NOT MEASUREMENT SENSITIVE

MIL-STD-1587E
23 July 2018
SUPERSEDING
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21 June 2017

DEPARTMENT OF DEFENSE

DESIGN CRITERIA STANDARD

MATERIAL AND PROCESS REQUIREMENTS FOR AEROSPACE WEAPONS SYSTEMS

AMSC 9963 AREA MFFP

FOREWORD

1. This standard is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. The purpose of this standard is to establish materials and process requirements for aerospace weapons systems.

3. Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Air Warfare Center Aircraft Division Lakehurst, Route 547, Mail Stop 120-3, Joint Base MDL, NJ 08733-5100, or emailed to michael.sikora@navy.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

4. For guidance on the technical content of this document, contact the Commander, Naval Air Warfare Center, Aircraft Division (Code 4.3), 48066 Shaw Road, 2188 Patuxent River, MD 20670.

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1. SCOPE

1.1 Scope. This standard establishes the requirements for materials and processes used during design and production of aerospace weapons systems and associated support equipment. When used in conjunction with MIL-STD-1530, the other integrity program documents (MIL-STD-1798, MIL-HDBK-1783, etc.), and MIL-STD-1568, it is expected that structurally reliable aerospace systems having a good balance between acquisition costs and life cycle costs will result. Authority to exceed or amend the requirements in this standard requires permission from the cognizant engineering authority (CEA) of the procuring activity.

1.2 Applicability. This standard is applicable for use by all Department of Defense procuring activities and their respective contractors involved in the design and procurement of aerospace weapons systems. Numerous materials and processes used in propulsion and electronic subsystems are not specifically covered in this standard.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

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 cited in the solicitation or contract.

FEDERAL STANDARD

FED-STD-191	Textile Test Methods

COMMERCIAL ITEM DESCRIPTIONS

A-A-59588	Rubber, Silicone
A-A-59877	Insulating Compound, Electrical, Embedding

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems
MIL-PRF-6855	Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes, General Specification for
MIL-PRF-8516	Sealing Compound, Synthetic Rubber, Electric Connectors

	and Electric Systems, Chemically Cured
MIL-S-9041	Sandwich Construction; Plastic Resin, Glass Fabric Base, Laminated Facings and Honeycomb Core for Aircraft Structural and Electronic Applications
MIL-PRF-23377	Primer Coatings: Epoxy, High-Solids
MIL-PRF-23586	Sealing Compound, (With Accelerator), Silicone Rubber, Electrical
MIL-M-24041	Molding and Potting Compound, Chemically Cured, Polyurethane
MIL-S-25392	Sandwich Construction, Plastic Resin, Glass Fabric Base, Laminated Facings and Urethane Foamed-in-Place Core, for Aircraft Structural Applications
MIL-P-25732	Packing Preformed, Petroleum Hydraulic Fluid Resistant, Limited Service at 275 DEG. F (135 DEG. C)
MIL-DTL-25988	Rubber, Fluorosilicone Elastomer, Oil- and Fuel-Resistant, Sheets, Strips, Molded Parts and Extruded Shapes
MIL-R-25988/1	Rubber, Fluorosilicone Elastomer, Oil- and Fuel-Resistant, O-Rings, Class 1, Grade 70
MIL-R-25988/2	Rubber, Fluorosilicone Elastomer, Oil- and Fuel-Resistant, O-Rings, Class 3
MIL-R-25988/3	Rubber, Fluorosilicone Elastomer, Oil- and Fuel-Resistant, O-Rings, Class 1, Grade 60
MIL-R-25988/4	Rubber, Fluorosilicone Elastomer, Oil- and Fuel-Resistant, O-Rings, Class 1, Grade 80
MIL-DTL-32495	Aluminum-Based Powders for Cold Spray Deposition
MIL-A-46106	Adhesive-Sealants, Silicone, RTV, One Component
MIL-A-46146	Adhesives-Sealants, Silicone, RTV, Noncorrosive (for Use With Sensitive Metals and Equipment)
MIL-T-81556	Titanium and Titanium Alloys, Extruded Bars and Shapes, Aircraft Quality
MIL-PRF-81733	Sealing and Coating Compound, Corrosion Inhibitive
MIL-DTL-83397	Rubber, Polyurethane, Castable, Humidity Resistant
MIL-PRF-83483	Anti-seize Thread Compound, Molybdenum Disulfide-Petrolatum

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-129	Military Marking for Shipment and Storage
MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests
MIL-STD-866	Grinding of Chrome Plated Steel and Steel Parts Heat Treated to 180,000 PSI or Over
MIL-STD-889	Dissimilar Metals
MIL-STD-1530	Aircraft Structural Integrity Program (ASIP)
MIL-STD-1568	Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems

MIL-STD-1689	Fabrication, Welding, and Inspection of Ships Structure
MIL-STD-1798	Mechanical Equipment and Subsystems Integrity Program
MIL-STD-3021	Materials Deposition, Cold Spray
MIL-STD-3024	Propulsion System Integrity Program (PSIP)
MIL-STD-7179	Finishes, Coatings, and Sealants, for the Protection of Aerospace Weapons Systems

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-275	Guide for Selection of Lubricants, Fluids and Compounds for Use in Flight Vehicles and Components
MIL-HDBK-838	Lubrication of Military Equipment
MIL-HDBK-1783	Engine Structural Integrity Program (ENSIP)
MIL-HDBK-6870	Nondestructive Inspection Program Requirements For Aircraft And Missile Materials And Parts
MIL-HDBK-83377	Adhesive Bonding (Structural) For Aerospace And Other Systems, Requirements For

JOINT SERVICE SPECIFICATION GUIDES

JSSG-2006	Aircraft Structures
JSSG-2007	Engines, Aircraft, Turbine
JSSG-2010	Crew Systems

(Copies of these documents are available online at http://quicksearch.dla.mil.)

2.2.2 Other Government documents and publications. The following other Government documents and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

AIR FORCE RESEARCH LABORATORY (AFRL)

ADB07732	Advanced Composite Repair Guide, AFWAL-TR-83-3092
AMMTIAC-R000841	Damage Tolerant Design Handbook, MCIC-HB-01
ADB096021	DOD/NASA Structural Composites Fabrication Guide, Vol I
AMMTIAC-P043851	DOD/NASA Structural Composites Fabrication Guide, Vol II
ADB080181	DOD/NASA Advanced Composites Design Guide, Vol I
ADB080182	DOD/NASA Advanced Composites Design Guide, Vol II
ADB080183	DOD/NASA Advanced Composites Design Guide, Vol III
ADB080184	DOD/NASA Advanced Composites Design Guide, Vol IV

(Copies of these documents are available online for DoD users at https://www.dtic.mil and can be located by searching for the accession number given in the left hand column above.)

AIR FORCE SYSTEMS COMMAND DESIGN HANDBOOKS (AFSC DH)

AFSC DH 1-2	General Design Factors
AFSC DH 1-7	Aerospace Materials
AFSC DH 2-1	Airframe

(Copies of these documents are available online and are permitted for release only to DoD employees and DoD contractors at: engineering.standards@us.af.mil. Hard copies requests are also available at: AFLCMC/EZSS, 2145 Monahan Way, Bldg 28, Wright Patterson AFB OH 45433-7017.)

AIR FORCE TECHNICAL ORDER

T.O. 1-1-690	General Advanced Composite Repair Processes Manual

(Private industry companies with government contracts may obtain copies of this document by going to http://www.e-publishing.af.mil/ and filling out an AFTO 43 form. The general public may obtain copies by emailing your request to AFLCMC.LZPTP.PublicTORequests@us.af.mil.)

FEDERAL AVIATION REGULATION (FAR)

FAR 25.853	Compartment Interiors Amendment 25-59 Appendix F, Part II, Flammability of Seat Cushions
FAR 25.853	Compartment Interiors Amendment 25-61 Appendix F, Part IV, Test Method to Determine the Heat Release Rate from Cabin Materials Exposed to Radiant Heat

(Copies of these documents are available online at: http://www.faa.gov.)

NASA TECHNICAL STANDARDS SYSTEM (NTSS)

MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments

(A copy of this document is available online at: https://standards.nasa.gov.)

NAVAIR TECHNICAL PUBLICATIONS

NAVAIR 01-1A-21	Technical Manual Organizational and Intermediate Maintenance General Composite Repair
NAVAIR 01-1A-22	Technical Manual Maintenance Instructions Organizational, Intermediate, and Depot Aircraft Radomes and Antenna

(A copy of these documents are available online at: https://mynatec.navair.navy.mil. NATEC has three difference processes to obtain the manuals, depending on if you are Government personnel (military and civilians), contractors with a Government contract, or everyone else. If unable to access this web site or require further assistance, contact (1) NATEC Customer Service: 619.545.1888, (2) NATEC Website Status Hotline: 619.545.1706, or (3) NATEC Customer Service E-mail: nani_customerservice@navy.mil.)

NAVSEA TECHNICAL PUBLICATIONS

NAVSEA T9074 AD-GIB-010/1688	Requirements for Fabrication, Welding, and Inspection of Submarine Structure
NAVSEA S9074 AR-GIB-010/278	Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

(Copies of these documents are available online via Technical Data Management Information System (TDMIS) at https://mercury.tdmis.navy.mil/ by searching for the document number without the suffix. Refer questions, inquiries, or problems to: DSN 296-0669, Commercial (805) 228-0669. These documents are available for ordering (hard copy) via the Naval Logistics Library at https://nll.navsup.navy.mil. For questions regarding the NLL, contact the NLL Customer Service at nllhelpdesk@navy.mil, (866) 817-3130, or (215) 697-2626/DSN 442-2626.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

AMERICAN GEAR MANUFACTURERS ASSOCIATION (AGMA)

AGMA 99FTM1	Barkhausen Noise Inspection Method for Detecting Grinding Damage in Gears

(Copies of this document are available online at http://www.agma.org.)

AMERICAN WELDING SOCIETY (AWS)

AWS A3.0	Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying
AWS C3.4M/C3.4	Specification for Torch Brazing
AWS C3.5M/C3.5	Specification for Induction Brazing
AWS C3.6M/C3.6	Specification for Furnace Brazing
AWS C3.7M/C3.7	Specification for Aluminum Brazing
AWS D1.1/D1.1M	Structural Welding Code Steel
AWS D1.2/D1.2M	Structural Welding Code Aluminum

AWS D1.6M/D1.6M	Structural Welding Code Stainless Steel
AWS D17.1/D17.1M	Specification for Fusion Welding for Aerospace Applications
AWS D17.2/D17.2M	Specification for Resistance Welding for Aerospace Applications
AWS D17.3/D17.3M	Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications

(Copies of these documents are available online at http://www.aws.org.)

