposed surfaces of cadmium or zinc.

   b. Mechanical and electronic parts within electronic boxes with pure unfused tin coated internal or external surfaces not including drawn wire products (see section 4of this handbook).

   c. Alloys or compounds containing mercury.

   d. Parylene (paraxylylene) coatings containing chlorine.

   e. Corrosive (acetic acid evolving) silicone sealants, adhesives, or coatings.

   f. Wood should not be used.

   g. Combustible materials, or materials that can generate toxic outgassing or toxic products of combustion.

SECTION 2100 - METALS

1. SCOPE This section provides the common requirements for the use of metals in space and launch vehicles.

2 APPLICATION MIL-HDBK-5 should be used as the basic document for defining strength allowables and other mechanical / physical properties for metallic materials. When data is not contained in MIL-HDBK-5, contractor allowables developed in accordance with MIL-HDBK-5 may be used.

3. SPECIAL CONSIDERATIONS

3.1 Forging

3.1.1 Forging Design. Forgings should be produced in accordance with MIL-F-7190 for steel, MIL-A-22771 or QQ-A-367 for aluminum, and MIL-F-83142 for titanium. Recognized industrial association or contractor specifications should be used for alloys not covered by the above specifications. Because mechanical properties are maximum in the direction of material flow during forging, forging techniques should be used that produce an internal grain flow pattern such that the direction of flow in all stressed areas is essentially parallel to the principle tensile stresses. The grain flow pattern should be free from reentrant and sharply folded flow lines. After the forging technique, including degree of working is established, the first production forging should be sectioned to show the grain flow patterns and to determine mechanical properties and fracture toughness values at control areas. The procedure should be repeated after any significant change in the forging technique. The information gained from this effort should be utilized to redesign the forging as necessary. The data, material samples, and the results of the tests on redesign, should be retained by the contractor for the life of the Program for future reference.

3.1.2 Forging Surfaces. Surfaces of structural forgings in regions identified by analysis as fatigue critical or in regions of major attachment should be shot peened or placed in compression by other suitable means. Those areas of forgings requiring lapped, honed, or polished surface finishes for functional purposes should be shot peened prior to surface finishing operations.

3.2 Residual Stresses. Residual stresses are normally induced into manufactured parts as a result of forging, machining, heat treating, welding, or special metal removal processes. Residual stresses are generally controlled or minimized during the fabrication sequence by special heat treatment such as annealing and stress relieving. Even with in-process controls to minimize the potential buildup of residual stresses, the final production parts will usually contain some residual stresses. These stresses may be harmful in structural applications when the part is subjected to fatigue and loading, additive operation stresses, or corrosive environments. Therefore, every effort should be make to eliminate or minimize residual stresses from finished structural parts by appropriate heat treatments and process optimization.

3.3 Stress Corrosion Factors. Some high strength 2000 and 7000 series aluminum alloys and high strength alloy steels are subject to stress corrosion cracking. As a general criteria, MSFC-SPEC-522 and the references contained therein should be used to provide design and material selection guidelines for controlling stress corrosion cracking in all alloys. Alloys and heat treatments which result in a high resistance to stress corrosion cracking should be utilized in all structural, load-carrying applications. Particular emphasis should be in the area of design, fabrication, and installation of parts to prevent the sustained surface tensile stresses from exceeding the stress corrosion threshold limitations for the particular material and grain-flow orientation. Stress corrosion threshold values are generally determined by actual testing. Stress corrosion can be avoided by incorporating the guidelines for aluminum and steel alloys mentioned in the following sections.

3.4 Castings. Castings should be classified and inspected in accordance with MIL-STD-2175. Structural castings should be procured to guaranteed property, premium quality specifications including MIL-A-21180, AMS 5343, or other document(s) in accordance with the contractor's approved PMP control plan.

3.5 Protective Finishes. The requirements for, and the application of, protective finishes, including cleaning prior-to application, should be in accordance with MSFC-SPEC-250, with the exception of zinc, cadmium, and pure unfused tin finishes which are prohibited.

3.6 Dissimilar Metals. Use of dissimilar metals in contact, as defined by MIL-STD-889, should be limited to applications where similar metals cannot be used due to design requirements. When use is unavoidable, metals should be protected against galvanic corrosion by a method listed in MIL-STD-889. Composite materials containing graphite fibers should be treated as graphite in MIL-STD-889.

SECTION 2110 - ALUMINUM and ALUMINUM ALLOYS

1. SCOPE This section sets forth the common requirements for the use of aluminum and it's alloys.

2. APPLICATION In structural applications requiring the selection of aluminum alloys, maximum use should be made of those alloys, heat treatments, and coatings which minimize susceptibility to general corrosion, pitting, intergranular and stress corrosion, and maximize fracture toughness. Aluminum alloys 2020-T6, 7079-T6, and 7178-T6 should not be used for structural applications. The use of 7075-T6, 2024-T3, 2024-T4, and 2014-T6 sheet (<0.25" thick) material should only be used provided that short transverse loads (design, fitup, thermal, and residual) are below acceptable stress corrosion limits, and that proven corrosion protection systems are provided. Other forms of 7075 should be heat-treated to the -T73 temper.