ASTM INTERNATIONAL

ASTM A255	Standard Test Method for Determining the Hardenability of Steel
ASTM B265	Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate
ASTM D1003	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
ASTM D3039/D3039M	Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials
ASTM D4417	Standard Test Method for Field Measurement of Surface Profile of Blast Cleaned Steel
ASTM D4762	Standard Guide for Testing Polymer Matrix Composite Materials
ASTM E18	Standard Test Methods for Rockwell Hardness of Metallic Materials
ASTM E162	Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source
ASTM E1077	Standard Test Methods for Estimating the Depth of Decarburization of Steel Specimens

(Copies of these documents are available online at http://www.astm.org.)

BATTELLE MEMORIAL INSTITUTE

DOT/FAA/AR-MMPDS	Metallic Materials Properties Development and Standardization

(Copies of the current edition of MMPDS may be obtained in several forms, as described in www.mmpds.org or by e-mail at bcommpds@battelle.org.)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 15614-13	Specification and Qualification of Welding Procedures For Metallic Materials – Welding Procedure Test – Part 13: Upset (Resistance Butt) and Flash Welding

(Copies of this document are available online at http://www.iso.org.)

NATIONAL AEROSPACE STANDARD (NAS)

NAS 1514	Radiographic Standard for Classification of Fusion Weld Discontinuities

(Copies of this document are available online at http://www.aia-aerospace.org/standards.)

IPC ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

J-STD-001	Requirements For Soldered Electrical And Electronic Assemblies

(Copies of this document are available online at http://www.ipc.org.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) INTERNATIONAL

SAE AMS2175	Castings, Classification and Inspection of
SAE AMS2300	Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure
SAE AMS2301	Steel Cleanliness, Aircraft Quality, Magnetic Particle Inspection Procedure
SAE AMS2303	Steel Cleanliness, Aircraft-Quality, Martenistic Corrosion-Resistant Steels Magnetic Particle Inspection Procedure
SAE AMS2430	Shot Peening Automatic
SAE AMS2750	Pyrometry
SAE AMS2759	Heat Treatment Steel Parts General Requirements
SAE AMS2759/3	Heat Treatment Precipitation Hardening Corrosion Resistant and Maraging Steel Parts
SAE AMS2759/7	Carburizing and Heat Treatment of Carburizing Grade Steel Parts
SAE AMS2759/11	Stress Relief of Steel Parts
SAE AMS2770	Heat Treatment of Wrought Aluminum Alloy Parts
SAE AMS2771	Heat Treatment of Aluminum Alloy Castings
SAE AMS2772	Heat Treatment of Aluminum Alloy Raw Materials
SAE AMS3100	Adhesion Promoter for Polysulfide Sealing Compounds
SAE AMS3216	Fluorocarbon (FKM) Rubber High-Temperature - Fluid Resistant Low Compression Set 70 to 80
SAE AMS3218	Fluorocarbon (FKM) Rubber High-Temperature-Fluid Resistant Low Compression Set 85 to 95
SAE AMS3276	Sealing Compound, Integral Fuel Tanks and General Purpose, Intermittent Use To 360 °F (182 °C)
SAE AMS3277	Sealing Compound, Polythioether Rubber, Fast Curing for Integral Fuel Tanks and General Purpose, Intermittent Use to 360 °F (182 °C)
SAE AMS3278	Sealing and Coating Compound: Polyurethane (PUR) Fuel Resistant High Tensile Strength/Elongation For Integral Fuel

	Tanks/Fuel Cavities/General Purpose
SAE AMS3279	Sealing Compound, Sprayable For Integral Fuel Tanks and Fuel Cell Cavities, For Intermittent Use to 350 °F (177 °C) (Stabilized Type)
SAE AMS3281	Sealing Compound, Polysulfide (T) Synthetic Rubber for Integral Fuel Tank and Fuel Cell Cavities Low Density for Intermittent Use to 360 °F (182 °C)
SAE AMS3283	Sealing Compound, Polysulfide Non Curing, Groove Injection Temperature and Fuel Resistant
SAE AMS3376	Sealing Compound, Non Curing, Fluorosilicone Groove Injection Temperature and Fuel Resistant
SAE AMS3384	Rubber, Fluorocarbon Elastomer (FKM) 70 to 80 Hardness, Low Temperature Sealing Tg -22 °F (-30 °C) For Elastomeric Shapes or Parts in Gas Turbine Engine Oil, Fuel and Hydraulic Systems
SAE AMS3856	Cloth, Upholstery, Flame Resistant, Novoloid/Aramid, Waffle Type Weave
SAE AMS4900	Titanium Sheet, Strip, and Plate Commercially Pure Annealed, 55 ksi (379 MPa) Yield Strength - UNS R50550
SAE AMS4901	Titanium Sheet, Strip, and Plate Commercially Pure Annealed, 70.0 ksi (485 MPa) - UNS R50700
SAE AMS4902	Titanium Sheet, Strip, and Plate Commercially-Pure Annealed 40.0 ksi (276 MPa) Yield Strength - UNS R50400
SAE AMS4903	Titanium Alloy Sheet, Strip, and Plate 6Al - 4V Solution Heat Treated - UNS R56400
SAE AMS4904	Titanium Alloy Sheet, Strip, and Plate 6Al - 4V Solution Heat Treated and Aged - UNS R56400
SAE AMS4907	Titanium Alloy, Sheet, Strip, and Plate 6.0Al - 4.0V, Extra Low Interstitial Annealed - UNS R56401
SAE AMS4909	Titanium Alloy, Sheet, Strip, and Plate 5Al - 2.5Sn, Extra Low Interstitial Annealed - UNS R54521
SAE AMS4910	Titanium Alloy, Sheet, Strip, and Plate 5Al - 2.5Sn Annealed - UNS R54520
SAE AMS4911	Titanium Alloy, Sheet, Strip, and Plate 6Al - 4V Annealed - UNS R56400
SAE AMS4915	Titanium Alloy Sheet, Strip, and Plate 8Al - 1V - 1Mo Single Annealed - UNS R54810
SAE AMS4916	Titanium Alloy Sheet, Strip, and Plate 8Al - 1Mo - 1V Duplex Annealed - UNS R54810
SAE AMS4917	Titanium Alloy Sheet, Strip, and Plate 13.5V - 11Cr - 3.0Al Solution Heat Treated - UNS R58010
SAE AMS4918	Titanium Alloy, Sheet, Strip, and Plate 6AI - 6V - 2Sn Annealed - UNS R56620
SAE AMS4919	Titanium Alloy Sheet, Strip, and Plate 6AI - 2Sn - 4Zr - 2Mo - 0.08Si Duplex Annealed - UNS R54620

SAE AMS4921	Titanium Bars, Wire, Forgings, and Rings Commercially Pure 70 ksi (483 MPa) Yield Strength - UNS R50700
SAE AMS4939	Titanium Alloy Sheet, Strip, and Plate 3Al - 8V - 6Cr - 4Mo - 4Zr Solution Heat Treated - UNS R58640
SAE AMS4940	Titanium Sheet, Strip, and Plate Commercially Pure Annealed, 25.0 ksi (172 MPa) Yield Strength - UNS R50250
SAE AMS4970	Titanium Alloy Bars, Wire, and Forgings 7Al - 4Mo Solution and Precipitation Heat Treated - UNS R56740
SAE AMS4988	Titanium Alloy Sheet, Strip, and Plate 6Al - 6V - 2Sn Solution Heat Treated - UNS R56620
SAE AMS4989	Titanium Alloy Sheet, Strip, and Plate 3Al - 2.5V Annealed - UNS R56320
SAE AMS4990	Titanium Alloy Sheet, Strip, and Plate 6Al - 6V - 2Sn Solution Heat Treated and Aged - UNS R56620
SAE AMS5343	Steel, Corrosion Resistant, Investment Castings, 16CR - 4.1Ni - 0.28Cb(Nb) - 3.2 Cu, Homogenization, Solution, and Precipitation Heat Treated (H1000), 150 Ksi (1034 MPa) Tensile Strength 17-4
SAE AMS6900	Titanium Alloy Bars, Forgings and Forging Stock 5Al - 2.5Sn Annealed - UNS R54520
SAE AMS6901	Titanium Alloy Bars, Forgings, and Forging Stock 5Al - 2.5Sn, Extra Low Interstitial Annealed - UNS R54521
SAE AMS6905	Titanium Alloy Bars, Forgings and Forging Stock 6.0Al - 2.0Sn - 4.0Zr - 2.0Mo Duplex Annealed - UNS R54620
SAE AMS6906	Titanium Alloy Bars, Forgings, and Forging Stock 6.0Al - 2.0Sn - 4.0Zr - 6.0Mo Solution Heat Treated and Aged - UNS R56260
SAE AMS6907	Titanium Alloy Bars, Forgings and Forging Stock 6.0Al - 2.0Sn - 4.0Zr - 6.0Mo Duplex Annealed - UNS R56260
SAE AMS6910	Titanium Alloy Bars, Forgings and Forging Stock 8Al - 1Mo - 1V Duplex Annealed - UNS R54810
SAE AMS6915	Titanium Alloy Bars, Forgings and Forging Stock 7.0Al - 4.0Mo Annealed - UNS R56740
SAE AMS6920	Titanium Alloy Bars, Forgings and Forging Stock 3Al - 8V - 6Cr - 4Mo - 4Zr Solution Heat Treated - UNS R58640
SAE AMS6921	Titanium Alloy Bars, Forgings and Forging Stock 3Al - 8V - 6Cr - 4Mo - 4Zr Solution Heat Treated and Aged - UNS R58640
SAE AMS6925	Titanium Alloy Bars, Forgings and Forging Stock 13V - 11Cr - 3Al Solution Heat Treated - UNS R58010
SAE AMS6926	Titanium Alloy Bars, Forgings and Forging Stock 13V - 11Cr - 3Al Solution Heat Treated and Aged - UNS R58010
SAE AMS6930	Titanium Alloy Bars, Forgings and Forging Stock 6.0Al - 4.0V Solution Heat Treated and Aged - UNS R56400
SAE AMS6931	Titanium Alloy Bars, Forgings and Forging Stock 6.0Al - 4.0V Annealed - UNS R56400

SAE AMS6932	Titanium Alloy Bars, Forgings and Forging Stock 6.0Al – 4.0V Extra Low Interstitial Annealed - UNS R56401
SAE AMS6935	Titanium Alloy Bars, Forgings and Forging Stock 6.0Al – 6.0V – 2.0Sn Solution Heat Treated and Aged - UNS R56620
SAE AMS6936	Titanium Alloy Bars, Forgings and Forging Stock 6Al - 6V - 2Sn Annealed - UNS R56620
SAE AMS6940	Titanium Alloy Bars, Forgings and Forging Stock 3.0Al - 2.5V Annealed - UNS R56320
SAE AMS7259	Rubber: Fluorocarbon (FKM) High Temperature/Fluid Resistant, Low Compression Set / 85 to 95 Hardness, For Seals in Fuel Systems and Specific Engine Oil Systems
SAE AMS7276	Rubber: Fluorocarbon (FKM), High-Temperature-Fluid Resistant, Low Compression Set, For Seals In Fuel Systems and Specific Engine Oil Systems
SAE AMS7287	Fluorocarbon Elastomer (FKM) High Temperature / HTS Oil Resistant / Fuel Resistant, Low Compression Set / 70 to 80 Hardness, Low Temperature Tg -22 °F (-30 °C) For Seals in Oil / Fuel / Specific Hydraulic Systems
SAE AMS-A-21180	Aluminum-Alloy Castings, High Strength
SAE AMS-A-22771	Aluminum Alloy Forgings, Heat Treated
SAE AMS-C-7438	Core Material, Aluminum, for Sandwich Construction
SAE AMS-C-8073	Core Material, Plastic Honeycomb, Laminated Glass Fabric Base, for Aircraft Structural and Electronic Applications
SAE AMS-C-27725	Coating, Corrosion Preventative, for Aircraft Integral Fuel Tanks for Use to 250 °F (121 °C)
SAE AMS-F-7190	Forging, Steel, For Aircraft/Aerospace Equipment and Special Ordnance Applications
SAE AMS-H-81200	Heat Treatment of Titanium and Titanium Alloys
SAE AMS-P-5315	Acrylonitrile - Butadiene - (NBR) Rubber for Fuel-Resistant Seals 60 to 70
SAE AMS-P-5510	O-Ring, Preformed, Straight Thread Tube Fitting Boss, Type I Hydraulic (-65° to 160°F)
SAE AMS-P-83461	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275 Degrees F (135 Degrees C)
SAE AMS-QQ-A-367	Aluminum Alloy Forgings
SAE AMS-R-7362	Nitrile Rubber, Synthetic, Solid, Sheet, Strip and Fabricated Parts, Synthetic Oil Resistant
SAE AMS-R-83285	Rubber, Ethylene-Propylene, General Purpose -
SAE AMS-S-83318	Sealing Compound, Polysulfide Type, Low Temperature Curing, Quick Repair, Integral Fuel Tanks And Fuel Cell Cavities
SAE AMS-S-8802	Sealing Compound, Fuel Resistant, Integral Fuel Tanks and Fuel Cell Cavities
SAE ARP4462	Barkhausen Noise Inspection for Detecting Grinding Burns in High Strength Steel Parts

SAE ARP5316	Storage of Elastomer Seals and Seal Assemblies Which Include an Elastomer Element Prior to Hardware Assembly
SAE AS568	Aerospace Size Standard for O-Rings
SAE AS1933	Age Controls for Hose Containing Age-Sensitive Elastomeric Material
SAE AS3208	Packing, Preformed - AMS 7276 - Seal
SAE AS3209	Packing, Preformed - AMS 7276, 'O' Ring
SAE AS3581	Packing, Preformed - O-Ring Seal AMS 7259
SAE AS28775	Packing, Preformed - MS28775 O-Ring
SAE AS28778	O-Ring, Straight Thread Tube Fitting Boss, Molded From AMS-P-5510 Rubber
SAE AS29512	Hydrocarbon Fuel Resistant, Tube Fitting, O-Ring, Molded From AMS-P-5315 Rubber
SAE AS29513	Packing, Preformed, Hydrocarbon Fuel Resistant O-Ring
SAE AS29561	O-Ring, Synthetic Lubricant Resistant, Molded From AMS-R-7362 Rubber
SAE AS50881	Wiring Aerospace Vehicle
SAE AS81550	Insulating Compound, Electrical, Embedding, Reversion Resistant Silicone
SAE AS83461/1	M83461 O-Ring Molded From AMS-P-83461 Rubber
SAE AS83461/2	Straight Thread Tube Fitting Boss O-Ring Molded From AMS-P-83461 Rubber
SAE CMH-17-1	Polymer Matrix Composites, Guide for Characterization of Structural Materials
SAE CMH-17-2	Polymer Matrix Composites, Materials Properties
SAE CMH-17-3	Polymer Matrix Composites, Materials, Usage, Design and Analysis
SAE CMH-17-4	Metal Matrix Composites
SAE CMH-17-5	Ceramic Matrix Composites
SAE CMH-17-6	Structural Sandwich Composites
SAE J406	Methods of Determining Hardenability of Steels
SAE R422	Composite Materials Handbook (CMH-17) Volume 1, Polymer Matrix Composites, Guidelines for Characterization of Structural Materials

(Copies of these documents are available online at http://www.sae.org.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, 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. DEFINITIONS

3.1 Definitions. Definitions are in accordance with the documents listed in section 2.

4. GENERAL REQUIREMENTS

4.1 Material selection. The selection of materials and processes shall be the result of design studies for each system. The studies shall include all the relevant parameters specified by the contract, such as operational environments, performance, manufacturing capabilities, safety of flight structure, life cycle costs, and reliability and maintainability requirements. The studies shall determine the acceptable initial flaw types and size, defects, and tolerances associated with the manufacturing processes, fabrication, and assembly. The initial manufactured quality of the design shall meet the fatigue, rigidity, strength, durability, and damage tolerance requirements specified in the contract. Materials related considerations that shall form a part of the trade studies include mechanical properties as identified in DOT/FAA/AR-MMPDS or other sources approved by the CEA, stability under environmental conditions, corrosion susceptibility, fracture toughness, and crack growth (da/dn) under the service stresses. Any material considered shall have a specification (Government, Non-Government, or Industry) available for review by the CEA. The service experience of established materials in similar applications shall also be considered. Standard methods and materials used for the protective surface treatments and finishes shall be used on weapons system parts (including spares) and assemblies (such as fuselages, wings, cowlings, empennage, and rotor blades). When materials or processes with only a limited amount of data or experience are proposed, their use shall require approval by the CEA (see 6.6).

4.2 Restricted materials. The materials listed in Table I are commonly restricted from use in structural applications on Department of Defense (DoD) weapons systems. Any use of these materials requires specific approval from the CEA.

4.3 Material properties/fracture mechanics. Materials considered for aerospace applications must be adequately characterized and evaluated for use. Because of the extreme variation in environmental conditions that weapons may be used or stored in, it is imperative to acquire high confidence data that has been reviewed (along with the analysis techniques applied) and accepted by the CEA. At a minimum, static properties (TS, YS, EL, Mod, etc.), dynamic properties (e.g., toughness, fatigue crack growth rates, impact resistance, etc.), physical properties, stress corrosion cracking (SCC) thresholds, corrosion resistance as required for the application, thermal stability, and ability to fabricate (machining, welding, forming, etc.) shall be evaluated. Typical alloys exhibiting unacceptable characteristics in one or more of these areas are listed in the Table I. Fracture mechanics analysis shall be in accordance with MIL-STD-1530 and MIL-STD-1798. Fracture mechanics analysis should also be in accordance with MIL-HDBK-1783. MCIC-HB-01 shall be used to establish material properties when conducting fracture mechanics analysis. For engine hardware analysis guidance, JSSG 2006, JSSG 2007, and MIL-HDBK-1783 should be used.

4.4 Disclosure of materials. Proposed materials and processes shall be selected from existing DoD or non-Government standards (AMS, etc.). Selected materials and processes shall have been approved under the technical proposal (see 6.4). A technical proposal shall contain:

a. Information identifying operating environment and loading conditions.
b. List of materials and processes.
c. Rationale and materials process selection
d. Material classification

4.5 Material and process specifications. All materials and processes to be employed are required to have approved government or industry specifications (MIL, DOT, FAA, SAE etc.). For cases where an approved government or industry specification does not exist for a proposed material or process, a contractor prepared specification, containing rationale and tests to be performed, shall be prepared in accordance with DI-MFFP-82119 for approval by the CEA (see 6.3).

4.5.1 Material specification. A material specification shall be established in accordance with DI-MFFP-82119 (see 6.3). The material specification shall contain requirements and criteria (typically by mechanical, chemical or thermal analysis) required for approval of materials supplied by material vendors to be used in a particular aerospace application. The specification as a minimum shall identify in detail the types of chemical, mechanical, and other tests to be performed, the types and numbers of test specimens to be employed, the range of test results that are needed for the incoming material to be acceptable for manufacturing, and conformance inspections for individual purchase lots of incoming material after that material has been approved. The specification shall specify the minimum requirements for acceptance of raw materials and their inspection.

4.5.2 Process specification. A process specification shall be established in accordance with DI-MFFP-82119 (see 6.3). The process specification shall provide for and detail all processes that are essential to fabrication or procurement of a product or material, particularly the processing of the raw material or preform into an assembly component conforming to engineering design requirements. Process control shall include a tracking method, preferably companion (or traveler) coupons that accompany all production parts during the manufacturing process cycle. These coupons shall be tested to verify that the manufacturing cycle has produced parts within an acceptable range.

4.6 Corrosion/finishing requirements. Corrosion prevention and control shall be in accordance with MIL-STD-1568 and MIL-STD-889. Finishes, coatings, and sealants shall be in accordance with MIL-STD-7179 and MIL-DTL-5002.

4.7 Material property design allowables. The material property design allowables shall be developed according to a material characterization and design allowable substantiation plan. This plan shall include but not be limited to materials property data (i.e., A-basis, B-basis, and S-basis, as defined and included in DOT/FAA/AR-MMPDS) and shall be subject to review and approval by the CEA. Although static strength design allowables are important, other properties such as creep, fatigue, stress corrosion cracking, etc., shall be addressed as necessary. Mechanical property design allowables shall be derived from a statistically significant amount of test data subject to review and approval by the CEA, and the derivation of design allowables from the test data shall consider the distribution of property values within the same data population. The material qualification, procurement, and manufacturing process specifications used in preparation of test specimens shall be identical to those used in production. During production, material properties shall be verified periodically by testing of materials processed during a production run. The effects upon the design allowables of impact damage and repairs shall be evaluated.

4.8 Joining and fastening. Fastening methods (bonding, bolting, stitching, welding, brazing, soldering, etc.) for the chosen materials and processes shall be validated and approved by the CEA. The effect of joining and fastening techniques on the net material property design allowables shall be evaluated, including sensitivities to material and process variations such as hole quality, bondline thickness, stitching quality, etc. Joint system design allowables, test methods, and data reduction methods for determining those allowables are described in DOT/FAA/AR-MMPDS Chapters 8 and 9. Hole tolerances, fastener pull-through resistance, corrosion implications, and galvanic compatibility shall be evaluated during design development. Allowances shall also be made to preclude problems from over-torqued fasteners and fit-up mismatches on removable/interchangeable structures. Attaching parts such as nuts, bushings, spacers, washers, screws, self-tapping screws, sleeves, self-locking nuts, speed nuts, clamps, and bolts shall be wet installed. Permanent installations shall use MIL-PRF-23377 and removable installations shall use MIL-PRF-81733. For Naval Aviation Systems, both permanent and removable installations shall use MIL-PRF-81733 Grade A, unless an alternative is approved by the CEA.

4.9 Electrical/electromagnetic behavior. The behavior of the material shall be considered in the structural design for electrical/electromagnetic performance. Of particular concern are shielding effectiveness, joint design (condition, corrosion, sealing, maintainability, etc.), fuel tank design (spark-free fuel tanks, lightning-strike hot spots, etc.), power system grounding, high and low frequency antenna performance, analytical techniques and combined space environmental effects.