3. SPECIAL CONSIDERATIONS

3.1 Aluminum Heat Treatment. Heat treatment of aluminum alloy parts should meet the requirements of MIL-H-6088. Heat treatments not included in MIL-H-6088 may be used if sufficient test data is available to prove that the specific heat treatment improves the mechanical and/or physical properties of the specific aluminum alloys without altering susceptibility to degradation. This data should be retained by the contractor and is subject to review.

3.2 Aluminum Forming and Straightening. Forming and straightening operations should be limited to processes which do not result in stress corrosion sensitivity of the part, to detrimental residual stresses, losses in mechanical properties, or fracture toughness on structurally critical parts. The contractor should maintain adequate controls and data which support the use of the forming and straightening processes.

3.3 Stress Corrosion Cracking. Aluminum alloys should not be used where assembly or assembly-induced stresses are greater than 75% if the stress corrosion threshold for that alloy (including consideration of the grain direction, launch, and mission environments).

4. PROHIBITED MATERIALS LIST

a. Alloys with a stress corrosion threshold in any grain direction less than 25 ksi
b. Aluminum alloy 5083-H32, where temperature > 150 Degrees F
c. Aluminum alloy 5083-H38, where temperature > 150 Degrees F
d. Aluminum alloy 5086-H34, where temperature > 150 Degrees F
e. Aluminum alloy 5086-H38, where temperature > 150 Degrees F
f. Aluminum alloy 5456-H32, where temperature > 150 Degrees F
g. Aluminum alloy 5456-H38, where temperature > 150 Degrees F

SECTION 2120 - BERYLLIUM

1. SCOPE This section sets forth the common requirements for the use of beryllium and it's alloys.

2. APPLICATION Beryllium and beryllium alloys should be restricted to applications in which their properties offer definite performance and cost advantages over other materials. Additionally, the life of beryllium parts should be tested (prior to Critical Design Review) under simulated service conditions, including any expected corrosive environments.

3. SPECIAL CONSIDERATION

3.1 Toxicity. The toxicity of beryllium dust and fumes is a critical problem and minimization of exposure should be a goal during fabrication, assembly, installation, and usage of beryllium parts.

3.2 Storage. Beryllium products that may generate dust or particles should be stored in closed containers, and should only be opened in a controlled environment.

3.3 Design. Design of beryllium parts should include consideration of it's low impact resistance and notch sensitivity (particularly at low temperatures), and it's directional material properties and sensitivity to surface finish requirements.

SECTION 2130 - MAGNESIUM

1. SCOPE This section sets forth the requirements for the use of magnesium and it's alloys.

2. APPLICATION Magnesium alloys should not be used for structural applications in areas subject to wear, abrasion, erosion, or where fluid entrapment is possible. Magnesium alloys should 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.

3. SPECIAL CONSIDERATIONS

3.1 Stress Corrosion Cracking. Magnesium and magnesium alloy products should be treated after forming to avoid stress corrosion cracking.

3.2 Corrosion. Magnesium and magnesium alloy products should not be used without a corrosion protection system that can be maintained with ease and high reliability.

SECTION 2140 - MERCURY

1. SCOPE This section sets forth the requirements for the use of Mercury and Mercuric compounds.

2. APPLICATION Since mercury and mercuric compounds can cause accelerated stress cracking of aluminum and titanium alloys, their use is prohibited in conjunction with the manufacturing, storage, or use of aluminum or titanium alloys.

3. SPECIAL CONSIDERATIONS The use of devices containing mercury or mercuric compounds, including temperature sensing devices, should be prohibited from use during fabrication or utilization of space flight structures and subsystems.

SECTION 2150 - STEELS

1. SCOPE This section sets forth the requirements for the use of steels.

2. APPLICATION Special consideration should be given when using high strength steels heat-treated at or above 200 ksi Ultimate Tensile Strength (UTS). These steels are subject to delayed failure mechanisms, such as those caused by contamination elements introduced during fabrication processing. Also, the effect of low temperature on reducing high strength steel toughness and ductility should be considered. Steels heat-treated to strength levels at or above 200 ksi UTS should be used in accordance with the contractor's approved PMP Control Plan.

3. SPECIAL CONSIDERATIONS

3.1 Heat Treatment of Steels. Steel parts should be heat-treated as specified to meet the requirements of MIL-H-6875. All high strength steel parts heat-treated at or above 180 ksi UTS should include appropriate test coupons or specimens which will accompany the part through the entire fabrication cycle to assure that desired properties are obtained. Heat treatments not included in MIL-H-6875 may be used if sufficient test data is available that assures the heat treatment improves the mechanical and/or physical properties of the specific steel without altering susceptibility to degradation. This data should be retained by the contractor.