4.10 Repairability. The selection of materials and processes shall be compatible with system repair and maintenance requirements and facilitate identification of repair concepts that meet or exceed repair requirements.

4.11 Thermal expansion. The effects of thermal expansion mismatches between dissimilar materials (different coefficients of thermal expansion) and resulting induced stresses shall be evaluated during design and manufacturing process evaluation.

4.12 Supportability. Materials and processes for aerospace weapons systems shall be supportable and correlated with mechanical property design allowable data. Supportability means that thermal, environmental, and mechanical deterioration of materials have been identified and that acceptable quality and cost-effective preventive methods and in-service repair methods are either available or can be developed in a timely manner to mitigate the deterioration of materials and structures fabricated using the selected manufacturing processes and joining methods.

5. DETAILED REQUIREMENTS

5.1 Metals. General material allowable requirements are specified in 4.7. Some metal alloy material property design allowables can be obtained from DOT/FAA/AR-MMPDS.

5.1.1 Minimum thickness. The recommended minimum thickness of materials for structural applications (except sandwich constructions) shall be as specified in Table II. Deviations to these thickness limits shall be approved by the CEA. The minimum thickness for countersinking shall be in accordance with Design Note 4A1 of AFSC DH 1-2. Deviations to these thickness limits may be permitted depending upon structural design requirements and exact material selection.

5.1.2 Aluminum.

5.1.2.1 Heat treatment. Heat treatment of aluminum alloy, raw materials, parts, and castings shall be in accordance with SAE AMS2770, SAE AMS2771, SAE AMS2772. In all cases, maximum thickness for heat treatment shall be controlled to ensure that the thickness design properties are met. Special considerations such as quench medium, delay in final aging, or forming prior to aging shall be approved by the CEA.

5.1.2.2 Forming and straightening. Forming and straightening operations performed on sheet metal, plate, extrusions or forgings shall be limited to processes that do not result in detrimental residual stresses or losses in mechanical properties or lead to stress corrosion sensitivity of structurally critical parts, as defined by the cognizant engineering authority, or lead to stress corrosion sensitivity of the part. Peen forming is permissible. Adequate controls shall be maintained to ensure forming and straightening processes meet the foregoing requirements.

5.1.3 Steel. Steels used at or above 200 ksi (1379 MPa) ultimate tensile strength (UTS) shall meet SAE AMS2300 cleanliness requirements except that the cleanliness rating for heat treatments to 260 ksi (1793 MPa) and above shall have a frequency/severity rating of 0.10/0.20 maximum, respectively. Steels used below 200 ksi (1379 MPa) shall meet SAE AMS2301 cleanliness requirements. Ferromagnetic corrosion resistant steels shall meet SAE AMS2303 cleanliness requirements. Compositions shall be selected which have ductile to brittle temperature measured by impact that are below any temperature that the part will experience in service. Alloys with low to moderate resistance to stress corrosion cracking (SCC), as detailed in MSFC-STD-3029 and MIL-STD-1568, shall not be used without the approval of the CEA.

5.1.3.1 Heat treatment. Heat treatment shall be accomplished in accordance with SAE AMS2759 or methods recognized therein. The equipment and controls shall comply with SAE AMS2750. After heat treatment, parts shall meet the reduction in area requirements in Table III.

5.1.3.2 Peening. After final machining, all parts that have been heat treated to, or above 200 ksi (1379 MPa) UTS, shall be peened in accordance with SAE AMS2430 except for: rolled threads, inaccessible areas of holes, pneumatic or hydraulic seat contact areas; and thin sections or parts which, after peening, violate engineering and functional configuration. Areas requiring lapped, honed, or polished surfaces shall be peened prior to such finishing. Surface removal of up to 0.0038 centimeter (0.0015 inch) based on pre-peened dimensions shall be permissible.

5.1.3.3 Hardenability. Hardenability shall ensure transformation during quenching to not less than 90 percent martensite at the center of the maximum cross section. Hardenability shall be determined by ASTM A255 or SAE J406.

5.1.3.4 Forming or straightening of steel parts. All precautions shall be taken to minimize warping during heat treatment of steel parts. Non-destructive inspections (NDI) shall be performed on parts after straightening or forming. Steel parts or sections of steel parts shall be formed or straightened one time, unless approved by the CEA, in accordance with the following:

a. Parts hardened up to 165 ksi (1138 MPa) UTS may be room temperature straightened.

b. Parts hardened from 165 to 200 ksi (1138 to 1379 MPa) UTS may be straightened at room temperature providing they are given a stress relieving heat treatment in accordance with SAE AMS2759/11 subsequent to straightening.

c. Parts hardened over 200 ksi (1379 MPa) UTS shall be hot formed or straightened within a temperature range from the tempering temperature to 28 ºC (50 ºF) below the tempering temperature.

5.1.3.5 Decarburization. Complete decarburization shall not be present in a finished machined surface. On steels heat treated below 200 ksi (1379 MPa) UTS, partial decarburization to a maximum depth of 0.0127 cm (0.005 inch) may be present. On steels heat treated above 200 ksi (1379 MPa) UTS, partial decarburization to a maximum depth of 0.0076 cm (0.003 inch) may be present. Use of appropriate platings, atmosphere control, paints and finish machining, as approved by the CEA, shall be applied to assure decarburization has not occurred. Hardness and decarburization shall be evaluated in accordance with ASTM A255, ASTM E1077, ASTM E18, or equivalent as approved by the CEA.

5.1.3.6 Carburization. Minimum carburization of hardened steel parts shall be a prime objective. Furnace atmospheres shall not increase the carbon content of surface zones above the maximum for the respective composition. Surface of steel parts shall show no evidence of carbon increase as a result of heat treating. When carburization and heat treatment of carburized steel is performed, it shall be in accordance with SAE AMS2759/7 or equivalent as approved by the CEA.

5.1.3.7 Drilling of high strength steels. The drilling of holes, including chamfering and spot facing, in martensitic steels subsequent to hardening to strength levels of 180 ksi (1241 MPa) UTS and above shall only be performed with the approval of the CEA. When drilling and reaming is unavoidable because of manufacturing sequence, tooling and techniques necessary to avoid formation of any undesirable microstructure (i.e., untempered/overtempered martensite, grain boundary carbide formation, or stress concentrations) shall be used. The documents controlling such techniques shall specify a final sizing pass with minimal radial loads, speed and feed rates, coolant flow rates, tool life limits, inspection techniques, and other requirements necessary to ensure the production of holes of high quality, smooth bore surfaces, and free from "hard spots" and microcracks. Tooling and processes used shall be approved by the CEA. Microhardness and metallurgical examinations of test specimens shall be used to determine the depth of disturbed metal and possible untempered martensitic areas resulting from drilling. The surface roughness of the finished hole, including any countersink or spot faced surfaces, shall not be greater than Ra 63, when measured in accordance with ASTM D4417 Method B. Both ends of the holes shall be deburred by a method that has been demonstrated not to cause untempered martensite except where the materials stackups or assemblies preclude accessibility of both ends of the holes in each layer of the stackups. Carbide reamers shall be used in steel heat treated to 260 ksi (1793 MPa) UTS and above. For tapered holes, reamers having not less than 12 flutes shall be used.

5.1.3.8 Grinding of high strength steel. Grinding of martensitic steels or chromium plated martensitic steels hardened to 180 ksi (1241 MPa) UTS and above shall be performed in accordance with MIL-STD-866. Ground martensitic steels shall be tested in accordance with SAE ARP4462, AGMA 99FTM1 or other relevant government or industry specification as approved by the CEA.

5.1.3.9 Corrosion resistant steels.

5.1.3.9.1 Austenitic stainless steels. Free machining stainless steels shall not be used for fatigue critical applications, unless approved by the CEA. The use of stabilized or low carbon (L grade) austenitic steels shall be used for all applications where the temperature during manufacturing or service exceeds 315 ºC (600 ºF). The use of hydrochloric acid, silver, chlorinated cutting fluids, chlorinated solvents, methyl alcohol, fluorinated hydrocarbons, and components containing mercury is prohibited on austenitic stainless steels, as these materials may induce SCC.

5.1.3.9.2 Precipitation hardening stainless steels. Precipitation hardening stainless steels shall be aged in accordance with SAE AMS 2759/3 or equivalent at temperatures not less than 552 ºC (1025 ºF) unless approved by the CEA. Exception is made for castings aged at 501.5 ±9.4 ºC (935 ±15 ºF), for fasteners used in the H950 condition, and for springs that have optimum properties at the CH 900 condition. H950 shall not be used for 17-4 PH or 15-5 PH alloys.

5.1.4 Titanium. All Titanium and titanium alloys shall be used in accordance with MIL-STD-1568. The use of hydrochloric acid, silver, chlorinated cutting fluids, chlorinated solvents, methyl alcohol, fluorinated hydrocarbons, and components containing mercury is prohibited on titanium and its alloys, as these materials may induce SCC.

5.1.4.1 Forgings. All titanium bar and forging stock, as applicable, shall be in accordance, with SAE AMS4921, SAE AMS4970, SAE AMS6900, SAE AMS6901, SAE AMS6905, SAE AMS6906, SAE AMS6907, SAE AMS6910, SAE AMS6915, SAE AMS6920, SAE AMS6921, SAE AMS6925, SAE AMS6926, SAE AMS6930, SAE AMS6931, SAE AMS6932, SAE AMS6935, SAE AMS6936, SAE AMS6940, or equivalent as approved by the CEA and shall meet the metallurgical and structural properties required to meet the reliability and durability requirements of the system. Billet material or minimally worked material forging stock shall not be used to manufacture components. The processing, including heat treatment, cleaning, surface treatments, and joining shall not alter the composition outside of the specification limits. Witness specimens attached to the component shall be used for determination.

5.1.4.2 Sheet and plate. Titanium sheet and plate stock, as applicable, shall be in accordance, with ASTM B265, SAE AMS4900, SAE AMS4901, SAE AMS4902, SAE AMS4903, SAE AMS4904, SAE AMS4907, SAE AMS4909, SAE AMS4910, SAE AMS4911, SAE AMS4915, SAE AMS4916, SAE AMS4917, SAE AMS4918, SAE AMS4919, SAE AMS4939, SAE AMS4940, SAE AMS4988, SAE AMS4989, SAE AMS4990 and shall provide the quality, properties and processing to meet its intended use.

5.1.4.3 Extrusions. All titanium extruded bars, rods, or special shaped sections shall be in accordance with MIL-T-81556 and shall meet the metallurgical and structural properties required to support reliability and durability requirements of the weapons system.

5.1.4.4 Heat treatment. Heat treatment of titanium shall be in accordance with SAE AMS-H-81200.

5.1.5 Beryllium. All beryllium and beryllium containing alloys shall be used in accordance with MIL-STD-1568. The use of beryllium shall be restricted to applications where its properties offer definite performance and cost advantages and in applications where its expected service life matches that of the surrounding structure. The capability to provide predictable and adequate service longevity shall be demonstrated using preproduction tests under simulated service loading conditions and environments. Load paths shall be oriented so that large stresses do not occur in the short transverse grain direction. The toxicity of beryllium dust and fumes is a critical problem and shall be considered during fabrication, assembly, and in service usage and maintenance of beryllium parts.

5.1.6 Other metals. Magnesium alloys shall not be used as specified in MIL-STD-1568. Nickel and copper base alloys, along with other commonly used metals, may be used if approved by the CEA. Where design trade studies show the desirability for the use of less common metals other than those discussed herein, the CEA's approval for use shall be obtained (see 6.5).

5.2 Nonmetallic materials. Nonmetallic materials shall be selected and used in compliance with the requirements contained in the following subparagraphs.

5.2.1 Composites. Composite materials are material systems made up of a reinforcing fiber and a matrix. 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, high stiffness fibers such as boron or carbon (graphite). Metal matrix composites are fiber, whisker, or particulate reinforced metals. Selection of materials and processes for composites shall consider all aspects of the intended application, such as: service environment, systems requirements, structural and functional requirements, serviceability and repairability, etc. Composite materials shall be evaluated in accordance with ASTM D4762, ASTM D3039/D3039M, or other relevant government or industry specifications as approved by the CEA.

5.2.1.1 Organic resins. The organic matrix (binder, resin, and matrix are interchangeable terms) of the conventional or advanced composite can be a thermoset or a thermoplastic polymer. A thermoset composite is processed to a product form by a chemical reaction known as cure. The curing reaction can be facilitated by heat and pressure, as in an autoclave cure, or by other means such as radio frequency, or radiation exposure. Typically, the cure temperature can be room temperature, 121-176 °C (250-350 °F) for epoxies, approximately 232 ºC (50 ºF) for bismaleimides, and 288-371 ºC (550-700 ºF) for polyimides, etc. A thermoplastic composite is processed to a product form by operations such as deformation forming or injection molding, conducted at elevated temperatures where viscous flow of the matrix is possible.

5.2.1.2 Conventional composites. Glass fiber, continuous or chopped, can be used to reinforce any number of various organic resins. The use of materials and processes for conventional composites shall be in accordance with SAE CMH-17-1, SAE CMH-17-3, NAVAIR 01-1A-21 and NAVAIR 01-1A-22 or equivalent as approved by the CEA.

5.2.1.3 Advanced composites. Advanced composites consist of an organic matrix reinforced by high modulus and high strength (compared to fiberglass) fibers. The fiber reinforcement takes the form of continuous unidirectional filaments (tape), woven fabric (cloth), chopped fibers, etc. The fiber materials are carbon (graphite), aromatic polyamide (aramid), etc. Guidance in the processing and production of advanced composite materials and structures 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, and in SAE CMH-17-1, SAE CMH-17-3, NAVAIR 01-1A-21, and NAVAIR 01-1A-22. SAE CHM-17-5 shall be used as guidance for the materials and processes of ceramic matrix composites.

5.2.1.4 Metal matrices. 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. SAE CHM-17-4 shall be used as guidance for the materials and processes of metal matrix composites.

5.2.1.5 Composite material property design allowables. In addition to the requirements in 4.7, the effects of variations in processing and resulting products upon the design allowables for conditions such as fiber (ply) misorientations, temperature and pressure variations, non-uniform chopped fiber distribution, thermoplastic morphology, etc. shall be evaluated. Some material property design allowables can be obtained from SAE CMH-17-2.

5.2.1.6 Material specifications for composites. General material specification requirements are specified in 4.5.1. In addition, raw material shelf or freezer life limits shall be specified, including requalification procedures prior to use, if needed. Storage and marking requirements shall also be specified. Material shall be labeled for storage with the date of freezer life expiration, date received, batch or lot number, name, specification or procurement document number, unique storage requirements, etc., or as specified in MIL-STD-129.

5.2.1.7 Sandwich assemblies. Honeycomb or foam core sandwich assemblies shall be designed and fabricated to preclude the accumulation and entrapment of water or other contaminants within the core structure. Post assembly edge sealing shall be used in addition to design techniques to preclude liquid entry. Perforated metallic honeycomb core shall not be used. Aluminum honeycomb core shall be in accordance with SAE AMS-C-7438 and shall be of the corrosion resistant type. Phosphoric acid anodized (PAA) aluminum core is preferred for sandwich assemblies at risk for damage or corrosion. Sandwich construction using plastic honeycomb core and facings shall be in accordance with MIL-S-9041 except Section 3.3 and Table I shall not apply. MIL-S-25392 shall apply for construction using foamed-in-place core and uniform plastic facings and SAE AMS-C-8073 shall apply for plastic and foam core materials. Design of structural sandwich assemblies shall be guided by SAE CMH-17-6. The design shall be validated by tests typical of the end-use environment. They shall include vibration and acoustic testing. Other core materials or designs, for which the above specifications do not apply, require approval of the CEA (see 6.7).

5.2.1.8 Joining and fastening. The effect of repeated removal and insertion of fasteners into holes in composite joints shall be evaluated. Components that are cured together (co-cured) shall be treated as bonded assemblies.

5.2.1.8.1 Thermal expansion. The effect of residual stresses, introduced by cool-down from some stress-free elevated temperature existing during cure, shall be evaluated in design. Particular attention shall be paid to thermal expansion mismatch in evaluation of any manufacturing process that employs multiple elevated temperature cure cycles. Any elevated temperature cure (including secondary bonding and post-curing operations) shall not result in degradation of bondline integrity, either for load transfer or sealing purposes. Aluminum fittings, etc., shall not be bonded in conjunction with graphite composites, unless demonstrated to be thermally compatible by an acceptable thermal stress analysis procedure.

5.2.1.8.2 Galvanic corrosion. Most metals in contact with graphite composites will corrode; therefore, conditions in which metals and graphite composites are in contact shall be avoided and treated as dissimilar metals in contact in accordance with the requirements of MIL-STD-889, MIL-STD-7179, and MIL-STD-1568.

5.2.1.9 Repairability. Information and guidance in the selection of composite repair materials and processes, identification of appropriate standardized composite repair methods, and engineering design of composite repairs can be found in NAVAIR 01-1A-21, NAVAIR 01-1A-22, AFWAL-TR-83-3092, or equivalent as approved by the CEA. T.O. 1-1-690 should be used to cover current shop best practices for executing the repairs.

5.2.2 Elastomeric materials.

5.2.2.1 General requirements. All elastomeric components shall be reversion resistant, hydrolytically stable, and possess adequate resistance to aging, operational environmental conditions, and fluid exposure for the intended system use.

5.2.2.1.1 Cured elastomers. Cured elastomers that are age sensitive shall be in accordance with SAE AS1933 and SAE ARP5316. All cured elastomeric materials shall have the cure date either on the item itself or on the packaging. A policy of first in, first out should be maintained. Cured elastomeric materials shall be protected from sunlight, fuel, oil, water, dust, and ozone (which is generated by electric arcs, fluorescent lamps, and similar electrical equipment). The storage temperature of cured elastomers should not exceed 38 ºC (100 ºF) and shall not exceed 55 ºC (125 ºF).

5.2.2.1.2 Non-cured elastomers. Materials that are procured in a non-cured state, such as sealants and potting compounds, shall be held in controlled temperature storage that does not exceed 26 ºC (80 ºF). Some specific materials may require storage at reduced temperatures and these materials shall be given the storage recommended by the manufacturer. Materials requiring reduced temperature storage shall be avoided because of the added burden on reduced temperature storage and the likelihood of reduced temperature storage not being maintained at all times. Adequate storage times shall be set up and maintained. Most polysulfide, polythioether, and polyurethane sealants can be stored for at least nine months at less than 26 ºC (80 ºF) and the materials remain suitable for use. A policy of first in, first out should be maintained. If materials become overage, tests approved by the CEA shall be conducted to ensure the material is adequate for use.

5.2.2.1.3 Silicone elastomers. Unless otherwise specified by the CEA, non-corrosive one-part silicone sealants, in accordance with MIL-A-46146, shall be used. Caution shall be exercised to prevent silicone cross with other operations/processes. The one-part silicone sealants liberate alcohol during cure and are preferred over the acetic acid liberating sealants. One-part silicone products that liberate acetic acid during cure shall not be specified to pot, seal, embed, encapsulate, or to be used in any manner on or near avionics, electronics, or electrical equipment. These include commercial adhesives/sealants and those in accordance with MIL-A-46106. When materials that liberate acetic acid are used, the following shall be required:

a. Good ventilation during cure.
b. Thickness limit of ¼ inch, maximum.
c. Glue line limit of 1 inch, maximum when used between nonporous surfaces.
d. Sufficient moisture to complete cure.
e. Full cure before enclosure (7 days, minimum).

5.2.2.2 O-rings. Dimensions and tolerances for all O-rings shall be in accordance with SAE AS568. O-rings conforming to Table IV shall be used.

5.2.2.3 Other molded parts, sheets, strips, and extruded shapes. These items shall be obtained from the specifications listed in Table V.

5.2.2.4 Potting compounds. The potting compounds in accordance with Table VI shall be used.

5.2.2.5 Integral fuel tank sealing. Integral fuel tanks shall be sealed using sealants conforming to SAE AMS-S-8802, SAE AMS3276, SAE AMS3277, SAE AMS 3278, SAE

AMS3279, SAE AMS3281, and SAE AMS-C-83318. When non-curing groove injection type sealing is used, the material shall be beaded comparably to MIL-S-85334 (or equivalent as approved by the CEA), SAE AMS3376, or SAE AMS3283. Adhesion promoter in accordance with SAE AMS3100 or as recommended by the sealant manufacturer shall be used prior to sealing over SAE AMS-C-27725 polyurethane coating. The use of an adhesion promoter is advantageous when applying curing type sealant over polyurethane coating conforming to SAE AMS-C-27725 in accordance with MIL-STD-7179. While the sealant will adequately adhere to a new polyurethane coating, as the coating becomes older, obtaining proper adhesion becomes more difficult. This is true not only with fuel aged coatings, but also with coatings that have only been subjected to air.

5.2.2.6 General sealing. MIL-STD-1568 shall be used for sealing other than fuel tanks.

5.2.3 Foamed plastics. Foamed plastics can absorb moisture when exposed to humidity or to water. Foams shall be hydrolytically stable. Polyester based polyurethane foams lack such stability and shall not be used in a moisture containing environment. The design of foam core sandwich or other constructions shall provide complete sealing against exposure to humidity and to fluids. The design shall be thoroughly tested to ensure adequate sealing and provide resistance to vibration and acoustic noise.