3.2 Drilling and Machining of High Strength Steels. The drilling of holes, including beveling and spot facing, in martensitic steel hardened to 180 ksi UTS or above should be avoided. When such drilling or machining is unavoidable, carbide tipped tooling and other techniques necessary to avoid formation of untempered martensite should be used. Microhardness and metallurgical examination of test specimens typical of the part should be used to determine if martensite areas are formed as a result of drilling or machining operations. The surface roughness of finished holes should not be greater that 63 RHR, and the ends of the holes should be deburred by a method which has been demonstrated not to cause untempered martensite. (An etching procedure may be used as an alternate to metallurgical testing to determine the presence of untempered martensite.)

3.3 Grinding of High Strength Steels. Grinding of martensitic steels hardened to 180 ksi UTS and above should be performed in accordance with MIL-STD-866. Grinding of chromium plated martensitic steels hardened to 180 ksi UTS and above should also be performed in accordance with MIL-STD-866.

3.4 Corrosion Resistant Steels

3.4.1 Austenitic Stainless Steels. Free machining stainless steels intended for fatigue critical applications should be avoided. Sulfur or selenium additions improve machinability but lower fatigue life.

3.4.2 Precipitation Hardened Stainless Steels. These steels should be aged at temperatures not less than 1000 degrees F. Exception is made for castings which may be aged at 935 degrees F ± 15 degrees F, fasteners which may be used in the H950 condition, and springs which have optimum properties at the CH 900 condition.

3.5 Forming or Straightening of Steel Parts. Precautions should be taken to minimize warping during heat treatment of steel parts. Steel parts should be formed or straightening as follows:

a. Parts hardened up to 165 ksi UTS may be straightened at room temperature.

b. Parts hardened from 165 to 200 ksi UTS may be straightened at room temperature provided they are given a stress relieving heat treatment subsequent to straightening.

c. Parts hardened over 200 ksi UTS should be hot formed or straightened within a temperature range from the tempering temperature to 50 degrees F below the tempering temperature.

3.6 Shot Peening. After final machining, shot peen in accordance with MIL-S-13165, all surfaces of critical or highly stressed parts which have been heat treated to or above 200 ksi UTS, exception can be made for rolled threads, inaccessible areas of holes, pneumatic or hydraulic seat contact areas, and thin sections or parts which (after shot peening) violate engineering and functional configuration. Areas requiring lapped, honed, or polished surfaces should be shot peened prior to finishing.

3.7 Stress Corrosion Cracking. The assembly stresses of low alloy steel heat treated above 200 ksi UTS should not exceed the stress corrosion threshold limitation for the particular material and grain-flow orientation.

3.8 Low Alloy, High Strength Steel Corrosion Prevention. All low alloy, high strength steel parts 180 ksi UTS and above, including fasteners, require corrosion preventative metallic coatings by a process that is nonembrittling to the alloy/heat treatment combination.

SECTION 2160 - TITANIUM

1. SCOPE This section sets forth the requirements for the use of titanium and it's alloys.

2. APPLICATION Titanium sheet and plate stock should be procured to meet the requirements of MIL-T-9046, and supplemented by contractor specifications, drawing notes, or other approved documents which reflect the quality properties and processing to provide material suitable for it's intended use. All titanium extruded bars, rods or special shaped sections should be procured to meet the requirements of MIL-T-81556 and supplemented by such contractor documents as necessary to assure that the metallurgical and structural properties required to meet the reliability and durability requirements of the system are met. Heat treatment of titanium and titanium alloy products should be in accordance with MSFC-SPEC-469. For titanium alloy products not covered in MSFC-SPEC-469, heat treatment should be in accordance with MIL-H-81200, as specified by contractor specifications.

3. SPECIAL CONSIDERATIONS

3.1 Hardenability. Most titanium alloys have limited hardenability with section size and should not be used in sections which exceed their specified limits. The surfaces of titanium parts should be machined or chemically milled to eliminate all contaminated zones formed during processing.

3.2 Titanium Forgings. All titanium bar and forging stock should be procured in accordance with the requirements of MIL-T-9047, supplemented by contractor documents as necessary to assure the metallurgical and structural properties required to meet the reliability and durability requirements of the system.

3.3 Titanium Contamination. Care should be exercised to ensure that cleaning fluids and other chemicals used on titanium are not detrimental to performance. Materials that can induce stress corrosion, hydrogen embrittlement, or reduce fracture toughness include:

a. Hydrochloric Acid
b. Silver
c. Halogenated Solvents
d. Methyl Alcohol
e. Mercury
f. Mercuric Compounds
g. Trichloroethylene/Trichloroethane
h. Carbon Tetrachloride
i. Halogenated Cutting Oils
j. Halogenated Hydrocarbons
k. Cadmium or silver plated clamps, tools fixtures or jigs

Use of any of these materials on or with titanium, or in it's manufacturing should be prohibited.