5.2.4 Flexible and semi-flexible materials for manned aircraft interiors. The provisions of FAR 25.853, including Amendments 25-59 and 25-61, and other Federal Aviation Regulations shall apply in the design and selection of aircraft cabin interiors. The primary purpose of FAA Amendment 25-61 is to ensure that aircraft cabin interior materials with large outer surface areas will not become involved rapidly and contribute to a fire when exposed to flames. Background information for the design and selection of materials for aircraft cabin interiors to minimize fires and emission of smoke and toxic fumes is found in JSSG-2010. Certain components are exempt from FAA Amendment 25-61 fire standards (e.g., internal structure of galleys and storage bins, lenses on signs and lights, window materials, door and window molding, seat trays, arm rests, etc.). Those exempt components shall pass the FAR 25.853 tests, including the Bunsen burner test, the flash resistance test, and the ASTM E162 radiant panel test. Any material that is used on material aircraft cabin interior design that has not been certified by the FAA testing requirements shall be self-extinguishing and meet the following requirements, when tested in accordance with FED-STD-191, Method 5903.

After flame time (seconds, maximum)

- Single for 5 specimens -2
- Single determination -5

After glow time (seconds, maximum)

- Average for 5 specimens -5
- Single determination -10

Char length (inches, maximum)

- Average for 5 specimens -3.5
- Single determination -4.5

For upholstery fabric, only self-extinguishing materials shall be used that meet the flame resistance and smoke generation requirements of the respective material types, as specified in SAE AMS3856. For carpeting, material used shall not meet a maximum average of 75, when tested in accordance with ASTM E162. Any cabin furnishings, upholstery fabrics, and carpeting materials used that contain wool shall be properly treated with fire retardants. Polyvinyl chloride (vinyl or vinyon), modified aramid (durette), and phosphorous-based fire retardant treated cotton shall be prohibited due to the toxic hazard level of the thermal decomposition products. Polyvinyl chloride-coated fabrics shall also be prohibited due to the toxic hazard level of the thermal decomposition products. Materials in fabric category for usage such as curtains, coated fabrics, insulation covers, outermost seat coverings, headliners, nonwoven, and thermal barriers shall be self-extinguishing, and if not certified to FAA testing requirements shall meet FED-STD-191 testing requirements stated herein.

5.2.4.1 Aircraft seats. Materials used for aircraft seats shall pass the following test(s): the outermost covering used to cover ejection seats shall be tested in accordance with FED-STD-191, Method 5903 (vertical burn test) and shall meet the after flame time, after glow time, and char length requirements specified in 5.2.4. Non-ejection crew and passenger seating shall pass the flame impingement test prescribed in FAR Part 25.853, Amendment 25-59. Fire blocking layers between the outermost seat upholstery and cushions (seat back and bottom) may be required to meet FAR Part 25.853 requirements. The outermost seat covering for all seats shall pass their respective flame retardancy test requirements before and after 10 dry cleanings as specified in FED-STD-191, Method 5509 or launderings as specified in FED-STD-191, Method 5518. Test samples shall be determined individually as well as the average value.

5.2.5 Lubricants and working fluids.

5.2.5.1 Lubricants. These materials include lubricating oils, greases, solid film lubricants, and anti-seize compounds. Graphite containing lubricants may be safely used in contact with corrosion resistant stainless steels, titanium, nickel alloys, and cobalt alloys, and similar corrosion resistant metals and alloys. Molybdenum disulfide based anti-seize compounds such as MIL-PRF-83483 shall be used but only up to 410 ºC (800 ºF). When polytetrafluoroethane (PTFE) and similar materials are used as a self-lubricating surface, such as on wing pivot fittings, bearing races, and other applications, the design shall be based on demonstrating wear life in the presence of fluids typically used on the system. This applies if fluids are considered to be likely in contact with such wear surfaces. Lubricants or anti-seize compounds containing graphite shall not be used, except for use on aircraft engine spark plugs and threaded fasteners and fittings where temperatures are expected to be above 410 ºC (800 ºF). Graphite containing lubricants may promote corrosion of aluminum, ferrous, magnesium, zinc, or cadmium alloys or platings, and thus shall not be used in contact with these metals. Solid film lubricants shall not be employed on the internal surfaces of hydraulic or fuel systems. Lubricants containing sulfur shall not be used in contact with gold or silver.

5.2.5.2 Working fluids. These materials include hydraulic fluids, coolants, and heat transfer fluids. The selection of fluids and lubricants should refer to MIL-HDBK-838 and MIL-HDBK-275.

5.2.6 Transparent materials. Transparent materials shall be selected and applied in accordance with AFSC DH 2-1, DN 3A1; and the optical requirements of AFSC DH 1-7, ASTM D1003, SAE CMH-17-2, or equivalent should be used for guidance in selecting materials and designing transparencies (windshields, canopies, etc.). As a general guide for the critical area of transparency, distortion criteria rate of change of deviation are as follows:

Optically Flat Units	1.0 minutes of arc per inch of windshield or window surface
Flat Units	2.5 minutes of arc per inch of windshield or window surface
Units having Curvature in One Plane	4.0 minutes of arc per inch of windshield or window surface
Compound Curved Units	5.0 minutes of arc per inch of windshield or window surface

Polycarbonate, in either monolithic or laminated construction, provides the highest degree of bird impact protection obtainable of any transparent material. However, both its interior and exterior surfaces must be protected against adverse chemical or abrasion environments. Protection can be accomplished by laminating a thin sheet of either as-cast acrylic or glass to the exterior polycarbonate surfaces by means of a compatible, non-plasticized interlayer material. Polyvinyl butyral (PVB) interlayer material shall not be used with polycarbonate. The plasticizer (butyl sebacate) shall not be used since it will, in time, migrate or permeate through such a coating. There are no impermeable barrier coatings that will prevent this attack. Extreme care must be exercised when drilling edge attachment holes into a polycarbonate transparency. Guidance for drilling holes is found in SAE CMH-17-2. If appropriate, hole drilling procedures are not used, the integrity of the transparency can be very seriously degraded. Crazes can easily be induced that will develop into cracks or upon bird impact and provide a site for crack propagation thus causing failure of the transparency.

5.2.7 Electrical insulation. Vinyl and polyvinylchloride as insulation on wiring or as sleeving shall not be used because of their well-known fungus nutrient characteristics and the dangers of outgassing during storage. These organics give off corrosive vapors that are active in attacking metals, plastics, elastomers, and insulation. Outgassing proceeds under normal room temperature conditions, but is accelerated by high temperature or low pressure, and is most serious in closed containers. Additionally, precaution shall be given to ethylene tetrafluoroethylene (XL-ETFE), as it is known to release fluorine gas. Satisfactory insulation includes polytetrafluorethylene, fluorinated ethylene propylene (FEP), Kel-F, polyimide (H-film), polyamide (nylon), polyurethane, polycarbonate, polyethylene, polyalkene, polyethylene terephthalate, polyolefin, polysulfone, and silicone sleeving in all grades. Precaution shall be given to polyimides in regard to moisture absorption and arcing. Where materials other than these are required, fungus resistant classes shall be specified and established by test in accordance with MIL-STD-810. Exercise caution in the use of PTFE covered silver plated copper wire because of possible corrosion at pin holes. Obtaining good adhesion when potting or encapsulating PTFE insulated wire is difficult. Coated wire, both PTFE and FEP, may “cold flow” when installed under stress, against sharp edges, and in sharp bend configurations resulting in shorting failures. Polyimide insulation is considered to be the best for elevated temperature wire. Wiring installation procedures as described in SAE AS50881 shall be used to ensure long term insulation performance.

5.2.8 Tape. Tapes shall be selected that are noncorrosive, do not outgas, do not absorb moisture nor support fungus. Tapes shall not be used in exterior areas without the approval of the CEA.

5.2.9 Hygroscopic materials. Non-wicking, non-hygroscopic gaskets shall be used to prevent moisture intrusion. Felt, leather, cork, or glycol impregnated gaskets shall be avoided as well as cotton core material in electrical cables. Asbestos shall not be used. The outer edges of laminated assemblies shall be sealed to prevent moisture intrusion.

5.2.10 Water displacing compounds. Water displacing compounds may be used to coat metal surfaces against moisture, fingerprints, and corrosion. On plated surfaces or electrical devices including leads, contacts, and terminal posts, the soft film types of such compounds have been found to be effective protection against corrosion at pores or pinholes in the protective plating, a defect frequently found with standard commercial items. The water displacing compounds shall be in accordance with applicable military specifications or non-government standards. Other corrosion preventive compounds shall be approved by the CEA.

5.2.11 Moisture and fungus resistance. Parts and equipment shall be designed so that the materials are not nutrients for fungi, except when used in permanent hermetically sealed assemblies and other accepted and qualified parts such as treated transformers. Other necessary fungi nutrient material applications shall require treatment by a method that will render the resulting exposed surface fungi resistant. The criteria for the determination of fungi and moisture resistance shall be in accordance with MIL-STD-810.

5.3 Processes. Processing specifications for forgings, castings, welding, inspections, etc., specified herein represent minimum standards of quality required for aerospace weapons systems. In most cases, part procurements and manufacturing processes are controlled by manufacturer specifications. The use of these specifications is acceptable provided the minimum standard of quality and testing required by the appropriate military specification is achieved. The overall objective is to establish processes that provide repeatable quality and properties of materials that are assumed in the design. This is a major element of the damage control plan and shall be in accordance with MIL-STD-1530, MIL-STD-1798, MIL-STD-3024, and MIL-HDBK-1783.

5.3.1 Forging practices. All structural forgings shall comply with the following requirements.

5.3.1.1 Forging design. Forgings shall be produced in accordance with SAE AMS-F-7190 for steel: SAE AMS-A-22771 or SAE AMS-QQ-A-367 for aluminum: and SAE AMS4921, SAE AMS4970, SAE AMS6900, SAE AMS6901, SAE AMS6905, SAE AMS6906, SAE AMS6907,

SAE AMS6910, SAE AMS6915, SAE AMS6920, SAE AMS6921, SAE AMS6925, SAE AMS6926, SAE AMS6930, SAE AMS6931, SAE AMS6932, SAE AMS6935, SAE AMS6936, SAE AMS6940, or equivalent as approved by the CEA for titanium forging; or approved industry specifications or standards for alloys not covered by the above specifications. The forging dimensional design shall consider forging allowances such as parting line with regard to final machining such that short transverse grains (end grains) are minimized at the surface of the part. After the forging techniques (including degree of working) are established, the first production forgings shall be sectioned and etched to show the grain flow pattern and to determine mechanical properties at critical design points. This sectioning shall be repeated after any major change in the forging technique. The internal grain flow shall be such that the principal stresses are in the direction of flow as limited by forging techniques. The pattern shall be free from re-entrant or sharply folded flow lines.

5.3.1.2 Forging surfaces. Machined surfaces of structural forgings in fatigue critical regions or in regions of major attachment shall be peened or placed in compression by other industry accepted practices. Those areas of forgings requiring lapped, honed, or polished surface finishes for functional purposes shall be peened prior to the surface finish operations. Surface finish, clean up of peened surfaces, shall not exceed 0.0076 cm (0.003 inch) of material removal for aluminum and 0.0038 cm (0.0015 inch) for steels.

5.3.2 Castings. Castings shall be classified and inspected in accordance with SAE AMS2175. Structural castings shall be in accordance with SAE AMS-A-21180, SAE AMS5343, or equivalent as specified by the CEA. Design criteria shall be in accordance with JSSG 2006 and JSSG 2007.

5.3.3 Joining. This section does not cover weld-like processes used to produce significant portions of parts such as additive manufacturing, 3D printing, or freeform manufacturing. For those processes, refer to 5.4. Joining as applied herein is used to join two segments or major sections of parts.

5.3.3.1 Welding/joining. These processes are defined in AWS A3.0. All production welding/brazing/soldering made in accordance with this specification shall be accomplished to the requirements detailed in an approved welding procedure specification (WPS) that is supported by an approved procedure qualification record (PQR). Soldering for electrical applications is covered in 5.3.6. Welder and welder operator qualification shall conform to AWS D17.1, or equivalent approved by the CEA. For the purposes of this military standard the term weldable or joinable is a measure of the joint's ability to meet service requirements. The specific quality requirements required to meet in service environment shall be detailed in the approved WPS, or as detailed in AWS D17.1. For flight hardware, the appropriate PQR (including quality requirements, NDI methods, and properties) shall be approved by the CEA. Pre- and post-weld treatments (thermal, chemical, mechanical) used to control metallurgical response, residual stresses, and or distortion shall be detailed in the applicable WPS. Conformance to AWS D17.1 is required as applicable. For non-flight hardware (such as ground support equipment), welding shall be applied in accordance with the appropriate specification for that material/class, as determined by the requirements in 5.3.3.2. Solid-state welding (IW, FW, LFW, SFW, DW, etc.) shall be made in accordance with an approved PQR/WPS. Post-weld inspections, including acceptance criteria, shall be clearly identified. Pre-weld fit-up, surface condition, alignment, application of diffusion modifiers, and tooling operation shall be clearly identified in the appropriate WPS. Any deviations from the qualified WPS shall be approved by the CEA. When using isothermal brazing, the thermal cycles to condition the material after brazing shall be clearly identified and characterized in the brazing/soldering qualification. The effect of melting point depressants (MPD) on the base metal properties shall be a factor considered by the CEA in the approval process.

5.3.3.2 Welding on ground support equipment. For ground support equipment (GSE), welds shall be designed within the requirements of the appropriate GSE weld specification, as determined by the CEA. Structural welds shall be defined as, but not limited to, those welds that make up a framework or load bearing structure, whose failure would have a significant detriment to mission efficacy or result in injury to personnel. Any components that are welded to NAVSEA equipment shall reference 5.3.3.2.2. All other welds that fall outside of the categories in 5.3.3.2.1, 5.3.3.2.2, and 5.3.3.2.3, shall be in accordance with 5.3.3.2.4. All welds shall be made utilizing a WPS, supported with a PQR. The requirements for WPS/PQR generation shall be established by the appropriate welding specification, selected in accordance with the guidelines below.

5.3.3.2.1 Critical welds. For support equipment Critical Safety Items or Critical Application Items (CSI/CAI), welds shall be in accordance with NAVSEA S9074-AR-GIB-010/278.

5.3.3.2.2 Welding to NAVSEA equipment. For equipment welded to NAVSEA hardware, welds shall be in accordance with NAVSEA S9074-AR-GIB-010/278, NAVSEA T9074-AD-GIB-010/1688, and MIL-STD-1689 as appropriate and defined by the CEA.

5.3.3.2.3 Structural welds. Structural, non-critical welds shall be in accordance with AWS D1.1 for steel, AWS D1.2 for aluminum and AWS D1.6 for stainless steel.

5.3.3.2.4 Other welds. Non-structural and non-critical welds shall be in accordance with AWS D17.1.

5.3.3.3 Welding /joining repair. Weld repair is limited to the repair of welding of defects in a production fusion weld revealed by inspection. The repair shall be accomplished to the approved WPS. Repair of full penetration high energy density (EB, PA, LB) weld repairs (10^{10}–10^{13} W/m2) will be limited to two passes, unless otherwise authorized by the CEA. If rough or final machining has occurred, the CEA shall specify the locations where current can be introduced into the component (ground attach locations) and appropriate post repair inspection to ensure no damage due to arcing. The jigs and fixtures used for the original welding and post weld treatments shall be used for repair welding, unless otherwise authorized by the CEA. Weld repair does not include the correction of dimensional deficiencies by weld build-up or “buttering,” except with design approval. Weld repair of castings is to be accomplished to a qualified repair process including joint configurations, welding procedures and post weld inspections. Brazing and soldering repair shall use approved procedures and shall be limited to three attempts on critical components. The effect of repair operations on brazed/solder joints shall consider the loss of wall thickness (erosion), dewetting, and alloying effects on braze/solder performance.

5.3.4 Brazing. Brazing shall be in accordance with AWS C3.4M/C3.4, AWS C3.5M/C3.5, AWS C3.6M/C3.6 and AWS C3.7M/C3.7. Subsequent fusion welding operations or other high temperature operations in the brazed area shall be avoided, unless it can be shown that the brazed joint will not be damaged. Tension loaded joints require the approval of the CEA. The number of re-brazing operations or number of braze cycles for each assembly shall not be greater than 3, without the approval of the CEA. Metals not covered by the AWS specifications herein shall not be brazed without prior approval of the brazing process by the CEA. Isothermal brazing, which uses a melting point depressant (MPD) in the braze alloy, will consider the effect of the MPD on the base metal properties. Post braze thermal operations to modify the effect of the MPD on base metal properties shall be approved by the CEA.

5.3.5 Cold spray metallization. Cold spray metallized coatings shall be in accordance with MIL-STD-3021 and MIL-DTL-32495 when applied for dimensional restoration or as a galvanic protective coating. Cold spray metallization applies to any thermal spray process that utilizes a high-velocity jet of solid phase particles propelled via a pressurized carrier gas resulting in mechanical bonding with the substrate through adiabatic shear and a coating with porosity less than one percent. Thermal inputs to the cold spray metallization process shall be limited to the heated carrier gas, and shall not include an open flame, plasma arc, or other means to cause a phase change in the powder during flight. Surfaces shall be cleaned in accordance with 4.2.2.1 of MIL-STD-3021 and damage requiring dimensional restoration shall be prepared by blending to a repair-specific depth ratio as determined by the CEA. The surface preparation, powder handing, and cold spray process variables shall be set for each application or family of applications to ensure that cold spray operations are repeatable, consistent, and documented in accordance with MIL-STD-3021. The use of cold spray metallization on structural applications or any safety, flight, or foreign object damage (FOD) critical applications shall require approval by the CEA. The powdered raw materials used by cold spray (whether metallic, polymer, ceramic, or intermetallic) are a critical process variable, and shall be monitored or controlled in accordance with the standards defined by the CEA. Relevant powder characteristics include, but are not limited to chemical composition, microstructure, size distribution, shape distribution, pretreatment, surface morphology, flow properties, packing density, manufacturing process, heat treatment, and oxygen/moisture content. Sampling and measurement procedures for each critical characteristic shall be determined by the CEA. Depending on the requirements of the specific cold spray application, control limits on each characteristic shall be determined by the CEA. Traceability of powder characteristics shall be maintained and require approval of the CEA.

5.3.6 Soldering. For electrical, the soldering IPC J-STD-001, Class 3 requirements shall be used.

5.3.7 Adhesive bonding. For adhesive bonding, MIL-HDBK-83377 should be used.

5.3.8 Material inspection. Unless authorized by the CEA, inspections shall be capable of detecting critical flaws and anomalies to a 90 percent Probability Of Detection (POD) and a 95 percent confidence limit using production inspection hardware and personnel. When developing inspections for critical structure, in-service capability shall be considered. MIL-HDBK-6870 provides inspection guidance.

5.4 Metal additive manufacturing/3D printing. Metal additive manufacturing (AM) is also referred to as metal 3D printing. This refers to a computer-based process that is used to create a three dimensional object from raw metallic wire or powder stock that is thermally fused via laser or by a form of welding using such technology as directed laser powder fed, electron beam wire fed, and direct metal laser sintering powder bed. Metal AM parts and materials have different material properties from equivalent wrought, sheet, plate, or cast parts and materials. To be able to use these AM materials, a standard approach needs to be taken to establish material properties that can be used to design and certify components. The process for generation of material properties for AM metals shall be in accordance with DOT/FAA/AR-MMPDS. AM material property data will be documented using standard methods in accordance with SAE R422 or DOT/FAA/AR-MMPDS. The process materials used in the systems shall be standardized to ensure repeatable quality. For example, the standardization of powders in a powder bed system is critical to repeatability. Powder characteristics, such as, powder size distribution, powder shape, manufacturing route (gas atomization versus plasma rotating electrode process), and powder composition, can have an effect on the resulting material properties of AM components. Post treatment of the metal AM part, such as heat treatment, hot isostatic pressing (HIP), and surface finishing shall be considered for the specific application and material system to enhance or tailor the material properties. Metal AM material shall have the designation AD assigned to the material identifier. For example, Ti-6Al-4V, if additively produced, shall be designated Ti-6Al-4V AD. A procedure qualification record (PQR) and procedure specification (PS) shall be generated and approved by the CEA for all metal AM materials/parts.

5.4.1 Metal Additive Processes (MAP). A development plan shall be established for each component and metal additive process (MAP) vendor/process. This plan shall include the number of MAP parts/samples required to qualify the process/component for production and the steps to be taken by the MAP vendor to qualify the production processes in order to meet the customer requirements. It shall be built on the best practices for MAP parts using welding and casting experience, and shall include defect size and shall be derived from distribution data and POD methods of all defect types. Development and verification of mechanical properties such as yield strength, ultimate strength, and fatigue crack growth, etc. and physical properties such as corrosion shall be included in the development plan. The verification data shall consider data obtained from production equivalent configuration(s) and various build sequences, source materials (powder, wire, foil) heats or batches and tooling considerations that have undergone the entire manufacturing sequence, to include all deposit, inspection, cleaning and thermal treatments. The process must be captured in a procedure specification. It is imperative that the CEA identify early in the feasibility discussions what the requirements are for both the first article inspection and the expectations for the first part to be incorporated on an aircraft for full-scale evaluation.

The following considerations are typically applicable in all MAP parts procurements:

- Materials/Process specifications
- Mechanical property development and verification
  - -Build sequence and all steps to produce the deposits
  - -Manage distortion and residual stress

-Post deposit processing to achieve microstructural uniformity and properties

Repair/rework procedures

-Concurrent engineering

-Inspection criteria and methods

-POD methodology

5.4.1.1 Material/process specifications. Material and process specifications need to be in place at the onset of any MAP development activity, including the appropriate Non-Government, Military or CEA standard. Part processing typically evolves as the initial development phase of the MAP part development effort progresses. It is important that the CEA provide the MAP vendor with a clear understanding of the part requirements and expectations as they relate to first article inspection and the substantiation of the specified component attributes. Specifications shall address both MA processing, including all pre-deposit and post-deposit processes and material including base metals and deposit materials.