3.4 Fretting of Titanium. Components manufactured of titanium and titanium alloys should be designed to avoid fretting.

3.5 Titanium Corrosion Considerations.

3.5.1 Surface Considerations. The surfaces of titanium and titanium alloy mill products should be 100 percent machined, chemically milled, or pickled to a sufficient depth to remove all contaminated zones and layers formed while the material was at elevated temperature. This includes contamination as a result of mill processing, heat treating, and elevated temperature forming operations.

3.5.2 Special Considerations. Titanium parts should not be cadmium or silver plated. Cadmium plated clamps, tools, fixtures and jugs should not be used for fabrication or assembly of titanium and titanium alloy components or structures.

SECTION 2170 - OTHER METALS

1. SCOPE This section sets forth the requirements for the use of metals not otherwise specified in this handbook.

2. APPLICATION Other metals such as nickel and copper and their alloys, that are commonly utilized in aerospace applications, may be used. Metals and alloys that are rarely utilized in aerospace application should not be used unless the contractor performs and maintains a design trade study that: (1) demonstrates the desirability over commonly used materials, and (2) indicates that no additional reliability risks or hazards, such as specified in paragrpah 4.3, will be incurred by using these uncommon materials.

3. SPECIAL CONSIDERATIONS

3.1 Stress Corrosion Cracking. For those metals and alloys which have no available stress corrosion data, documented use history, or are not covered in MIL-HDBK-5, the contractor should develop and use threshold values similar to those listed for other alloys based on the ability to withstand exposure to alternate immersion test in 3.5 percent sodium chloride solutions in water for 180 days without cracking, where cracking is defined as detectable by Class AA ultrasonic inspection per MIL-I-8950, or for 30 days without cracking, where cracking is defined as detectable defects identified by cross-sectioning and metallographic examination at 200 times magnification, minimum.

SECTION 2200 - NONMETALS

1. SCOPE. This section covers the common requirements for the use of nonmetallic materials (including organics).

2. APPLICATION Nonmetallic materials should be selected and qualified with each application by consideration of the following, as a minimum:

a. Design engineering properties

b. Application operational requirements

c. Compatibility with other materials used

d. Material hazards and restrictions specified in Section 4

e. Environmental and health restrictions mandated by applicable federal, state and local regulation

2.1 Composition and Processing. Specifications for composition and processing should be used to ensure a product that is reproducible and meets all physical, chemical, and mechanical requirements.

2.2 Compatibility. Nonmetallic materials should be evaluated and tested, or documented on the basis of detailed history for compatibility with temperature, pressure, radiation, and fluid or gas environments. Tests for compatibility with hazardous fluids and gases such as oxygen or hydrogen must consider energy sources available in the proposed application that could initiate adverse reactions.

3. SPECIAL CONSIDERATIONS

3.1 Chlorinated Fluorocarbons (CFCs). All PMP should be free of CFCs as mandated by federal or state regulations.

3.2 Shelf-Life Limitations. Many nonmetallic flight materials have a shelf life specified by the manufacturer. All flight materials so specified should be controlled by a shelf-life control program and should not be used beyond expiration dates unless based on test information supplied by the manufacturer (or test information obtained by the user for the production lot(s) of concern).

SECTION 2210 - ELASTOMERS

1. SCOPE This section sets forth the general and specific requirements for the use of Cured elastomers, Non-cured Elastomers, and Silicone Elastomers.

2. APPLICATION Elastomeric components should be hydrolytically stable, not subject to reversion, and possess adequate resistance to aging, low temperature, ozone, heat aging, working fluids, lubricants, and propellants for the system. Elastomeric materials in contact with hydrazine should be limited.

3. SPECIAL CONSIDERATIONS

3.1 Cured Elastomers. Cured elastomers that are age sensitive should be controlled by MIL-STD-1523. All cured elastomeric materials should be cure dated either on the item itself or on the packaging. A policy of first in, first our should be maintained. Cured elastomeric materials should be protected from sunlight, fuel, oil, water, dust, and ozone. A maximum storage temperature of 37.8 degrees C (100 degrees F) is recommended; the maximum storage temperature should not exceed 51.7 degrees C (125 degrees F).

3.2 Non-cured Elastomers. Materials that are procured in non-cured state such as sealants and potting compounds should be held in controlled temperature storage not to exceed 26.7 degrees C (80 degrees F). Some specific materials require storage at reduced temperatures and should be stored as recommended by the manufacturer. A first in first out system is recommended as the most effective method for tracking and maintaining adequate storage times. Overage materials may be used if testing can insure that the material is adequate for the intended uses.

3.3 Silicone Elastomers. Some one-part silicone products including commercial adhesives / sealants, as well as those meeting the requirements of MIL-S-46106, give off acetic acid during cure. These materials can cause corrosion to copper, aluminum, and steel. Alcohol liberating sealants should be used instead of acetic acid liberating sealants.

SECTION 2220 - FOAMED PLASTICS

1. SCOPE This section sets forth the requirements for the use of foamed plastics.

2. APPLICATION Foamed plastics should be applied in a manner as to preclude damaging fragile components or exerting undue stress on adjacent surfaces. They should be hydrolytically stable and should not be subject to reversion.

2.1 Outgassing and Flammability. Only a few foamed plastics meet outgassing and flammability requirements. Often such materials require baking at elevated temperatures to reduce outgassing to acceptable levels.

3. SPECIAL CONSIDERATIONS Foam plastics should not be used for metal skin reinforcement in structural components, nor as a core material in sandwich structural components other than all plastic sandwich parts, low density filler putties, or syntactic foam.

SECTION 2230 - LUBRICANTS

1. SCOPE This section sets forth the general requirements for the use of lubricants.

2. APPLICATIION NASA SP-8063 should be used as a guide in the design and application of lubricants for space flight systems and components.

3. SPECIAL CONSIDERATONS

3.1 Application Documents. Application documents for dry film lubricants should define surface finish requirements for surfaces to be coated. The use of film lubricants are recommended for applicants requiring minimum levels of friction, maximum life, and maximum load-bearing capability.

3.2 Lubricant. Selection of a lubricant should consider life cycles, including installation, test, and utilization, as well as a design margins.

SECTION 2240 - ADHESIVES, SEALANTS, COATING, & ENCAPSULANTS

1. SCOPE This section sets forth the requirements for the use of adhesives, sealants, coatings, and encapsulants.

2. APPLICATION

2.1 Adhesives. Adhesives for general use should be qualified to MIL-A-46146. Adhesives for structural applications should be qualified to MIL-A-83377 for the specific materials to be bonded.

2.2 Couplants. Silicone grease should not be used as a thermal couplant except in hermetically-sealed assemblies.

2.3 Coatings. Conformal coatings should be qualified to MIL-I-46058 and should meet the requirements of section 4.1.10 of this handbook.

2.4 Encapsulants. Materials and processes used to encase components and assemblies in plastic or elastomeric resins for electrical insulation, protection from environmental conditions, and protection form mechanical damage should be qualified by component or assembly-level testing or past space experience under equivalent or more limited thermomechanical and radiation stresses.

2.5 Cleaning Prior to Application. All processes involving these materials require careful surface preparation to ensure adequate adhesion. Each qualified material should be associated with one or more documents describing its application and usage. Each application document should detail the specific cleaning procedure for all surfaces to be coated (or bonded) and a maximum time period between surface preparation and coating (or bonding), after which, surfaces should be reprocessed. Materials covered by this section should be qualified with the specific surface preparation procedure described.

3. SPECIAL CONSIDERATIONS

3.1 Glass Transition Temperature. The secondary or glass transition temperature of silicone-based adhesives or sealants subjected to application of cryogenic temperatures during test or usage should be a minimum of 30 degrees F lower than the usage qualification temperature.

3.2 Parylene. When parylene (paraxylylene) is used as a conformal coating, the chlorine-free grade of parylene should only be used.

3.3 Processing Requirements. Processing requirements for encapsulation should consider as a minimum the following: surface preparation or cleaning, resin or elastomers preparation, processing temperatures (including exothermic heat of reaction), shrinkage during cure, and rework or repair requirements.

3.4 Asbestos. Asbestos-containing materials should not be used.

SECTION 2250 - COMPOSITES

1. SCOPE This section sets forth the general requirements for the use of composites and the specific requirements for the use of advanced composites, metal matrix composites, and conventional composites.

2. APPLICATION Composite materials are material systems made up of more than one constituent, usually a strong stiff fiber and a relatively weak soft binder. For the purposes of this handbook, composite materials are divided into three broad categories: conventional composites, advanced composites, and metal matrix composites. Conventional composites are fiberglass reinforced organic resins. Advanced composites are organic resins reinforced with high strength and or high stiffness fibers such as aramid boron or carbon. Metal matrix composites are fiber, whisker or particulate reinforced metals. Selection of materials and processes for composites must consider all aspects of the intended application. These aspects include: service environments, system requirements, structural and functional requirements, electrical or dielectric requirements, serviceability, and reparability.

3. SPECIAL CONSIDERATIONS

3.1 Advanced Composites. Advanced composites consist of an organic matrix reinforced by high modulus and/or high strength fibers. The fiber reinforcement takes the form of continual unidirectional filaments (tape), woven fabric (cloth), chopped fibers, etc. The fiber materials are boron, carbon, aromatic polyimide, etc. Guidance in the processing and production of advanced composite materials can be found in the DOD/NASA Structural Composites Fabrication Guide. Guidance in the effective utilization of advanced composite materials and design concepts in aerospace structures can be found in the DOD/NASA Advanced Composites Design Guide, Volume I - Volume IV.

3.2 Metal Matrix Composites. In a metal matrix composite, the metal serves the same purpose as the organic binder of an organic matrix composite, Aluminum, magnesium, and titanium alloys are common metal matrices.

3.3 Conventional Composites. Glass fiber reinforced plastic parts should be designed using the guidelines of MIL-HDBK-17.

SECTION 2260 - GLASSES AND CERAMICS

1. SCOPE This section sets forth the general requirements for the uses of glasses and ceramics as structural elements.

2. APPLICATION

2.1 Limitations on Material Use. Glasses and ceramics are limited in their use as structural elements due to their brittleness at ambient temperatures and lack of suitable nondestructive inspection techniques to ensure adequate strength and fracture resistance for specific stress and environmental conditions. Mechanical properties and fracture toughness information, as well as a plan to ensure adequate quality, are thus mandatory to demonstrate ability to use these materials.

3. SPECIAL CONSIDERATIONS

3.1 Materials Design Information. There is no central source of materials design on glasses and ceramics similar to MIL-HDBK-5 for metals. The following sources of information are useful:

a. Larsen, D.C., J.W. Adams, and S.A. Bortz, “Survey of Potential Data for Design Allowable MIL-Handbook Utilization for Structural Silicon-Based Ceramics,” prepared by IIT Research Institute, Materials and Manufacturing Technology Division, Chicago, IL 60616, December 1981, Final Report in Contract No. DAAG 46-79-C-0078.

b. Touloukian, Y.S., R.W., Powell, C.Y. Ho, and P.G. Klemens, “Thermophysical Properties of Matter - the TPRC Data Series, “volumes 2,5,8,9,11,and 13 IFI/Plenum, New York-Washington 1970.

c. Lynch, J.F., C.G. Ruderer, and W.H. Duckworth, “Engineering Properties of Selected Ceramic Materials,” published and distributed by the American Ceramic Society, Inc. 4055 N. High Street, Columbus , Ohio43214, 1966.

d. Bradt, R.C., D.P.H. Hasselman, and F.F. Lange, “Fracture Mechanics of Ceramics, “Volumes 1-6, Plenum Press, New York-London 1974 (Volumes 1 and 2), 1978 (Volumes 3 and 4), 1983 (Volumes 5 and 6).

SECTION 2300 - SANDWICH ASSEMBLIES

1. SCOPE This section sets forth the requirements for the use of Sandwich Assemblies.

2. APPLICATION All sandwich assemblies should be vented and designed to prevent entrance and entrapment of water or other contaminants in the core structure. Sandwich assemblies should satisfy the requirements of MIL-HDBK-23 and be tested in accordance with MIL-STD-401. Aluminum honeycomb core sandwich assemblies should use MIL-C-7438 perforated core. Non-metallic cores may be used in structural applications where technically advantageous.

3. SPECIAL CONSIDERATIONS

3.1 Nonmetallic Sandwich Assemblies. Nonmetallic structural sandwich assemblies should be qualified for specific applications by passing a test program subjecting them to anticipated worst case environments.

SECTION 3000 - PROCESSES

1. SCOPE This section sets forth the common requirements for the use of processes.

2. APPLICATION Processing specifications herein represent minimum standards of quality required for space and launch vehicles and associated hardware. The manufacturing, installation, and inspection processes are controlled by the contractor through their own controls and specifications. The contractor should control the processes to ensure that these minimum requirements are met.

3. SPECIAL CONSIDERATIONS

3.1 Corrosion Considerations Adequate precautions should be taken to prevent introduction of contamination, corrosion, or corrosive elements during manufacturing, testing, and installation operations.

3.2 Statistical Process Control (SPC) All continuous with automated, or semiautomated product lines and or processes should be controlled through a formal and documented statistical process control program meeting the requirements of EIA-STD-557.

3.3 Process Records Written or computerized process records that demonstrate successful application and completion of all required processes and related quality assurance requirements should be kept and maintained. Certification of compliance are not acceptable proofs without the associated results of analyses or documentation showing successful processing or testing.

3.4 Cleaning and Storage The materials, parts, and assemblies should be cleaned and maintained clean between processing, installation, testing, steps as needed. Where appropriate, such as for clean room environment, chemical solutions etc., verification of appropriate levels of cleanliness and freedom from contamination should be performed.

SECTION 3100 - ADHESIVE BONDING

1. SCOPE This section sets forth the common requirements for adhesive bonding.

2. APPLICATION Structural bonding should meet the requirements of MIL-S-83377

3. SPECIAL CONSIDERATIONS All bonding processes and materials selected for structural components should be validated and verified to meet the desired properties for the entire life of the component. This has been accomplished through the test of tag-end test specimens under the simulated service conditions, except for high temperature nozzle bonds, or through hardware qualifications and acceptance tests plus lap shear witness coupons processed concurrently using the same material cleaning method and cure cycles.

SECTION 3200 - WELDING

1. SCOPE This section outlines the common requirements for welding operations, welding filler material, and welding rework in space applications.

2. APPLICATION Welding procedures and supplies should be selected to provide optimum weld quality with minimum weld energy input and maximum protection of heated metal from contaminants. The design and selection of parent materials and weld methods should consider the weldments, including the adjacent heat affected zones, as they affect the operational capability of the parts. The suitability of the process, equipment and equipment set-up, welding supplies and supplementary treatments selected should be validated through qualification tests. As a minimum, qualification should be in accordance with MIL-STD-1595. For optimum results, the contractor should only use operators trained and qualified for the applicable welding equipment and specific tasks.

2.1 Critical Weld Areas The following are considered critical to space flight hardware: pressure vessel weldments, tubing weldments, and other primary structural components.

2.2 Electronic Circuit Modules Resistance welding of electronic circuit module should meet MIL-W-8939 requirements.

3. SPECIAL CONSIDERATIONS

3.1 Weld Filler Material The weld rod or wire used as filler metal on structural parts should be traceable and have certified documentation for composition, type, heat number, manufacturer, supplier, etc. In addition, the quality of each filler rod segment, or of each weld filler metal on a lot by lot basis with testing of each structural weldment to simulated service or proof of loading, should be verified through qualitative and or quantitative analysis, and nondestructive testing as applicable.

3.2 Weld Rework Weld rework of high performance or critical parts should not be permitted. Weld rework should be minimized by discriminating selection of acceptable methods, procedures and specifications developed by the contractor. Weld rework is limited to the rework of welding defects. Weld rework does not include the correction of dimensional deficiencies by weld build-up or “buttering” of parts in areas where the design did not provide for a weld joint. All weld rework should be fully documented and should include weld procedures and schedules, location of rework, nature of problem, and the appropriate inspection and qualification requirements. The quality of rework should be confirmed by 100% inspection of both surface and subsurface, using visual, dimensional, and non destructive techniques.

SECTION 3300 - BRAZING

1. SCOPE This section outlines the common requirements for brazing operations.

2. APPLICATION Brazing should meet the requirements of MIL-B-7883. Brazed joints should be designed for shear loading and should not be used to provide tension strength for structural parts. Allowable shear strength and design limitations are specified in MIL-HDBK-5.

3. SPECIAL CONSIDERATIONS Fusion welding operations in the vicinity of brazed joints or other operations involving high temperatures which may affect the brazed joint are prohibited.

4. Prohibited Materials List

   a. All metal not listed in MIL-B-7883

   b. Cadmium and zinc alloys that are not plated as to preclude the material hazards in section 4 of this handbook.

SECTION 3400 - FASTENER INSTALLATION

1. SCOPE This section outlines the common requirements for the use and installation of fasteners.

2. APPLICATION The installation of mechanical fasteners and associated parts, including cleaning prior to installation and application of protective finishes, should meet MSFC-SPEC-250 and MIL-STD-403 a appropriate.

3. SPECIAL CONSIDERATIONS Zinc and or cadmium platings/coatings are prohibited materials in accordance with section 2170 af this handbook and should not be used on space flight hardware. Unfused tin coatings on space flight hardware is also prohibited.

SECTION 3500 - PRINTED CIRCUIT ASSEMBLY

1. SCOPE This section outlines the common requirements for printed circuit assemblies.

2. APPLICATION

2.1 Rigid Printed Circuit Assemblies The design of printed circuit assemblies should be in accordance with MIL-STD-275 for feed through designs, and ANSI/IPC-D-275 for surface mount designs.

2.2 Flexible Printed Circuit Assemblies The design of flexible printed circuit assemblies should be in accordance with MIL-STD-2118.

2.3 Installation and Mounting Appendix B of MIL-STD-2000 should be used for installation and mounting. For through-hole mounting NASA NHB 5300.4 (3A-2) may also be used.

2.3.1 Fragile Parts Fragile parts should be protected through sleeving, buffer coating, etc. to prevent damage.

2.3.2 Lead Formation Lead formation operation should be controlled so it does not mechanically damage devices or cause the loss of hermetic seal. Adequate inspection points and hermetic seal testing should be inserted after the lead form operation to monitor either on a sample or 100% basis the integrity of the operation.

2.4 Soldering MIL-STD-2000, and NASA NHB 5300.4 (3A-2) for through-hole only, should be used for soldering.

2.4.1 Terminal Soldering Step-soldering mounting of terminals to the printed circuit boards should be per MIL-STD-2000 using high temperature solder per QQ-S-571.

2.4.2 Solder in Bend Radius Solder in the bend radius should be allowed on axial leaded components with body diameter less than .125” and with lead formed to a 90° bend.

2.5 Cleanliness Testing All uncoated printed wiring assemblies (circuit card assemblies) should be verified through test that are free from ionic contaminants using the testing outlined in MIL-STD 2000 or equivalent. All cleaned printed wiring assemblies (PWA) should be protected from the environment.

2.6 Conformal Coatings Conformal coatings materials should be selected from MIL-I-46058 and the guidelines provided in TABLE 3500-1 and 3500-2. The conformal coating operation should follow MIL-STD-275. Conformal coating should coat the underside of components spaced off the PWA. A flexible polymeric coating should be used to bridge the gap between the underside of components and substrate. When rigid coating is used, it should not bridge the PWA surface and the parts or parts leads.

2.6.1 Visual Criteria The coated assemblies should not have any blisters, cracking, crazing, peeling, wrinkles, measling, or evidence of reversion or corrosion. A pin-hole, bubble, or combination thereof should not bridge more than 50% of the distance between the nonconnecting conductors wile maintaining the minimum dielectric spacing. Bridging of greater than 50% cannot be reworked more than twice.

3. SPECIAL CONSIDERATIONS Special considerations should be given to designs using leadless ceramic chip carriers (LCCC), surface mount components, grid arrays etc. whenever the following exist:

a. The body size is greater than 0.400 square inches

b. The difference between PWA and component Coefficient of Thermal Expansion (CTE) is more than a factor of 2.

c. The device operating power is greater than 300mW

TABLE 3500-1: General Physical Properties and Application Methods of Conformal Coatings

Conformal Coatings	General Physical Properties	Application Methods
Paraxylylene	Excellent moisture and solvent resistance, provides pin-hole free conformal coating with uniformity of thickness, high purity.	Material applied by vapor condensation to the substrate at room temperature in vacuum.
Epoxies	Excellent chemical resistance, good mechanical properties, low permeability to moisture, high dielectric strength and volume resistivity, brittleness at low temperatures.	Material can be applied by either dipping or flow coating. Brush coating is used to spot coat areas of poor coverage.
Silicones	Excellent electrical properties, elasticity, ionic purity and thermal stability, low permeability to moisture, poor mechanical stability.	Material can be applied by either dipping, spraying, brushing, or flow coating. Dilute as necessary to achieve the desired thickness.
Urethanes	Good mechanical, chemical and moisture resistance properties, excellent electrical insulating properties, relatively poor thermal stability.	Material can be supplied with viscosities appropriate to their applications such as dipping, spraying, brushing, or flow coating.
Fluoropolymers	Excellent electrical properties, good thermal stability, water repellent, resistant to high energy radiation.	Materials can be used as received or diluted to a 0.1 to 5% solution with suitable solvents. Apply by either dipping or spraying. Best film properties achieved at film thickness of 5mills.
Acrylics	Excellent moisture resistance and dielectric properties, poor chemical and solvent resistance, poor resistance to mechanical abrasion.	Material can be applied by spray, roller or curtain coating methods. For high production applications, automated spraying methods are recommended.

TABLE 3500-2: General Physical Properties of selected Conformal Coatings

Property	Paraxylylene	Epoxies	Silicones	Urethanes	Pluoropolymers	Acrylics
Dielectric Strength Volt/MIl(ASTM D149-64)	5400-7000	4000-5000	5400	4500-5000	2500-3000	3500
Dielectric Constant	2.65-2.95	3.3-4.0	2.6-2.7	4.2-5.2	2.7	2.2-3.2
Dissipation Factor 23°C at 1MHz	0.006-0.013	0.03-0.05	0.001-0.002	0.05-0.07	0.016	0.02-0.04
Volume Resistivity (23°C & 50%RH, Ω-cm	10^{16}	10^{14}	10^{15}	10^{14}	10^{15}	10^{15}
Young's Modulus PSI (ASTM D882-565)	350,000-400,000	350,000	900	1000-10,000	-------	-------
Tensile Strength PSI (ASTM D882-56T)	10,000-13,000	10,800	800-1,000	175-10,000	-------	2500
Rockwell Hardness	R80-R85	M80-M110	40-45	10A-250	-------	D90
Glass Transition (°C)	60-100	110	-130	-10	-------	-------
Thermal Conductivity 10^{-4} Cal/s/cm/°C/cm	2.0-3.0	4.5	3.5-7.5	5	-------	-------
Pot Life	-------	Good-Poor	Good-Poor	Good-Poor	Excellent	Excellent
Reparability (Solder-Through)	Fair	Poor	Poor	Good	Excellent	Good
Reparability (Removal by Solvent)	No	No	Poor	No	Excellent	Excellent
Reparability (Physical Removal)	Fair	Poor	Good	Good	---------	Good

CONCLUDING MATERIAL

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I RECOMMEND A CHANGE:	**1. DOCUMENT NUMBER** MIL-HDBK-1547	**2. DOCUMENT DATE (YYMMDD)** 97/11/09

3. DOCUMENT TITLE ELECTRONIC PARTS, MATERIALS, AND PROCESSES FOR SPACE AND LAUNCH VEHICLES

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

5. REASON FOR RECOMMENDATION

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a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON *(if applicable)*	**7.DATE SUBMITTED** (YYMMDD)

8. PREPARING ACTIVITY

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Space and Missile System Center	(1) Commercial (310)363-2406 (2) AUTOVON 833-1744
c. ADDRESS *(Include Zip Code)* SMC/AXMP 160 Skynet Street, Suite 2315 El Segundo, CA 90245-4683	**IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:** DEFENSE QUALITY AND STANDARDIZATION OFFICE 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22401-3466 Telephone (703) 756-2340 AUTOVON 289-2340