5.4.1.2 Mechanical property development and verification. Mechanical property databases can be obtained from various sources. However, it is essential for the MAP vendor and CEA to develop a detailed plan to verify that any existing database is statistically representative of the population of parts to be produced. Before this database can be considered for use it must be verified to be applicable through destructive and analytical testing prior to the beginning of development. This plan shall include mechanical property data from production equivalent MAP parts/specimens. If the mechanical properties do not fit the existing database the plan should have contingencies to investigate the cause and determine corrective actions.

5.4.1.3 In-process repair procedures. In-process repair is commonly used in the production of MAP parts. However, it is important for the MAP vendor and CEA, early in the MAP part development phase, to jointly identify and agree upon the procedures to be used for in-process repair in order to minimize the potential for defects and loss of properties. If there are critical locations on any part under consideration, that cannot be weld or MAP repaired, the CEA must identify these areas to the MAP vendor. The CEA and MAP vendor must also agree on the inspection methodology to be used to verify that discontinuities, defined as defects, are detected and sized appropriately. A defect is any discontinuity that renders the part unserviceable.

5.4.1.4 Concurrent engineering. Concurrent engineering is the combination of part design and part producibility. The CEA must communicate with the MAP vendor early enough in the process to allow for the optimization of the design for producibility, as well as risk reduction. The risks associated with a MAP part will depend on a number of factors including how similar it is to previous MAP parts produced by the supplier, the alloy being considered, the flight criticality of the MAP part, the inspection capability of the supplier and inspectability of the part at various stages of the manufacturing process and the allowable margin in mechanical properties.

5.4.1.5 Inspection criteria and methods. Fracture critical (FC) requirements impose a different set of rules on the design and fabrication of a component. FC MAP parts shall be zoned for inspection and durability and damage tolerance criteria. Process controls must be in place to ensure the CEA that defects of a given size can be detected, and that they can be eliminated once they are detected. In addition, the designer needs to know the maximum size of defect that cannot be detected at various locations within the MAP component in order to identify the potential knockdown in static strength and service life properties associated with the existence of that potential defect. The MAP vendor must have the defect size distribution database for all defect types to allow the designer to conduct cost trade studies associated with various design approaches such as fail-safe, slow crack growth inspectable, or slow crack growth non-inspectable. The MAP vendor must be in a position to define the sensitivity limits for volumetric inspection processes, excluding visual and dimensional inspections. This requires a set of standards and POD data for a given volumetric inspection process. The effect of repair on the quality, properties and dimensional stability must be determined via testing to inform risk assessments during materials review board actions.

5.4.1.6 POD methodology. POD analysis is used to determine the size of a given flaw that can be reliably found using a particular NDI technique. POD results shall provide a minimum of 90 percent probability of detection at a 95 percent confidence limit. A POD study should use a set of inspection samples containing representative defects that are sized to define the limits of inspection capability. The end goal is to develop a qualified production process that minimizes the inspection and process burdens required for a given set of MAP generated volumes.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This design standard provides design criteria that provide timely and comprehensive consideration during systems design of the limitation of materials and processes and of the lessons learned over the years from military-unique operational systems worldwide. The standard employs military-unique design criteria and considerations that exceed commercial design practices in order to meet the military rigors and environment that the operational systems encounter. The use of this document will result in more durable systems in operational service. It should be used in conjunction with MIL-STD-1568 in selection of materials and processes that will meet the requirements of the system being designed in accordance with MIL-STD-1530, MIL-STD-1798, MIL-STD-3024, and MIL-HDBK-1783 or equivalent integrity program documents.

6.2 Acquisition requirements. Acquisition documents should specify the title, number, and date of this standard.

a. Title, number, and date of this standard.

b. If required, technical proposal (see 4.4 and 6.4)

6.3 Associated Data Item Descriptions (DIDs). This standard has been assigned an Acquisition Management Systems Control number authorizing it as the source document for the following DIDs. When it is necessary to obtain the data, the applicable DID must be listed on the Contract Data Requirements List (DD Form 1423).

Paragraph #	DID Title	Applicable DID
4.5, 4.5.1, 4.5.2	Program-Unique Material or Process Specification	DI-MFFP-82119

The above DID was current as of the date of this standard. The ASSIST database should be researched at (http://quicksearch.dla.mil) to ensure that only current and approved DIDs are cited on the DD Form 1423.

6.4 Technical proposal. Technical proposal information must be provided to the CEA for review and approval (see 4.4 and 6.2).

6.5 Less common metals. Trade studies, together with the design properties, probability of detection studies, proposed processing, inspection processes, finishing, and manufacturing must be provided to the CEA for review and approval.

6.6 Less common nonmetallic materials. Background data must be provided to the CEA for review and approval.

6.7 Other materials. Approval of other materials requires that a test program be developed to substantiate the structural and environmental suitability for the system's intended use.

6.8 Subject term (key word) listing.

Aircraft
Composites
Lessons learned
Metals
Properties
Nonmetals

6.9 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

TABLE I. Commonly restricted structural materials.

Metal	Alloy	Temper	Mill products
Magnesium	All	All	All
Additively Manufactured Metals	All	All	All
Aluminum	7178	All	All
	7079	All	All
	2XXX	-T3/4	All
	2014	All	All except wheel forgings
	2020	All	All
	2024	-T8XX	Forgings
	7XXX	-T6XX	Extrusion over 0.250 inch thick and all bar, plate, forgings, and sheet (AF, Army)
	7XXX	-T6XX	All (Navy)
	7XXX	Overaged 1/	All
	Die Cast	All	All
	4340	All	All except for constant diameter pins and shafts
	4330M	All	All
	H-11	All	All
	4130	Above 180 ksi	All
	4140	Above 180 ksi	All
	D6AC	All ksi	All
	300M	All	All (Navy)
Corrosion Resistant Steel	431	All	All
	19-9DL, 9-9 DX	All	All
	17-4PH	<1025°F	All
	17-7PH	<1025°F	All
	Custom 445	<1025°F	All
	Custom 450	<1000°F	All
	Custom 455	<1000°F	All
	Maraging Steel	<1000°F	All
	Maraging steel, annealed	All	All
	15-5PH	<1025°F	All
	PH 13-8 Mo	<1025°F	All
	400 Series	150-180ksi	All
	PH CRES Cond A	All	All
	303, 303S, 303SE	All	All

1/ Shall be equal to or exceed 25 ksi stress corrosion cracking threshold resistance in short transverse direction in order to be used in aircraft structure.

TABLE II. Recommended minimum thickness of materials for structural applications.

Material	Thickness	
	inch	cm
Corrosion resistant steel (non-precipitation hardened)	0.008	0.020
Aluminum alloys located in non-corrosion prone environments	0.016	0.041
Aluminum alloys located in corrosion prone environments	0.025	0.064
Titanium	0.016	0.041
Precipitation hardened nickel based alloys	0.015	0.038
Metal tubing for wing ribs, central surface ribs, and trailing edge structures	0.035	0.089
All other structural metal tubing	0.035	0.089
Hydraulic tubing - aluminum	0.035	0.089
Hydraulic tubing - stainless steel	0.020	0.051
Hydraulic tubing - titanium	0.020	0.051
Graphite/epoxy and boron/epoxy skins, exterior	0.020	0.051
Graphite/epoxy and boron/epoxy skins, interior	0.020	0.051

TABLE III. Minimum reduction of area (steels).

Material	Strength 2/ min. UTS ksi	Strength 2/ min. UTS MPa	Cross-sectional area 3/ of billet from which specimens are taken	Reduction of area (percent) minimum value single test
4330 VAR 1/				
Longitudinal	220	(1517)	To and including 1452 sq cm (225 sq in)	35
Transverse	220	(1517)	To and including 1452 sq cm (225 sq in)	25
4340 VAR				
Longitudinal	260	(1793)	To and including 1452 sq cm (225 sq in)	25
Transverse	260	(1793)	To and including 1452 sq cm (225 sq in)	15
300M (VAR)				
Longitudinal	280	(1931)	To and including 1452 sq cm (225 sq in)	25
Transverse	280	(1931)	To and including 1452 sq cm (225 sq in)	15
9N1-4Co VAR				
Longitudinal (0.30 Carbon)	220	(1517)	All sizes	30
Longitudinal (0.20 Carbon)	190	(1310)	All sizes	40
PH13-8Mo				
Longitudinal	205	(1413)	All sizes	50
Transverse				40
17-4PH				
Longitudinal	190	(1310)	All sizes	50
Transverse				40

1/ VAR - Vacuum arc remelted material.
2/ A range of 20 ksi is normal, however, material meeting ductility and other specification requirements but exceeding the 20 ksi provision shall not be subject to rejection.
3/ For cross-sectional areas larger than the upper limits, the properties shall be approved by the CEA.

TABLE IV. O-rings.

System	Materials Specification	Applicable Drawing
Fuel	SAE AMS-P-5315 (Buna N)	SAE AS29512, SAE AS29513
	MIL-DTL-25988 (Fluorosilicone)	MIL-R-25988/1, /2, /3, & /4
Lubrication	MIL-DTL-25988 (Fluorosilicone)	MIL-R-25988/1, /2, /3, & /4
	SAE AMS7276 (Fluorocarbon) SAE AMS7259 (Fluorocarbon) SAE AMS3216 (Fluorocarbon) SAE AMS3218 (Fluorocarbon)	SAE AS3208, SAE AS3209 SAE AS3581
	SAE AMS-R-7362 (Buna N,	SAE AS29561
Hydraulic	SAE AMS-P-83461 (Buna N)	SAE AS83461/1, SAE AS83461/2
	MIL-P-25732 (Buna N)	SAE AS28775
	SAE AMS-P-5510 (Buna N)	SAE AS28778

TABLE V. Other molded parts, sheets, strips, and extruded shapes.

Specification	Material
MIL-PRF-6855	Buna N, Neoprene, and Buna S
SAE AMS-R-7362	Buna N
MIL-DTL-25988	Fluorosilicone
SAE AMS7276 SAE AMS7259 SAE AMS3216 SAE AMS3218	Fluorocarbon elastomer Fluorocarbon elastomer Fluorocarbon elastomer Fluorocarbon elastomer
SAE AMS-R-83285	Ethylene-propylene
MIL-DTL-83397	Polyurethane
SAE AMS3384 SAE AMS7287	Low Temp Fluorocarbon elastomer High Temp Fluorocarbon elastomer
A-A-59588	Silicone

TABLE VI. Potting compounds. 1/

Specification	**Material**
MIL-PRF-8516	Polysulfide
A-A-59877	Epoxy
MIL-PRF-23586	Silicone
MIL-M-24041	Polyurethane
SAE AS81550	Silicone

1/ Materials other than those meeting the above specifications shall only be used if approved by the CEA.

CONCLUDING MATERIAL

Custodians:
Army - MI
Navy - AS
Air Force - 20

Preparing activity:
Navy-AS
Project MFFP-2018-003

Review activities:
Army - AR, AV, MR
Navy - CH, EC, MC, SA
Air Force - 11

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil.