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AERONAUTICAL DESIGN STANDARD HANDBOOK

AIR VEHICLE MATERIALS AND PROCESSES

UNITED STATES ARMY AVIATION AND TROOP COMMAND

ST.LOUIS, MISSOURI

AVIATION RESEARCH AND DEVELOPMENT CENTER

DIRECTORATE FOR ENGINEERING

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DIRECTORATE FOR ENGINEERING

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FOREWORD

1. This Army Aeronautical Design Standard handbook is approved for use by the United States Army Aviation and Troop Command and is available for public release; distribution unlimited.

2. This handbook combines and updates the contents of the former ADS-13 and ADS-35. Requirements from those documents have been revised to become guidelines. These guidelines are based on lessons learned in the effective use and processing of metallic, nonmetallic, and composite materials for Army aircraft applications.

3. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

4. Any beneficial comments (recommendations, corrections, additions, or deletions) which may be of use in improving this document should be addressed to: Commander, US Army Aviation and Troop Command, ATTN: AMSAT-R-E, 4300 Goodfellow Boulevard, St. Louis, Missouri 63 1204798.

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CHAPTER 1

SCOPE

1.1 Scope. This ADS handbook embodies the general guidelines of the Army Aviation and Troop Command (ATCOM) for the materials and processes utilized in the design and construction of Army aircraft. It is for guidance only and cannot be cited as a requirement. If it is so cited, the contractor does not have to comply.

CHAPTER 2

APPLICABLE DOCUMENTS

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

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the latest issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

FEDERAL SPECIFICATIONS

QQ-P-35	Passivation Treatments for Corrosion-Resistant Steel
O-A-5 1	Acetone, Technical
TT-N-95	Naptha; Aliphatic
TT-N-97	Naptha; Aromatic
O-M-232	Methanol (Methyl Alcohol)
TT-T-548	Toluene, Technical
P-D-680	Dry Cleaning and Degreasing Solvent
TT-I-73 5	Isopropyl Alcohol
TT-S-735	Standard Test Fluids, Hydrocarbon

0-E-760	Ethyl Alcohol (Ethanol); Denatured Alcohol; Proprietary Solvents and Special Industrial Solvents
0-E-708	Ethylene Glycol Monomethyl Ether, Technical
BB-F-1421	Fluorocarbon Refrigerants
O-C-1889	Cleaning Compound, Solvent
A-A-58044	N-methylpyrrolidone

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-M-3 17 1	Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on
MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems
MIL-B-5087	Bonding, Electrical, and Lightning Protection, for Aerospace Systems
MIL-G-5485	Glass, Laminated, Flat, Bullet-Resistant
MIL-C-554 1	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance
MIL-T-5624	Turbine Fuel. Aviation. Grades JP-4. JP-5, and JP-5/JP-8 ST
MIL-E-605 1	Electromagnetic Compatibility Requirements, Systems

MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-W-6729	Watertightness of Aircraft, General Specification for
MIL-I-6870	Inspection Program Requirements, Nondestructive for Aircraft and Missile Materials and Parts
ML-H-6875	Heat Treatment of Steel, Process for
MIL-E-7125	Ethylene Glycol Monoethyl Ether Acetate, Technical
MIL-F-7 179	Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems
MIL-L-7808	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-A-8243	Anti-Icing and Deicing-Defrosting Fluids
MIL-S-85 16	Sealing Compound, Polysulfide Rubber, Electric Connectors and Electric Systems, Chemically Cured
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-S-8784	Sealing Compound, Low Adhesion, For Removable Panels and Fuel Tank Inspection Plates
MIL-S-8802	Sealing Compound, Temperature-Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High-Adhesion

MIL-C-8837	Coating, Cadmium (Vacuum Deposited)
MIL-A-8866	Airplane Strength and Rigidity Reliability Requirements, Repeated Loads, Fatigue and Damage Tolerance
MIL-A-8867	Airplane Strength and Rigidity Ground Tests
MIL-A-8868	Airplane Strength and Rigidity Data and Reports
MIL-P-9400	Plastic Laminate and Sandwich Construction Parts and Assembly, Aircraft Structural, Process Specification Requirements
MIL-P- 11268	Parts, Materials and Processes Used in Electronic Equipment
MIL-S- 13 165	Shot Peening of Metal Parts
MIL-D- 1679 1	Detergents, General Purpose (Liquid, Nonionic)
MIL-T-19588	Toluene-Methyl Isobutyl Ketone Mixture
MIL-A-2 1180	Aluminum-Alloy Castings, High Strength
MIL-C-22750	Coating, Epoxy, High-Solids
MIL-P-23377	Primer Coatings: Epoxy, High-Solids
MIL-S-23586	Sealing Compound, Electrical, Silicone Rubber, Accelerator Required
MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Number 0- 156

M-IL-P-25690	Plastic, Sheets and Formed Parts, Modified Acrylic Base, Monolithic, Crack Propagation Resistant
MIL-G-25871	Glass, Laminated, Aircraft Glazing
MIL-P-27418	Plating, Soft Nickel (Electrodeposited, Sulfamate Bath)
MIL-S-38249	Sealing Compound, Firewall
MIL-C-38736	Cleaning Compound, Solvent Mixtures
MIL-C-43616	Cleaning Compounds, Aircraft Surface
MIL-M-45202	Magnesium Alloys, Anodic Treatment of
MIL-A-46146	Adhesives-Sealants, Silicone, RTV, Noncorrosive (For Use With Sensitive Metals and Equipment)
MIL-C-46168	Coating, Aliphatic Polyurethane, Chemical Agent Resistant
MIL-E-51454	Ethyl Alcohol (Ethanol)
MIL-P-53022	Primer, Epoxy Coating, Corrosion Inhibiting, Lead and Chromate Free
MIL-P-53030	Primer Coating, Epoxy, Water Reducible, Lead and Chromate Free
MIL-C-53039	Coating, Aliphatic Polyurethane, Single Component. Chemical Agent Resistant
MIL-C-53072	Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection

MIL-C-81302	Cleaning Compound, Solvent, Trichlorotrifluoroethane
MIL-G-81322	Grease, Aircraft, General Purpose, Wide Temperature Range
MIL-T-81533	Trichloroethane, 1,1,1 (Methyl Chloroform) Inhibited, Vapor Degreasing
MIL-I-81550	Insulating Compound, Electrical, Embedding, Reversion Resistant Silicone
MIL-S-81733	Sealing and Coating Compound, Corrosion Inhibitive
MIL-T-81772	Thinner, Aircraft Coating
MIL-T-83133	Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8) and NATO F-35
MIL-H-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537
MIL-P-83310	Plastic Sheet, Polycarbonate, Transparent
MIL-A-83377	Adhesive Bonding (Structural) For Aerospace and Other Systems, Requirements for
MIL-D-83488	Coating, Aluminum, Ion Vapor Deposited
MIL-C-83982	Compound, Sealing, Fluid Resistant
MIL-C-85570	Cleaning Compound, Aircraft, Exterior
MIL-P-85582	Primer Coatings: Epoxy, Waterborne

MIL-C-87937	Cleaning Compound, Aerospace Equipment

FEDERAL STANDARDS

FED-STD-376	Preferred Metric Units for General Use by the Federal Government

DEPARTMENT OF DEFENSE STANDARDS

MIL -STD-2 10	Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment
MIL-STD-46 1	Control of Electromagnetic Interference Emissions and Susceptibility, Requirements for the
MIL-STD-462	Measurement of Electromagnetic Interference Characteristics, Test Method Standard for
MIL-STD-8 10	Environmental Test Methods and Engineering Guidelines
MIL-STD-838	Lubrication of Military Equipment
MIL-STD-889	Dissimilar Metals
MIL-STD- 1220	Alcohols and Amines, Technical Grade
MIL-STD- 1500	Cadmium-Titanium Plating, Low Embrittlement, Electrodeposition
MIL-STD-1530	Aircraft Structural Integrity Program, Airplane Requirements
MIL-STD- 1587	Materials and Process Requirements for Air Force Weapon Systems

MIL-STD-1795	Lightning Protection of Aerospace Vehicles and Hardware
MIL-STD-1944	Polymer Matrix Composites

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Polymer Matrix Composites
MIL-HDBK-139	Plastic, Processing of
MIL-HDBK-149	Rubber
MIL-HDBK-337	Adhesive Bonded Aerospace Structure Repair
MIL-HDBK-454	Electronic Equipment, General Guidelines for
MIL-HDBK-691	Adhesive Bonding
MIL-HDBK-700	Plastics
MIL-HDBK-725	Adhesives: A Guide to Their Properties and Uses as Described by Federal and Military Specifications
MIL-HDBK-754	Plastic Matrix Composites with Continuous Fiber Reinforcement
MIL-HDBK-755	Plastic Material Properties for Engineering Design
MIL-HDBK-1250	Corrosion Prevention and Deterioration Control in Electronic Components and Assemblies

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.

ARMY AERONAUTICAL DESIGN STANDARDS

ADS-1 1	Survivability Program, Rotary Wing
ADS-27	Requirements for Rotorcraft Vibration Specifications, Modeling, and Testing
ADS-5 l-HDBK	Rotorcraft and Aircraft Qualification (RAQ) Handbook

ARMY MATERIEL COMMAND PAMPHLETS

AMCP 706-202	Engineering Design Handbook Helicopter Engineering, Part Two, Detail Design

ARMY REGULATIONS

AR 70-38	Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions
AR 70-71	Nuclear, Biological, and Chemical (NBC) Contamination Survivability of Army Materiel
AR 385-l 1	Ionizing Radiation Protection (Licensing, Control, Transportation, Disposal, and Radiation Safety)
AR 700-64	Radioactive Commodities in the DoD Supply Systems

ARMY TECHNICAL MANUALS

TM 1-1500-343-23	Avionic Cleaning and Corrosion Prevention/Control
TM 1-1500-344-23	Aircraft Weapons Systems Cleaning and Corrosion Control
TM 55-1500-345-23	Painting and Marking of Army Aircraft.

PUBLICATIONS

AFGS-87221	Aircraft Structures, General Specification for AFWAL Advanced Composite Repair Guide
AFWAL-TR-88-4217	Development of Engineering Data on Aerospace Materials
AMMRC TR 78-30	In-Plane Shear Test for Composite Materials
AR-56	Structural Design Requirements (Helicopters)
	DOD/NASA Advanced Composites Design Guide
	DOD/NASA Structural Composites Fabrication Guide
FAA Advisory Circular 20-107A	Composite Aircraft Structure
FAA Advisory Circular 21-26	Quality Control for the Manufacture of Composite Structures
FAR Part 25	Airworthiness Standards: Transport Category Airplanes

NADC-86 132-60 NADC-87042-60	Certification Testing Methodology for Composite Structures
NASA RP 1092	Standard Tests for Toughened Resin Composites
NASA RP 1142	NASA/Aircraft Industry Standard Specification for Graphite Fiber/Toughened Thermoset Resin Composite Material
SD-24	General Specification for Design and Construction of Aircraft Weapon Systems (Volume II -Rotary Wing Aircraft)
USAAVSCOM TR-85-D-12	Advanced Composite Structures R&M Design and Repair Guide

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 the documents which are DoD adopted are those listed in the latest issue of the DoDISS, and supplement thereto.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM A-380	Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
ASTM B-l 17	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B-686	Standard Specification for Aluminum Alloy Castings, High-Strength
ASTM C-177	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

ASTM C-236	Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box
ASTM C-35 1	Standard Test Method for Mean Specific Heat of Thermal Insulation
ASTM C-5 18	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission properties by Means of the Heat Flow Meter Apparatus
ASTM C-581	Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service
ASTM D-149	Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
ASTM D-150	Standard Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
ASTM D-235	Standard Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)
ASTM D-256	Standard Test Methods for Determining the Pendulum Impact Resistance of Notched Specimens of Plastics
ASTM D-257	Standard Test Methods for DC Resistance or Conductance of Insulating Materials

ASTM D-304	Standard Specification for n-Butyl Alcohol (Butanol)
ASTM D-330	Standard Specification for 2-Butoxyethanol
ASTM D-543	Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents
ASTM D-570	Standard Test Method for Water Absorption of Plastics
ASTM D-6 18	Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing
ASTM D-635	Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position
ASTM D-648	Standard Test Method for Deflection Temperature of Plastics Under Flexural Load
ASTM D-67 1	Standard Test Method for Flexural Fatigue of Plastics by Constant-Amplitude-of-Force
ASTM D-673	Standard Test Method for Mar Resistance of Plastics
ASTM D-695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D-696	Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between –30°C and 30°C
ASTM D-740	Standard Specification for Methyl Ethyl Ketone

ASTM D-756	Standard Practice for Determination of Weight and Shape Changes of Plastics Under Accelerated Service Conditions
ASTM D-785	Standard Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials
ASTM D-790	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D-792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D-794	Standard Practice for Determining Permanent Effect of Heat or Plastics
ASTM-D-846	Standard Specification for Ten-degree Xylene
ASTM D-896	Standard Test Method for Resistance of Adhesive Bonds to Chemical Reagents
ASTM D-897	Standard Test Method for Tensile Properties of Adhesive Bonds
ASTM D-903	Standard Test Method for Peel or Stripping Strength of Adhesive Bonds
ASTM D-905	Standard Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading
ASTM D-950	Standard Test Method for Impact Strength of Adhesive Bonds

ASTM D-952	Standard Test Method for Bond or Cohesive Strength of Sheet Plastics and Electrical Insulating Materials
ASTM D-953	Standard Test Method for Bearing Strength of Plastics
ASTM D- 1002	Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)
ASTMD-1151	Standard Test Method for Effect of Moisture and Temperature on Adhesive Bonds
ASTM D-l 153	Standard Specification for Methyl Isobutyl Ketone
ASTM D-l 183	Standard Test Methods for Resistance of Adhesives to Cyclic Laboratory Aging Conditions
ASTM D- 1184	Standard Test Method for Flexural Strength of Adhesive Bonded Laminated Assemblies
ASTM D- 1242	Standard Test Methods for Resistance of Plastic Materials to Abrasion
ASTM D-1435	Standard Practice for Outdoor Weathering of Plastics
ASTM D- 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D-1655	Standard Specification for Aviation Turbine Fuels

ASTM D-1781	Standard Test Method for Climbing Drum Peel for Adhesives
ASTM D-1828	Standard Practice for Atmospheric Exposure of Adhesive-Bonded Joints and Structures
ASTM D- 1870	Standard Practice for Elevated Temperature Aging Using a Tubular Oven
ASTM D- 1876	Standard Test Method for Peel Resistance of Adhesives (T-Peel Test)
ASTM D-2093	Standard Practice for Preparation of Surfaces of Plastics Prior to Adhesive Bonding
ASTM D-2095	Standard Test Method for Tensile Strength of Adhesives By Means of Bar and Rod Specimens
ASTM D-2240	Standard Test Method for Rubber Property – Durometer Hardness
ASTM D-2344	Standard Test Method for Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method
ASTM D-2583	Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
ASTM D-2584	Standard Test Method for Ignition Loss of Cured Reinforced Resins
ASTM D-2734	Standard Test Methods for Void Content of Reinforced Plastics
ASTM D-2766	Standard Test Method for Specific Heat of Liquids and Solids

ASTM D-2843	Standard Test Method for Density of Smoke from the Burning or Decomposition of Plastics
ASTM D-2863	Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D-2918	Standard Practice for Durability Assessment of Adhesive Joints Stressed in Peel
ASTM D-2919	Standard Test Method for Determining Durability of Adhesive Joints Stressed in Shear by Tension Loading
ASTM D-2990	Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
ASTM D-3029	Standard Test Methods for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Tup (Falling Weight)
ASTM D-3039	Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials
ASTM D-3045	Standard Practice for Heat Aging of Plastics Without Load
ASTM D-3 163	Standard Test Method for Determining Strength of Adhesively Bonded Rigid Plastic Lap-Shear Joints in Shear by Tension Loading

ASTM D-3 164	Standard Test Method for Strength Properties of Adhesively Bonded Plastic Lap-Shear Sandwich Joints in Shear by Tension Loading
ASTM D-3 165	Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single-Lap-Joint Laminated Assemblies
ASTM D-3 166	Standard Test Method for Fatigue Properties of Adhesives in Shear by Tension Loading (Metal/Metal)
ASTM D-3 167	Standard Test Method for Floating Roller Peel Resistance of Adhesives
ASTM D-3171	Standard Test Method for Fiber Content of Resin-Matrix Composites by Matrix Digestion
ASTM D-3386	Standard Test Method for Coefficient of Linear Thermal Expansion of Electrical Insulating Materials
ASTM D-3410	Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading
ASTM D-34 17	Standard Test Method for Heats of Fusion and Crystallization of Polymers by Thermal Analysis
ASTM D-34 18	Standard Test Method for Transition Temperatures of Polymers by Thermal Analysis

ASTM D-3479	Standard Test Methods for Tension-Tension Fatigue of Oriented Fiber, Resin Matrix Composites.
ASTM D-3518	Standard Practice for In-Plane Shear Response of Polymer Matrix Composites by Tensile Test of a ±45° Laminate
ASTM D-3528	Standard Test Method for Strength Properties of Double Lap Shear Adhesive Joints by Tension Loading
ASTM D-3801	Standard Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position
ASTM D-3807	Standard Test Method for Strength Properties of Adhesives in Cleavage Peel by Tension Loading (Engineering Plastics-to-Engineering Plastics)
ASTM D-3846	Standard Test Method for In-Plane Shear Strength of Reinforced Plastics
ASTM D-3916	Standard Test Method for Tensile Properties of Pultruded Glass-Fiber-Reinforced Plastic Rod
ASTM D-3933	Standard Guide for Preparation of Aluminum Surfaces for Structural Adhesives Bonding (Phosphoric Acid Anodizing)
ASTM D-4065	Standard Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics
ASTM D-4080	Standard Specification for Trichloroethylene, Technical and Vapor-Degreasing Grade

ASTM D-4126	Standard Specification for Vapor-Degreasing Grade and General Solvent Grade 1, 1,1-Trichloroethane
ASTM D-4255	Standard Guide for Testing Inplane Shear Properties of Composite Laminates
ASTM D-4364	Standard Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight
ASTM D-4376	Standard Specification for Vapor-Degreasing Grade Perchloroethylene
ASTM D-46 15	Standard Specification for n-Butyl Acetate (All Grades)
ASTM D-470 1	Standard Specification for Technical Grade Methylene Chloride
ASTM D-5045	Standard Test Methods for Plane-Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials
ASTM D-5229	Standard Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
ASTM D-5379	Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method
ASTM D-5528	Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites

ASTM E-139	Standard Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E-143	Standard Test Method for Shear Modulus at Room Temperature
ASTM E-162	Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source
ASTM E-168	Standard Practices for General Techniques of Infrared Quantitative Analysis
ASTM E-228	Standard Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer
ASTM E-380	Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)
ASTM E-399	Standard Test Method for Plane-Strain Fracture Toughness of Metallic Materials
ASTM E-472	Standard Practice for Reporting Thermoanalytical Data
ASTM E-662	Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials
ASTM E-831	Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis

ASTM E-906	Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products
ASTM E-1252	Standard Practice for General Techniques for Qualitative Infrared Analysis
ASTM E-1434	Standard Guide for Development of Standard Data Records for Computerization of Mechanical Test Data for High-Modulus Fiber-Reinforced Composite Materials
ASTM F-814	Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials for Aerospace Applications
ASTM G-7	Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials
ASTM G-2 1	Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi
ASTM G-22	Standard Practice for Determining Resistance of Plastics to Bacteria
ASTM G-23	Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
ASTM G-47	Standard Test Method for Determining Susceptibility to Stress-Corrosion Cracking of High-Strength Aluminum Alloy Products
ASTM G-64	Standard Classification of the Resistance to Stress-Corrosion Cracking of Heat-Treatable Aluminum Alloys

ASTM G-85	Standard Practice for Modified Salt Spray (Fog) Testing
ASTM STP 463	Review of Developments in Plane Strain Fracture Toughness Testing

SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

AMS 1424	Deicing/Anti-Icing Fluid. Aircraft. SAE Type I
AMS 1428	Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian, (Pseudoplastic), SAE Types II, III, and IV
AMS 2300	Premium Aircraft-Quality Steel Cleanliness Magnetic Particle Inspection Procedure
AMS 2301	Cleanliness, Aircraft Quality Steel Magnetic Particle Inspection Procedure
AMS 2303	Aircraft Quality Steel Cleanliness Martensitic Corrosion-Resistant Steels Magnetic Particle Inspection Procedure
AMS 3 166	Solvent, Cleaning Cleaning Prior to Application of Sealing Compounds
AMS 3276	Sealing Compound, Integral Fuel Tanks and General Purpose, Intermittent Use to 360°F (182°C)
SAE 31882	Method for Evaluating the Cleavage Strength of Structurally Bonded Fiberglass Reinforced Plastic (Wedge Test)

RADIO TECHNICAL COMMISSION FOR AERONAUTICS

RTCA/DO-160	Environmental Conditions and Test Procedures for Airborne Equipment

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

CHAPTER 3

GENERAL MATERIALS AND PROCESSES INFORMATION

3.1 Introduction. The following chapter provides general guidelines on materials selection and issues which should be considered in the design and construction of Army aircraft.

3.2 Materials and processes All materials and material processes utilized in the construction of the aircraft should be in accordance with Chapter 2 of AMCP 706-202 and ADS-5 1-HDBK. Raw materials, in mill-product form, should be specified and produced on the basis of appropriate Government, contractor, or industrial/commercial specifications.

3.3 Materials properties. Properties of materials for design purposes should be obtained from MIL-HDBK-5, MIL-HDBK-17, or from appropriate contractor or industrial/ commercial sources. Allowable properties based on static and fatigue test data other than handbook data may be used; properties other than those contained in the aforementioned handbooks should be substantiated and analyzed in accordance with procedures used for corresponding data in the appropriate handbook. Where it is necessary to develop data for materials, the test materials and processes should be those intended for use in production aircraft and should represent a minimum of three batches of material. Minimum properties obtained from the aforementioned sources should be used for design purposes. “A” values should be used in the design of structural components. "B" values can be used for all crash conditions, floor loading conditions, fail safe or redundant structures which are designed to carry full limit loads after failure of one member, and structure the failure of which would have no safety of flight implications. Where only "S" values exist, the use of such values should be quantitatively justified. For substantiation of structural integrity by analytical calculations, the nominal gage of materials should be the average gage between tolerances.

3.4 Corrosion protection. All system parts should be suitably finished so as to provide protection from corrosion and other forms of material deterioration. This protection should be in accordance with a contractor-prepared corrosion prevention and control plan, as detailed in Chapter 7 of this handbook.

3.5 Temperature effects. The selection of allowable stresses used for design should include consideration of any reductions in material strength, both at expected maximum elevated temperatures and at ambient temperatures which follow exposure to elevated temperatures. All factors which can contribute to elevated temperature should be considered in the determination of expected maximum elevated temperatures, including but not limited to the effects of ambient climate, solar radiation, internal heat generation (e.g., electronics, engines), and weapons firing. Allowable stresses should be selected on the basis of creep, thermal expansion, joint-fastener relaxation, and elevated temperature fatigue.

3.6 Minimum gage of materials. The minimum gage of materials for structural applications (except for honeycomb core) should be as follows:

a. Corrosion resistant steel	0.20 mm (0.008 inch)
b. Aluminum alloys (in noncorrosion-prone environments)	0.40 mm (0.016 inch)
c. Aluminum alloys (in corrosion-prone environments)	0.65 mm (0.025 inch)
d. Titanium and titanium alloys	0.40 mm (0.016 inch)
e. Superalloys	0.40 mm (0.015 inch)
f. Structural metal tubes	0.90 mm (0.035 inch)
g. Hydraulic tubing – aluminum	0.90 mm (0.035 inch)
h. Hydraulic tubing – corrosion resistant steel	0.50 mm (0.020 inch)
i. Hydraulic tubing – titanium	0.50 mm (0.020 inch)
j. Fiber-reinforced materials	2 plies

3.7 Fracture toughness. In selecting a material, one of the primary properties to be considered should be fracture toughness. To ensure adequate toughness, all damage tolerance and fatigue critical structural parts should be analyzed using fracture mechanics technology in accordance with the principles set forth in ASTM STP 463. Materials fracture toughness testing should be in accordance with appropriate Government, contractor, or industrial/commercial specifications, such as ASTM E-399, ASTM D-5045, or equivalent for homogeneous materials and ASTM D-5528 or equivalent for composite materials. MIL-HDBK-17 also provides guidelines for fracture toughness testing of composite materials.

3.8 Flammability characteristics. Materials used in aircraft should be selected to provide a fire-retardant capability and should not absorb oils or hydraulic fluid. In addition, materials should be self-extinguishing consistent with the state-of-the-art and should comply with FAR 25.853, FAR 25.855, or FAR 25.1359, as applicable. Combustible materials, if used, should be isolated from high-energy electrical circuits and components and from other potential sources of combustion. Smoke generation characteristics and products of combustion, particularly toxic fumes, should be identified, and appropriate hazard warnings should be issued. The use of materials with undesirable flammability or outgassing characteristics, such as halogenated materials like polyvinyl chloride (PVC), should be justified by quantitative trade-off analyses.

3.9 Materials for survivability. The ability of aircraft materials to withstand the adverse effects of ballistics, chemical and biological agents, nuclear environments, and directed energy should be determined in accordance with ADS-? 1. Whenever required, materials selections should be made which harden/protect aircraft systems and which maximize the resistance of aircraft systems to such threats.

a. Protection of critical subsystems and components should be accomplished primarily by design. Armor, plastic foams, or the like to protect critical components against projectile impacts may be used, provided that the method chosen is demonstrated to be more efficientthan any other means of protection.

b. The effects of chemical agents and decontaminants on the propertics of all selected aircraft materials should be considered. Materials, material forms, coatings, and finishing systems should be chosen to minimize the absorption of chemical agents and to facilitate the rapid removal of such agents with decontaminants which are readily available on the battlefield (e.g., detergent washing, DS2, and STB). If a method of decontamination is not specified for a particular system, the most practical method should be assumed.

c. Where appropriate, low observability (LO) materials should be incorporated into aircraft design to reduce radar and infrared detectability.

3.10 Radioactive materials. If radioactive materials are incorporated into any aircraft component, the design and life-cycle controls for such components should comply with AR 385-11 and AR 700-64, or equivalents.

3.11 Carcinogenic materials. The use of materials which are deemed to be carcinogenic should be justified by quantitative trade-off analyses. Protective measures should be incorporated to minimize the hazardous effects of such materials on Army personnel. The use of asbestos and asbestos-containing materials is banned by the Department of Defense.

3.12 Ozone depleting chemicals. The use of Class I ozone depleting chemicals (ODCs) in or on Army aircraft should be avoided, since their availability is limited and diminishing due to Government and international regulations. Such chemicals include chlorofluorocarbons, halons, 1, 1, 1-trichloroethane, carbon tetrachloride, and methyl bromide. Any use of chlorinated fluorocarbons (CFCs) should be justified through quantitative substantiating data, including trade-offs with potential alternatives.

3.13 Processes. Appropriate Government, contractor, or industrial/commercial processing specifications and quality control methods should be utilized to ensure that the production of each specific material/part is consistent and repeatable and that all minimum requirements are met. In selecting a process, consideration should be given to ensuring that the material properties to which the part or assembly has been designed are not degraded during processing. Particular attention should be given to metals processes that may affect hydrogen embrittlement, stress corrosion, and fracture toughness, and to composite material processes that may affect damage tolerance and environmental resistance (both natural and induced).

3.14 Nondestructive inspection. Nondestructive inspection methods should be used to verify the quality. and integrity of aircraft components, particularly structural components and safety-of-flight parts. The minimum detectible flaw size should be at least as small as the largest allowable flaw for each region of the examined component, and the inspection method should have no adverse effect on component properties or performance. As required, inspections should be performed on metal components, composite material components, and adhesive bondlines, in accordance with accepted Government, contractor, or industrial/commercial practices. Critical aircraft components should be 100 percent inspected and should meet all acceptance criteria prior to delivery or installation on Army aircraft.

CHAPTER 4

METALS

4.1 Introduction. The following chapter includes guidelines and lessons learned on the use of metals in the construction of Army aircraft.

4.2 Steel.

4.2.1 Cleanliness. Steels should meet appropriate Government, contractor, or industrial/ commercial cleanliness requirements. Steels used at or above 1250 MPa (180 ksi) ultimate tensile strength (UTS) should meet AMS 2300 or equivalent, except that the cleanliness rating for heat treatments to 1790 MPa (260 ksi) and above should have a frequency/ severity rating of 0.10/0.20 maximum, respectively. Steels used below 1250 MPa (180 ksi) should meet AMS 2301 or equivalent cleanliness requirements. Magnetic corrosion resistant steels should meet AMS 2303 or equivalent cleanliness requirements.

4.2.2 Composition. Steel compositions should be selected such that ductile-to-brittle transition temperatures (measured by impact) are below any temperature which the part is likely to experience in service.

4.2.3 Heat treatment. Steel parts should be heat treated in accordance with appropriate Government, contractor, or industrial/commercial specifications and practices, such as MIL-H-6875 or equivalent.

4.2.4 Shot peening. When required and feasible, surfaces of critical or hi& stressed parts should be shot peened in accordance with appropriate Government, contractor, or industrial/commercial specifications and practices. After fmal machining and heat treating, all surfaces of critical or highly stressed parts which have been heat treated to or above 1250 MPa (180 ksi) UTS should be shot peened in accordance with MIL-S-13 165 or equivalent, except for rolled threads, inaccessible areas of holes, pneumatic or hydraulic seat contact areas, and thin sections or parts which, after shot peening, would violate engineering and functional configuration. Areas requiring lapped, honed, or polished surfaces should be shot peened prior to such finishing. Surface removal of up to 10 percent of the "A" intensity arc height, based on pre-shot peened dimensions, is acceptable.

4.2.5 Hardenability. Hardenability should.be sufficient to ensure transformation of quenching to 90 percent of a mixture of not less than 80 percent martensite and 20 percent or less bainite at the center of the maximum cross section.

4.2.6 Forming; or straightening of steel parts. All reasonable precautions should be taken to minimize warping during heat treatment of steel parts. Steel parts should be formed or straightened in accordance with appropriate Government, contractor, or industrial/ commercial specifications and practices. No cracks which exceed the maximum allowable flaw size should be present after forming/straightening. Excessive residual stresses should be relieved, and no loss of temper should occur as a result of forming/straightening processes

a. Parts hardened up to 1150 MPa (165 ksi) UTS may be room temperature straightened.

b. Parts hardened from 1150 to 1400 MPa (165 to 200 ksi) may be straightened at room temperature providing they are inspected for cracks and given a stress relieving heat treatment.

c. Parts hardened over 1400 MPa (200 ksi) UTS should be hot formed or straightened within a temperature range of from 28°C (50°F) below the tempering temperature up to the tempering temperature.

4.3 Ahlminum.

4.3.1 Heat treatment. Heat treatment of aluminum alloys should be in accordance with appropriate Government, contractor, or industrial/commercial specifications and practices, such as MIL-II 6088 or equivalent. Maximum thickness for heat treatment should be controlled to assure that design properties are met.

4.3.2 Forming and straightening. Forming and straightening operations performed on sheet metal, plate, extrusions, or forgings should be limited to processes which do not result in detrimental residual stresses or losses in mechanical properties on structurally critical parts. Such processes should also not lead to stress corrosion sensitivity of the part. Shot peen forming is acceptable. The contractor should maintain adequate controls and supportive data which substantiate that the employed forming and straightening processes meet the foregoing requirements.

4.4 Magnesium allovs. Any application utilizing magnesium should have quantitative substantiating data to justify its use. Whenever magnesium alloys are used, parts should be adequately protected from corrosion by anodizing in accordance with MIL-M-45202 or equivalent and by sealing with an organic coating. Magnesium alloys should not be used for parts which are not readily accessible for inspection, application of protection finish, and repair/replacement. Magnesium alloys should not be used for parts where deterioration of the protective finish can occur as the result of erosion or wear. Such parts include leading edges, parts subject to engine exhaust impingement and rocket blast, doors, steps, wheels, and flooring.

4.5 Castings. Castings should be designed with factors of safety which conform to appropriate Government, contractor, or industrial/commercial practices. Unless the strength of a casting is substantiated by static structural tests which simulate the design conditions critical for the casting, or unless the casting is procured to the requirements of MIL-C-21180, ASTM B-686, or equivalent (i.e., a specification which requires tensile testing of specimens machined from actual castings), an analytical positive margin of safety of not less than 0.25 should be demonstrated by methods appropriate for the particular casting. One, two, or three castings may be statically tested to verify the adequacy of the design. If one casting is tested, a minimum casting factor of 1.25 should be demonstrated at ultimate load. If two castings are tested, a minimum casting factor of 1.20 should be demonstrated at ultimate load. If three castings are tested, a minimum casting factor of 1.15 should be demonstrated at ultimate load.

CHAPTER 5

NONMETALLIC MATERIALS

5.1 Introduction. The following chapter includes guidelines and lessons learned on the use of homogeneous nonmetallic materials in the construction of Army aircraft. Composite material guidelines can be found in Chapter 6 of this handbook.

5.2 Organic materials. Information on plastic materials and design guidelines may be found in MIL-HDBK-700 and MIL-HDBK-755. Information and guidelines on rubber/elastomeric materials may be found in MIL-HDBK-149. The following considerations should be applied to the selection of elastomers, plastics, and other organic materials used in the fabrication of aircraft structures and components:

5.2.1 Environmental resistance. All organic materials should have maximum practicable resistance to degradation and aging (including fungus resistance and resistance to hydrolysis, ozonolysis, and other degradative chemical processes attendant upon atmospheric exposure) and minimum flammability consistent with performance requirements and applicable specifications.

5.2.2 Corrosion characteristics. Organic materials used in contact with other types of materials (metals in particular, as well as with other organics) should not induce corrosion or stress corrosion and should be otherwise entirely compatible. Decomposition and other products, including volatile and leachable constituents released by organic materials under normal operating conditions, should not be injurious or otherwise objectionable with respect to materials, components, or personnel with which they may be reasonably expected to come in contact.

5.2.3 Cellular materials. The use of cellular (foamed) plastics and wood for skin stabilization or as sandwich core material in structural components, other than in radomes, should be quantitatively justified. These materials may be used as such in noncritical, nonstructural components.

5.2.4 Leather. Natural leather may be used for removable upholstery. Any other uses should be justified through property trade-off analyses.

52.5 Elastomeric potting/encapsulating compounds. Elastomeric potting/encapsulating compounds should have appropriate insulating and sealing properties and should not adversely affect electrical or electronic components. Such compounds should conform to MIL-S-85 16, MIL-S-23586, MIL-I-8 1550, or equivalent whenever possible.

5.2.6 Adhesives/bonding. Adhesives used in the fabrication of aircraft structure, including metal-faced or metal-core sandwich, should meet appropriate Government, contractor, or industrial/commercial specifications. MIL-HDBK-691 may be used as a guideline for joint design, adhesive selection, and adherend surface preparation. All bonding processes should be in accordance with MIL-A-83377 or equivalent, appropriate contractor bonding process specifications, or industrial/commercial bonding practices

5.2.7 Fuel tank sealing compounds. Integral fuel tank sealing compounds should have suitable chemical/environmental resistance and should have no adverse effect on aircraft fuels. Such compounds should conform to MIL-S-8802, MIL-S-8784, AMS 3276, or to an appropriate Government, contractor, or industrial/commercial specification.

5.2.8 Corrosion-inhibiting sealants. Corrosion-inhibiting sealants, such as those conforming to MIL-S-8 1733 or equivalent, should be used when substrates require such protection, as described in Chapter 7.

5.2.9 Silicone sealants. Silicone sealants should have no detrimental effect on substrates or on nearby surfaces and components due to corrosive cure by-products. Such sealants should be the "noncorrosive" type (i.e., little or no corrosive by-products generated during cure) whenever possible. If used in closed areas near delicate electronic components, silicone sealants should conform to MIL-S-46146 or equivalent.

5.2.10 Polyurethane elastomers. The use of polyester-based polyurethane elastomers in fabricating molded components or in potting and sealing applications should be justified by quantitative trade-off analyses.

5.3 Transparent materials. Transparent materials used in the fabrication of cockpit canopies, cabin enclosures, windshields, windows, and ports (enclosures) should retain acceptable optical properties when exposed to environmental conditions, including temperature extremes, chemicals, and abrasive materials. Where required, transparent materials should have acceptable ballistic characteristics.

a. Acrylic plastic should be of the stretched type, conforming to MIL-P-25690 or equivalent. Stretched acrylic plastic shouldnot be used where it will be exposed to temperatures above 120°C (250°F).

b. Polycarbonate should conform to MIL-P-833 10 or equivalent and should be protected from chemical and abrasive damage.

c. Laminated glass should conform to MIL-G-25871 or equivalent, or to MIL-G-5485 or equivalent when bullet resistance is required.

5.4 <u>Lubricants</u> Provisions should be made for the lubrication of all parts which are subject to wear. The selection of lubricants (oils, greases, solid film coatings, anti-seize compounds, heat transfer fluids, coolant and hydraulic fluids) should be in accordance with appropriate Government, contractor, or industrial/commercial specifications, such as MIL-STD-838 or equivalent. The number of different lubricants required should be kept to a minimum by using multi-purpose lubricants (such as the wide temperature general purpose grease MIL-G-8 1322 or equivalent) wherever possible, without compromising aircraft performance and reliability. All lubrication fittings should be readily accessible.

CHAPTER 6

COMPOSITE MATERIALS

6.1 Introduction. The following chapter provides guidelines on the characterization of heterogeneous/composite materials and represents lessons learned on their use in Army aircraft. It includes methodologies for the establishment of data bases for composite material properties and design allowables. Such information is needed for the proper qualification of composite materials and alternates for use in the design and construction of Army aircraft. Guidelines for composite material design methodology are also included in this chapter. This chapter does not include guidelines for generating detailed characterization/qualification data for composite constituent materials (i.e., matrix resins, fiber reinforcements, prepregs, etc.), since it is the properties of the resultant composite materials produced from these constituents that are needed to evaluate aircraft applications. Further detailed information on composite material properties, design considerations, and constituent materials can be found in MIL-HDBK-17 and MIL-HDBK-754.

6.2 Summary of composite material guidelines. Composite material selection should be based on the physical, mechanical, environmental/durability, thermal, and electrical properties of the material, ensuring that the chosen material is suitable for the intended application. Risk assessment, property trade-offs, processing/producibility requirements, adhesive/sealant bondability, sourcing and supply requirements, maintainability/ supportability requirements, and cost factors should also be considered in selecting composite materials. Composite material processing and quality control should be in accordance with appropriate Government, contractor, or industrial/commercial specifications.

6.3 General guidelines for composite material property determinations. When Government or commercial/industrial handbook design properties are not available for a particular composite system, material properties should be generated in accordance with an appropriate Government, contractor, or industrial/commercial specification, such as MIL-HDBK- 17.

6.3.1 MIL-HDBK-17 compliance. The procedures described in this ADS handbook are for the characterization of organic matrix composite materials, and they are generally in accordance with the guidelines contained in MIL-HDBK-17. Once a suitable data base of

B-basis allowables for a particular composite material has been established, it should ideally be included in the statistically-based materials property compilation of MIL-HDBK- 17 (Volume II).

6.3.2 Critical material properties. The contractor should determine the material properties which are deemed to be critical/important, based on the anticipated end use of a given composite material. The contractor may select and perform only those tests which are necessary to sufficiently characterize a material for a given application, producing a data base which is adequate for a specific design purpose. However, it is preferable that the entire series of material characterization tests be done with each composite material, creating complete data bases for any future applications.

6.3.3 Screening; tests. When two or more composite materials are under consideration for a particular application, screening tests may initially be appropriate. Such reduced test matrices should be devised by the contractor, using MIL-HDBK-17 (Volume I, section 2.8.1) or equivalent as a guideline. The selected tests should be based on the material properties and conditions which are deemed to be most important in the intended end use. Screening test matrices should be designed to enable efficient preliminary comparisons of key characteristics of the candidate materials, eventually leading to an educated material selection for further characterization.

6.3.4 Contractor test plan. A complete test plan, including detailed descriptions of all intended material property evaluation procedures, testing equipment, and instrumentation, should be prepared by the contractor prior to the start of testing. General guidelines for composite material property testing may be found in such references as MIL-HDBK- 17, MIL-HDBK-755, MIL-STD-1944, and DOD/NASA Advanced Composites Design Guide (Chapter 4.2). However, the test methods and parameters described in this ADS handbook should be used whenever possible. In general, ASTM standard test methods are recommended for ascertaining materials property data. If contractor methods or other alternate test methods are to be used, they should be thoroughly documented in the test plan.

6.3.5 Test specimen preparation techniques. This ADS handbook does not recommend specific sample fabrication techniques and constructions which should be used, except that specimens should be suitable for the intended testing procedures. Preparation procedures will usually include 1) mapping of panels to identify specific sample and discard areas, 2) panel cutting, machining, and finishing equipment and techniques, 3) tab material, application, and corresponding adhesive(s)/cure cycle, and 4) strain gauge type(s), application, locations, and corresponding adhesive(s). Proper handling and storage methods of all materials should be used. All samples should be thoroughly inspected to ensure that no defects are present which could cause misleading or erroneous material test results. Appropriate dimensional measurements should be made and recorded for each test specimen, and all samples should be indelibly marked to sufficiently identify the material and construction which each represents and the test/conditioning for which each is intended.

6.3.6 Process control. Composite material processing should be controlled to ensure repeatability of material data bases and component production. Constituent materials should be verified as meeting the requirements of their corresponding materials specifications prior to use, using methods similar to those found in MIL-HDBK-17 (Volume I, Chapters 3, 4, and 5) or equivalent for characterizing matrix resin, reinforcement, and/or prepreg materials. Appropriate processing specifications should be developed as necessary and utilized. Test sample preparation methods should be as similar as possible to intended manufacturing procedures, in order to assure that the generated data base will be representative of fmal composite component properties. All nondestructive evaluation (NDE) methods (visual, ultrasonic, acoustic, radiographic, thermographic, etc.) should be in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.2) or equivalent.

6.3.7 Svstems of units. Materials property data should be presented in the International System of Units (SI). FED-STD-376 and ASTM E-380 should be used as guidelines for proper conversions between SI and English units.

6.4 Composite material property determinations.

6.4.1 Physical properties.

6.4.1.1 Composite material description. The reinforcement(s)/filler(s) and resin(s) which are used to make the composite material should each be completely identified. This information should be fully documented and reported, including the commercial designation(s), manufacturer(s)/source(s), and particular manufacturing details pertinent to composite construction and/or final properties. If the reinforcement consists of fabric(s), the weave, finish, and manufacturer/source (if different than that of the fiber) should also be identified. Reinforcement configuration/orientation within the composite material, including pertinent information such as ply/winding sequence or braid pattern, should be completely described. MIL-HDBK-17 (Volume I, section 8.1.2) should be used as a guideline for the important parameters which should be included in a data base to properly document the composite material identity.

6.4.1.2 Constituent contents. Reinforcement/filler content should be determined in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.3.2), using a test method such as ASTM D-3 171, NASA RP 1142 (B.3), or equivalent. In cases where reinforcements/fillers are not adversely affected by high temperatures, a burn-off procedure such as ASTM D-2584 or equivalent may alternatively be used. Porosity/void content should be determined in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.3.3), using a test method such as ASTM D-2734 or equivalent. Matrix/resin content should be calculated, based on reinforcement/filler, void, and moisture contents. All constituent content test methods/procedures/equipment, sample preparation techniques, and test parameters and results should be fully documented and reported.

6.4.1.3 Matrix chemical composition. Appropriate methods should be used to verify the identity of the composite matrix/resin material and to ensure that its chemical composition remains constant. Potentially-suitable test methods are described in MIL-HDBK- 17 (Volume I, section 4.2), including infrared (IR) spectroscopy and high performance liquid chromatography (HPLC). IR spectroscopy should be performed in accordance with the guidelines of ASTM E-168, ASTM E-1252, or equivalent. All resin/matrix characterization test methods/procedures/equipment, sample preparation techniques, and test parameters and results should be fully documented and reported. Records should be maintained for future reference and comparisons.

6.4.1.4 Dens&v/specific gravity. The density/specific gravity of the composite material and its constituents should be determined in accordance with the guidelines of MIL-HDBK-17 (Volume I, sections 6.3.4 and 8.3.4.1) or MIL-HDBK-755 (section 7-2. 1), using a test method such as ASTM D-792, ASTM D- 1505, or equivalent. The moisture and void contents of the composite specimens should be accounted for in the density determination. The density test methods/procedures/equipment used, the sample preparation techniques, and all test parameters and results should be fully documented and reported.

6.4.1.5 Hardness. The hardness of the composite material should be determined in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 4.6.7) or MIL-HDBK-755 (section 7-2.2), using a test method such as ASTM D-2583, ASTM D-785, ASTM D-2240, or equivalent, as appropriate. The chosen test method or procedure used, the measurement equipment used, specimen preparation techniques and conditioning, and all test parameters and results should be fully documented and reported.

6.4.2 Mechanical properties.

6.4.2.1 Tensile properties. Tensile testing of the composite material should be done in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.6.2), using a test method such as ASTM D-3039 or equivalent. In certain cases, ASTM D-3916 or equivalent may be appropriate.

a. As a minimum, testing should be done in the principal directions of the material (longitudinal/transverse or warp/fill). Flat-wise tensile testing of composite laminates (perpendicular to the laminate plane) should also be done. For all tests, care should be exercised to ensure accurate specimen alignment in the testing machine. For unidirectional specimens, 0° axial alignment should be within 0.5 degree. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

c. Test specimens should include no-hole, open-hole (notched), and filled-hole configurations, as appropriate for intended applications. Open-hole specimens should be fabricated in accordance with NASA RP 1142 (B.9), NASA RP 1092 (ST-3), or equivalent.

d. The tensile test method chosen or procedure used, the equipment used to apply loads and to measure loads and displacements, the specimen preparation techniques and conditioning, and the test parameters used (e.g., sample dimensions/configuration, strain rate) should be fully documented and reported.

e. Tensile failure stresses and strains should be reported. Failure locations and descriptions should also be reported, particularly for open-hole and filled-hole tests. Failure criteria should be determined by the intended applications for the composite material and may include any or all of the following:

(1) Proportional limits, analogous to yield strengths and strains in homogeneous materials.

(2) Stresses/strains corresponding to the onset of any microcracking.

(3) First ply/fiber failures, corresponding to potential limit loads and strains.

(4) Complete failures, corresponding to ultimate strengths and strains.

f. Tensile test data should be used to generate full range stress-strain curves and tangent moduli curves. The average stress-strain and tangent moduli curves, with accompanying scatter bands, should be reported. The tensile modulus for each principle direction should also be reported. These moduli are calculated from the average slopes of the stress-strain curves over defmed strain ranges.

g. Poisson ratios should be calculated by using transverse strains measured at the same strain limits which were used to determine tensile moduli. Poisson ratios relative to all principle directions should be determined and reported.

6.4.2.2 Compressive properties. Compressive testing of the composite material should be done in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.6.3), using -a test method such as ASTM D-695, ASTM D-3410, or equivalent.

a. As a minimum, testing should be done in the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure accurate specimen alignment in the testing machine. For unidirectional specimens, 0° axial alignment should be within 0.5 degree. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

c. Test specimens should include no-hole, open-hole (notched), and filled-hole configurations, as appropriate for intended applications. Open-hole specimens should be fabricated in accordance with NASA RP 1142 (B. 10), NASA RP 1092 (ST-4), or equivalent.

d. The compressive test method chosen or procedure used, the equipment used to hold specimens, to apply loads, and to measure loads and displacements, the specimen preparation techniques and conditioning, and the test parameters used (e.g., sample dimensions/configuration, strain rate) should be fully documented and reported.

e. Caution should be exercised to ensure that specimens fail in primarily a compressive failure mode rather than in a buckling mode. Modifications of standard test fixtures, sample dimensions, gage lengths, and/or test procedures may be necessary to produce proper compressive test results.

f. Compressive failure stresses and strains should be reported. Failure locations and descriptions should also be reported, particularly for open-hole and filled-hole tests. Failure criteria should be determined by the intended applications for the composite material and may include any or all of the following:

(1) Proportional limits, analogous to yield strengths and strains in homogeneous materials.

(2) Stresses/strains corresponding to the onset of any microcracking.

(3) First ply/fiber failures, corresponding to limit loads and strains.

(4) Complete failures, corresponding to ultimate strengths and strains.

(5) Buckling failures, including column, panel, and local buckling modes.

g. Compressive test data should be used to generate full range stress-strain curves and tangent moduli curves. The average stress-strain and tangent moduli curves, with accompanying scatter bands, should be reported. The compressive modulus for each principle direction should also be reported. These moduli are calculated as the average slopes of the stress-strain curves over defined strain ranges. Poisson ratios relative to all principle directions should be calculated and reported, using transverse strains measured at the same strain limits which were used to determine compressive moduli.

6.4.2.3 Flexural properties. Flexural testing of the composite material should be done in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.6.4), using a test method such as ASTM D-790 or equivalent.

a. As a minimum, testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure accurate specimen alignment in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

c. The flexural test method chosen or procedure used, the equipment used to apply loads and to measure loads and displacements, the specimen preparation techniques and conditioning, and the test parameters used (e.g., specimen dimensions/configuration, span-to-depth ratio, strain rate) should be fully documented and reported.

d. Testing parameters should be selected per the chosen test method/procedure such that samples will fail either in compression on the top surface or in tension on the bottom surface. Shear failures are undesirable in this test mode.

e. Flexural test data should be used to generate stress-strain curves and tangent moduli curves. The average stress-strain and tangent moduli curves, with accompanying scatter bands, should be reported. The flexural modulus, yield strength and strain, and ultimate strength and strain for each principle direction should also be reported, as determined by methods similar to those described in ASTM D-790 or equivalent.

6.4.2.4 Shear properties. Shear testing of the composite material should be done in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.6.5), using an appropriate test method for the desired shear mode.

a. The following shear properties should be determined, using the corresponding test methods as indicated:

(1) In-plane shear should be determined by a test method such as ASTM D-35 18 (tensile shear), ASTM D-3846, ASTM D-4255 (rail/edgewise shear), ASTM D-5379, ASTM E-143, AMMRC TR 78-30, or equivalent.

(2) Interlaminar shear should be determined by a test method such as ASTM D-2344, ASTM D-5379, a modified ASTM D-790, or equivalent. Testing parameters should be selected per the chosen test method such that samples will fail in shear, not tension/compression. For example, a test similar to ASTM D-790 in sample and loading configurations may be used, but in a modified form such that shear failure is ensured. A four-point flexural loading with the specimen loaded at the quarter-points and L/D = 16 has been found to produce such failures.

b. As a minimum, testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure accurate specimen alignment in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

c. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

d. The shear test methods chosen or procedures used, the equipment used to apply loads and to measure loads and displacements, the specimen preparation techniques and conditioning, and the test parameters used (e.g., strain rate, specimen dimensions/ configuration, span-to-depth ratio, as applicable) should be fully documented and reported.

e. Shear test data should be used to generate stress-strain curves and tangent moduli curves. The average stress-strain and tangent moduli curves, with accompanying scatter bands, should be reported. The shear modulus, yield strength and strain, and ultimate strength and strain for each principle direction should also be reported, as determined per the guidelines of the test method/procedure used.

6.4.2.5 Fatigue properties. Fatigue testing of the composite material should be done in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.6.6), MIL-HDBK-755 (section 3-6), MIL-HDBK-5, and SD-24, using appropriate test methods.

a. As a minimum, testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure accurate specimen alignment in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

c. Test specimens should include no-hole, open-hole (notched), and filled-hole configurations, as appropriate for intended applications. Open-hole specimens should be similar to those fabricated for tensile or flexural tests, as dictated by the fatigue test mode being used.

d. Tension-tension (ASTM D-3479 or equivalent), compression-compression, tension-compression, bending (ASTM D-671 or equivalent), short beam shear, bearing, and torsion fatigue tests should be done as appropriate for the intended applications. The test methods chosen or procedures used, the equipment used to apply cyclic loads and to monitor specimens, the sample preparation techniques and conditioning, and the test parameters used (e.g., sample dimensions/configuration, any initial peak load, load/ displacement amplitude, stress ratio, cyclic load frequency) should be fully documented and reported.

e. Fatigue failure criteria (e.g., microcracking/crazing, delamination, initial ply failure, complete failure/loss of load carrying capability) should be established, based on the intended applications. A predetermined maximum number of cycles should be established to indicate when a test at a given load level may be terminated. This data point should be used as a run-out. Following fatigue testing, samples not completely failed should be tested statically to determine residual strength.

f. Fatigue test data should be used to generate and report stress life curves as a function of fatigue spectrum for each type of fatigue test done, and crack/delamination/ flaw growth should be monitored and reported when appropriate. If fatigue life is a function of cyclic load frequency, this relationship should be indicated or shown as a family of curves. Where appropriate, residual strengths, failure strains, and moduli of fatigued specimens should be noted on the curves.

6.4.2.6 Creep properties. Creep testing of the composite material should be done under constant loads in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.6.7) or MIL-HDBK-755 (sections 3-2 and 3-3), using a test method similar to ASTM D-2990, ASTM E- 139, or equivalent.

a. As a minimum, the matrix-dominated directions of the composite material should be tested. In general, creep will be most pronounced when the matrix is loaded in shearing modes. Depending upon the nature of the reinforcement material or the intended composite end use, creep testing in the reinforcement-dominated directions may be appropriate. Whatever the test mode, care should be exercised to ensure accurate specimen alignment in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions during testing. Test conditions should be selected such that creep phenomena can be measured in a reasonable time frame. As a minimum, elevated test temperatures in accordance with paragraph 6.5.4 should be used. Testing at or above the glass transition temperature of the matrix material may also be appropriate, depending upon the intended composite material application. If it is known that the composite material will be subjected to a harsh chemical environment when in use, then creep testing in this environment should be done.

c. The creep test method chosen or procedure used, the equipment/fixtures used to apply loads and to monitor samples, the specimen preparation techniques and conditioning, and the test parameters used (e.g., sample dimensions/configuration, loading mode, test loads as percentages of ultimate load or specified dead weight loads, test temperatures, specimen environment, duration of test) should be fully documented and reported.

d. Creep failure criteria (e.g., exceeding a predetermined strain level, initial ply failure, complete failure/loss of load carrying capability) should be established, based on the intended applications. A predetermined maximum time limit may be established to indicate when a test at a given load level may be terminated. Following creep testing, samples not completely failed should be tested statically to determine residual strength.

e. Creep test data should be used to generate and report strain-time and/or creep rupture curves for each combination of test parameters used. Where appropriate, residual strengths should be noted on the curves.

6.4.2.7 Damage tolerance. The damage tolerance of a composite material can be ascertained through impact and fracture toughness testing.

6.4.2.7.1 Impact properties. The resistance of the composite material to low velocity impact damage should be determined by a compression-after-impact test in accordance with the guidelines of MIL-HDBK-I7 (Volume I, section 7.4. 1), using a test method such as NASA RP 1092 (ST-l), NASA RP 1142 (B. 1 1), or equivalent. Where applicable, notch sensitivity and impact strength of the composite material should be determined in accordance with the guidelines of MIL-HDBK-755, (section 3-5), using a test method such as ASTM D-256, ASTM D-3029, or equivalent.

a. As a minimum, testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure accurate. specimen alignment in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

c. The compression-after-impact test method chosen or procedure used, the equipment used to hold, impact, and inspect samples, the sample preparation techniques and conditioning, and the test parameters used (i.e., specimen dimensions/configuration, impact level, compression test parameters) should be fully documented and reported. Any other impact/notch sensitivity testing done should also be fully documented and reported, including the test method(s)/procedure(s), test equipment, the sample preparation techniques and conditioning, and the test parameters (e.g., specimen dimensions/ configuration, sample orientations) which were used.

d. Compression-after-impact test data should be used to ascertain the threshhold of detectability of impact damage and to thereby determine and report design allowable loads and limits. Correlations should be made between visual damage, damage detectable with nondestructive evaluation (NDE) methods, and residual compressive strength. Impact strength, notch sensitivity, and any pertinent observations made during impact testing should also be reported as applicable

6.4.2.7.2 Fracture toughness. Interlaminar fracture toughness characteristics (resistance to delamination) of the composite material should be ascertained in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.6.8). The susceptability of the material to edge delamination should be determined by a test method such as NASA RP 1092 (ST-2), NASA RP 1142 (B. 13), or equivalent. Edge delamination data should be used to calculate mixed-mode interlaminar fracture toughness. Mode I interlaminar fracture toughness should be determined by a double cantilever method, such as NASA RP 1092 (ST-5) or equivalent. Mode II interlaminar fracture toughness should be determined by an end-notch flexure test, such as described in MIL-HDBK-17 (Volume I, section 6.6.8) and AFWAL-TR-88-4217 (8.8).

a. As a minimum, testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure accurate specimen alignment in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

c. The interlaminar fracture toughness test methods chosen or procedures used, the equipment used to apply loads and to monitor specimens, the sample preparation techniques and conditioning, and the test parameters used (e.g., specimen dimensions/ configuration, tensile/flexural test parameters) should be fully documented and reported.

d. Interlaminar fracture toughness test data should be used to calculate and report the strain energy release rates which correspond to the different loading modes.

6.4.2.8 Bearing strength. The bearing strength of the composite material should be determined in accordance with MIL-HDBK-17 (Volume I, section 7.2), ASTM D-953, or equivalent.

a. As a minimum, testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure accuratespecimen alignment in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions as much as possible during testing. Test conditions should be in accordance with paragraph 6.5.4.

c. The bearing strength test method chosen or procedure used, the equipment used to mount samples, to apply loads, and to monitor sample responses, the specimen preparation techniques and conditioning, and the test parameters used (e.g., sample and hole dimensions/configuration, testing rate, tensile or compressive mode) should be fully documented and reported.

d. Bearing strength test data should be used to determine bearing stresses as a function of hole deformation. The proportional limit bearing stress, the intermediate/yield bearing strength (usually corresponding to a hole elongation of four percent of the initial hole diameter), the maximum (sustained) bearing strength, and the ultimate (failure) bearing strength of the composite material, along with corresponding hole deformations, should be reported. Failure mode(s) which the specimens exhibit should also be noted.

6.4.3 Environmental resistance/durability properties.

6.4.3.1 Resistance to natural and induced environments. The resistance of the composite material to natural and induced environments should be determined in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.4) and MIL-HDBK-755 (section 8-l). While environmental testing is generally done on structures or substructures, some tests should be done on coupon specimens to ascertain a measure of material suitability. Specimens, particularly exterior surfaces, should be free of defects which might adversely affect test results. All samples should be carefully checked prior to conditioning.

a. The following environmental conditions and corresponding test methods may be appropriate for material testing, depending upon the intended application:

(1) Temperature Extremes/Variations	MIL-STD-810 (Methods 501-503) RTCA/DO-160 (Section 5.0)
(2) Humidity	MIL-STD.8 10 (Method 507) RTCA/DO-160 (Section 6.0)
(3) Solar Radiation (Sunshine)	MIL-STD-8 10 (Method 505)
(4) Fungus	MIL-STD.8 10 (Method 508) RTCA/DO-160 (Section 13.0)
(5) Salt Fog/Spray	MIL-STD-8 10 (Method 509) RTCA/DO-160 (Section 14.0)
(6) Sand and Dust	MIL-STD-8 10 (Method 5 10) RTCA/DO-160 (Section 12.0)
(7) Acoustic Noise	MIL-STD-8 10 (Method 5 15)

b. Alternative environmental tests may be also used, including ASTM G-2 1 (fungus), ASTM G-22 (bacteria), and ASTM B-l 17 or ASTM G-85 (salt fog), or equivalents.

c. Composite materials which are intended for exterior applications should be tested for weathering durability in accordance with the guidelines of MIL-HDBK-755 (section 8-7), using test methods such as ASTM D-1435, ASTM D-4364, ASTM G-7, ASTM G-23, or equivalents.

d. The environmental test methods chosen or procedures used, the equipment used to condition and monitor samples, the specimen preparation techniques, the test parameters used (e.g., sample configuration, specific environmental conditions, exposure times), and all results should be fully documented and reported.

6.4.3.2 Chemical resistance.

6.4.3.2.1 Solvents/cleaners/aircraft fluids. The resistance of the composite material to the effects of solvents, cleaners, and aircraft fluids should be determined by immersing samples in the appropriate fluids for specified times and at specified temperatures. RTCA/DO-160 (Section 1 l.O), MIL-HDBK-755 (section 8-2) and ASTM D-543, ASTM C-581, or equivalent should be used as guidelines for preparing, conditioning, and testing specimens.

a. Appropriate mechanical tests should be performed to ensure that conditioned samples meet the requirements of the intended application. Flexural tests and interlaminar and/or in-plane shear tests, as described in paragraphs 6.4.2.3 and 6.4.2.4, are commonly used for such evaluations. Specimens, particularly exterior surfaces, should be free of defects which might adversely affect test results. All samples should be carefully examined, measured, and weighed prior to conditioning.

b. The choices of specimen conditioning fluids, times, and temperatures should be based on the intended composite material end use application. The following represent some potentially-appropriate chemical conditioning environments:

(1) Turbine fuel (MIL-T-5624, MIL-T-83 133, ASTM D-1655, or equivalents) for 90 days at 24 ± 3°C (75 ± 5°F).

(2) Lubricating oil (MIL-L-7808, MIL-L-23699, or equivalents) for 90 days at 121 ± 3°C (250 ± 5°F).

(3) Hydraulic fluid (MIL-H-5606, MIL-H-83282, or equivalents) for 90 days at 24 ± 3°C (75 ± 5°F).

(4) Anti-icing fluid (MIL-A-8243, AMS 1424, AMS 1428, or equivalent) for 30 days at 0 ± 3°C (32 ± 5°F).

(5) Aircraft cleaning compounds/fluids, such as MIL-C-87937, MIL-C-85570, MIL-C-43616, and MIL-D-16791, or equivalents, solvent-blend cleaners, such as MIL-C-38736, AMS 3 166, MIL-T-19588, and O-C-1889, or equivalents, and commercial aqueous and solvent-blend cleaners for 7 days at 24 ± 3°C (75 ± 5°F).

(6) Dry cleaning solvent/mineral spirits (P-D-680, ASTM D-235, or equivalent) for 7 days at 24 ± 3°C (75 ± 5°F).

(7) Ketones, such as methyl ethyl ketone (ASTM D-740 or equivalent), acetone (O-A-5 1 or equivalent), and methyl isobutyl ketone (ASTM D-l 153 or equivalent), for 7 days at 24 ± 3°C (75 ± 5°F).

(8) Chlorinated solvents, such as 1,1, 1-trichloroethane (MIL-T-81533, ASTM D-4126, or equivalent), trichloroethylene (ASTM D-4080 or equivalent), and tetrachloroethylene/perchloroethylene (ASTM D-43 76 or equivalent), for 7 days at 24 ± 3°C (75 ± 5°F). mote: Since 1,1,1-trichloroethane has been designated as a Class I ozone depleting chemical (ODC), conditioning in this solvent is necessary only when there is a realistic potential for the composite material to be exposed to 1,1, 1-trichloroethane in its intended end-use application.]

(9) Methylene chlorideldichloromethane (ASTM D-470 1 or equivalent) for 7 days at 24 ± 3°C (75 ± 5°F).

(10) Chlorofluorocarbon (CFC) solvents/fluids, such as trichlorotrifluoroethane (MIL-C-81302, BB-F-1421, or equivalent), for 7 days at 24 ± 3°C (75 ± 5°F). [Note: Since CFCs have been designated as Class I ozone depleting chemicals (ODCs), conditioning in these solvents/fluids is necessary only when there is a realistic potential for the composite material to be exposed to CFCs in its intended end-use application.]

(11) Alcohols, such as isopropyl alcohol/isopropanol (TT-I-735, MIL-STD-1220, or equivalent), methyl alcohol/methanol (O-M-232, MIL-STD-1220, or equivalent), ethyl alcohol/ethanol (O-E-760, MIL-E-5 1454, or equivalent), and n-butyl alcohol/n-butanol (ASTM D-304 or equivalent), for 14 days at 24 ± 3°C (75 ± 5°F).

(12) Naphthas, such as aliphatic naptha (TT-N-95 or equivalent) and aromatic naptha (TT-N-97 or equivalent), for 7 days at 24 ± 3°C (75 ± 5°F).

(13) N-methylpyrrolidone (A-A-58044 or equivalent) for 7 days at 24 ± 3°C (75 ± 5°F).

(14) Aromatic solvents, such as toluene (TT-T-548 or equivalent) and xylene (ASTM D-846 or equivalent), for 7 days at 24 ± 3°C (75 ± 5°F).

(15) Hydrocarbon test fluids (TT-S-735 or equivalent) for 7 days at 24 ± 3°C (75 ± 5°F).

(16) Aircraft coating thinners (MIL-T-8 1772 or equivalent) for 7 days at 24 ± 3°C (75 ± 5°F).

(17) Miscellaneous aircraft maintenance solvents, such as butyl acetate (ASTM D-46 15 or equivalent), ethyl acetate (TT-E-75 1 or equivalent), ethylene glycol monobutyl ether (ASTM D-330 or equivalent), ethylene glycol monomethyl ether (0-E-780 or equivalent), and ethylene glycol monoethyl ether acetate (MIL-E-7125 or equivalent), for 7 days at 24 ± 3°C (75 ± 5°F).

(18) Distilled water for 14 days at 71 ± 3°C (160 ± 5°F).

c. Following conditioning, samples should be visually inspected for changes in appearance, degradation, or damage (e.g., dissolution, gelation, or swelling). Samples should be remeasured to determine whether any changes in dimensions and/or weight have occurred, and appropriate coefficients of expansion, such as hygroscopic expansion coefficients, should be calculated. Specimens should be mechanically tested as described in paragraph 6.4.3.2. la, using RTA and ETD test conditions per paragraph 6.5.4. Critical physical properties of specimens should also be measured to ascertain changes. Such characteristics might include, but are not limited to, glass transition temperature, hardness, and flammability; as described in paragraphs 6.4.4.4.1, 6.4.1.5, and 6.4.4.7.1, respectively. All test results should be documented and reported.

d. The conditioning fluids should be inspected following sample immersion to determine if any changes have occurred. Visual discrepancies or their absence, including changes in color, clarity, viscosity, and odor, should be noted and reported. Fluids should be analyzed by infrared spectroscopy, HPLC, or other appropriate method to determine what contaminants, if any, are present. Any alteration in the specification properties of the conditioning fluids should be noted and reported, particularly for such aircraft fluids as turbine fuels, lubricating oils, and hydraulic fluids.

6.4.3.2.2 Nuclear, biological, chemical (NBC) effects/decontaminants. The resistance of the composite material to the effects of nuclear blast (flash and radiation), biological agents, and chemical agents, as well as to potential adverse effects of decontaminating agents, should be determined.

a. ADS- 11 and AR 70-7 1 should be used as guidelines for establishing the NBC conditions to which samples will be subjected. For nuclear blast conditions, relative material strengths at peak exposure temperatures should be determined. For biological and chemical agents, absorption and desorption rates should be ascertained. The residual strengths of specimens after exposure to any and all NBC conditions should be measured by a procedure similar to that described in paragraph 6.4.3.2.1a. Visual inspections of exposed samples should also be made and observations noted.

b. The effects of decontamination agents, including STB, DS-2, C8, hot air, and steam, should be ascertained by the same procedure used to measure fluid resistance, as described in paragraph 6.4.3.2.1. Samples should be immersed for 24 hours at 24 ± 3°C (75 ± 5°F) prior to visual inspection and mechanical testing.

c. The test methods chosen or procedures used to evaluate NBC and decontaminant effects, the equipment used to condition and monitor samples, the specimen preparation techniques, the test parameters used (e.g., sample configuration, specific environmental conditions, exposure times), and all results should be fully documented and reported.

6.4.3.2.3 Miscellaneous chemicals. The resistance of the composite material to the effects of any chemical compounds to which the material may be exposed during maintenance operations or field usage should be determined. Aircraft operations and maintenance manuals should be consulted to ascertain the chemicals which might be called out for use on the aircraft and where and how they would be intended to be used. Such chemicals could include acids and bases, lubricants, and various organic and inorganic compounds. The composite material should be appropriately conditioned in the chemical environment and tested/examined using procedures similar to those described in paragraph 6.4.3.2.1. All results should be fully documented and reported.

6.4.3.3 Water/moisture absorption. The amount of moisture which the composite material absorbs should be determined 1) under nominal ambient conditions and 2) at equilibrium with the most severe average environmental conditions which would be expected for the specific application. The saturation moisture level in boiling water may also be determined to characterize the composite material under potentially extreme conditions. MIL-HDBK-17 (Volume I, sections 2.2.2, 2.2.3, 6.3.6, and 8.3.4.3) and

MIL-HDBK-755 (section 8-3) contain information on the theory and significance of moisture absorption (hygroscopy) in composite materials as well as guidelines for determining moisture contents. ASTM D-5229 or equivalent should be used as a guideline for sample preparation, conditioning, and testing. Samples may be considered to be at equilibrium with the chosen environment when three consecutive weighings (24-hour minimum interval between weighings) give weight changes that average less than 1% of the total change in weight.

a. The nominal (as-manufactured) moisture content should be determined by conditioning suitable samples to equilibrium in a room-temperature/ambient-humidity environment (see RTA, paragraph 6.5.4a), then drying to constant weight at elevated temperature. The actual drying temperature should be dictated by the composite material constituents, in that it should be the highest possible temperature that does not cause damage or other undesirable permanent changes to the materials. Samples should be cooled to ambient temperature in a desiccator prior to weighing on an analytical balance. This same drying procedure should also be used prior to subjecting moisture content samples to elevated temperature/moisture environments.

b. The chosen severe average temperature/humidity conditions should be selected and justified by the contractor. MIL-STD.210 and AR 70-38 are recommended for use as guidelines for choosing appropriate climate-related conditions, though other bona fide climate data may also be acceptable bases. In general, hot-humid environments (tropical jungle, coastal desert) have the most severe effects on composite materials, with temperatures ranging from 27°C to 41°C (80°F to 105°F) and relative humidities ranging from 60% to 100%.

(1) If no specific climate guidelines are defmed for the composite material end use, equilibrium moisture content should be determined at conditions equivalent to the Variable High Humidity diurnal cycle of MIL-STD-210 and AR 70-38. This cycle represents moist tropical areas for any month of the year, and it corresponds to an average relative humidity of 88%. The average temperature of this cycle is 30°C (86°F), though this is indicative only of the time required for moisture equilibrium to be reached and not the final composite moisture content.

(2) Prior to equilibrating test samples to constant weight in the desired severe temperature/humidity environment, preliminary accelerated conditioning at higher temperature and humidity (e.g., 71°C (160°F) and 95% RH) to the approximate fmal expected moisture content is acceptable.

c. Saturation of samples exposed to boiling water will determine the maximum moisture content which the composite material might possibly attain. This information may be useful in evaluating worst-case scenarios. Specimens should be conditioned to constant weight by a method similar to ASTM D-570 or equivalent. Care should be taken to ensure that all liquid water is removed from sample surfaces prior to weighings.

d. The rate of moisture diffusion into the composite material should be determined as a function of temperature, reinforcement orientation, and environmental moisture concentration. Moisture diffusion constants should be ascertained. MIL-HDBK- 17 (Volume I, section 2.2.2) should be consulted for the appropriate equations and for calculation guidelines.

e. The methods/procedures/equipment used for determining composite moisture absorption, the sample preparation techniques, and all conditioning parameters and test results should be fully documented and reported.

6.4.3.4 Surface wear resistance. The resistance of the composite material surface to wear, abrasion, and scratching should be determined in accordance with the guidelines of MIL-HDBK-755 (sections 7-3.2, 7-3.3, and 7-3.4), using test methods such as ASTM D-1242, ASTM D-673, or equivalent, as appropriate. Test methods may be developed as needed to ascertain material surface wear characteristics in specific end use environments, such as in sand/dust, in rain, or in moving contact with some other known material surface. The geometry of the expected abrasive impingement (i.e., low-angle/rubbing or high-angle/ impact) should be considered in chosing or designing suitable test methods.

6.4.4 Thermal properties.

6.4.4.1 Thermal expansion coefficients. The coefficients of thermal expansion of the composite material should be determined through thermomechanical analysis (TMA), in accordance with the guidelines of MIL-HDBK-17 (Volume I, sections 6.3.1.3, 6.3.5, and 83.5) and MIL-HDBK-755 (section 4-2.1). A test method such as ASTM D-696, ASTM D-3386, ASTM E-228, ASTM E-83 1, AFWAL-TR-88-4217 (9. 1), or equivalent should be used.

a. As a minimum. testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure that specimen surfaces are parallel and perpendicular and that specimen alignment is accurate in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and maintained at those conditions as much as possible during testing. Testing should be done with samples at the moisture contents corresponding to the conditions described in paragraph 6.4.3.3. Thermal expansion coefficients should be determined over a temperature range of –55°C to 104°C (–67°F to 220°F) unless otherwise dictated by the intended application.

c. The test method chosen or procedure used, the equipment used to mount samples, to apply heat, and to monitor sample responses, the specimen preparation techniques and conditioning, and the test parameters used (e.g., sample dimensions/configuration, temperature range, temperature change rate) should be fully documented and reported.

d. TMA data should be used to generate and report curves of thermal expansion as a function of temperature and composite material reinforcement orientation, in accordance with ASTM E-472 or equivalent. Thermal expansion coeffkients should be determined from curve tangents and reported.

6.4.4.2 Thermal conductivities. Thermal conductivity properties of the composite material should be determined in accordance with the guidelines of MIL-HDBK-755 (section 4-2.2), using a test method such as ASTM C-177, ASTM C-236, ASTM C-518, or equivalent. Another possible procedure is described in AFWAL-TR-88-42 17 (9.4), utilizing a thermal conductivity instrument.

a. As a minimum, testing should be done such that sample lengths and widths coincide with the principal directions of the material (longitudinal/transverse or warp/fill). Care should be exercised to ensure that specimen surfaces are parallel and perpendicular and that specimen alignment is accurate in the testing machine. Specimen surfaces and interiors should be free of defects which might adversely affect test results.

b. Specimens should be environmentally conditioned prior to testing and maintained at those conditions as much as possible during testing. Testing should be done with samples at the moisture contents corresponding to the conditions described in paragraph 6.4.3.3. Thermal conductivities should be determined over a temperature range of –55°C to 104°C (-67°F to 220°F) unless otherwise dictated by the intended application.

c. The test method chosen or procedure used, the equipment used to mount samples, to apply heat, and to monitor sample responses, specimen preparation techniques and conditioning, and test parameters used (e.g., sample dimensions/configuration, reference material, temperature range, temperature gradients/heat flux) should be fully documented and reported.

d. Test data should be used to plot and report curves of heat fluxes versus temperature gradients as functions of temperature and sample reinforcement orientation. Appropriate thermal conductivities for the composite material should then be determined and reported.

6.4.4.3 Heat capacity/specific heat. The heat capacity/specific heat of the composite material should be determined in accordance with the guidelines of MIL-HDBK-755 (section 4-2.3), using a test method such as ASTM C-35 1, ASTM D-2766, or equivalent. Differential scanning calorimetry (DSC) may also be used, as described in AFWAL-TR-88-42 17 (9.2). All test methods/procedures/equipment, sample preparation techniques and conditioning, test parameters (reference material, sample size/configuration, heating rate, temperature range) and results should be fully documented and reported. Specimens should be environmentally conditioned prior to testing and maintained at those conditions as much as possible during testing. Testing should be done with samples at the moisture contents corresponding to the conditions described in paragraph 6.4.3.3. Heat capacities/ specific heats should be determined over a temperature range of –55°C to 104°C (-67°F to 220°F) unless otherwise dictated by the intended application. Test results should be presented in accordance with ASTM E-472 or equivalent.

6.4.4.4 Thermal transitions. Thermal analysis should be used to ascertain the transitions which occur in the composite material as a function of temperature over a temperature range of –55°C to 104°C (-67°F to 220°F) unless otherwise dictated by the intended application. First-order transitions, such as melting points, and associated heats of fusion/crystallization should be determined and reported in accordance with ASTM D-34 17 or equivalent, as appropriate. Second-order transitions, such as glass transition temperature(s), should be determined and reported as follows:

6.4.4.4. 1 Glass transition temperature. The glass transition temperature (T_g) of the composite material should be determined by differential scanning calorimetry (DSC), differential thermal analysis (DTA), dynamic mechanical analysis (DMA), thermomechanical analysis (TMA), dielectric analysis (DEA), or other established test method. MIL-HDBK-17 (Volume I, sections 6.3.1.1 and 8.3.4.4) and MIL-HDBK-755 (section 4-2.5) provide guidelines for the determination of T,. A standard method for thermal analysis is described by ASTM D-3418, while standard dynamic mechanical methods are described in ASTM D-4065. Another possible procedure, using DMA, is described in AFWAL-TR-88-42 17 (9.3). The T_g measurement methods/procedures/ equipment used, the sample preparation techniques and conditioning, and all test parameters and results should be fully documented and reported. Specimens should be environmentally conditioned prior to testing and should be maintained at those conditions whenever possible during testing. Testing should be done with samples at the moisture contents corresponding to the conditions described in paragraph 6.4.3.3. Measured properties and corresponding tangent curves should be shown graphically as functions of temperature, as described in ASTM E-472 or equivalent.

6.4.4.5 Thermal mechanical stability. The thermal mechanical stability of the composite material should be ascertained from creep property data (paragraph 6.4.2.6) and reported. Heat deflection temperature should be determined and reported in accordance with ASTM D-648 or equivalent as a function of reinforcement orientation. Thermal mechanical stability should be determined over a temperature range of –55°C to 104°C (-67°F to 220°F) unless otherwise dictated by the intended application. The resistance of the composite material to heat aging should be determined in accordance with the guidelines of MIL-HDBK-755 (section 8-6), using test methods such as ASTM D-794, ASTM D-1870, ASTM D-3045, or equivalent. Dimensional stability of the composite material as a function of temperature and humidity should be determined by a test method such as ASTM D-756 or equivalent.

6.4.4.6 Thermal/oxidative stability. The thermal and oxidative stability of the composite material should be determined by thermogravimetric analysis (TGA). All test methods/ procedures/equipment, sample preparation techniques and conditioning, test parameters (sample size/configuration, heating rate, temperature range, sample chamber atmosphere) and results should be fully documented and reported. Specimens should be environmentally conditioned prior to testing and maintained at those conditions as much as possible during testing. Testing should be done with samples at the moisture contents corresponding to the conditions described in paragraph 6.4.3.3. Thermal/oxidative stability should be determined up to at least the maximum expected temperature for the intended application. Test results should be presented in accordance with ASTM E-472 or equivalent.

6.4.4.7 Thermal decomposition.

6.4.4.7.1 Flammability/fire resistance. The flammability/burning resistance characteristics of the composite material should be determined in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.5) and MIL-HDBK-755 (section 4-3. 1), using the methods described in FAR Part 25, Appendix F, and FAA Advisory Circular 20-107A, section 9b, or equivalent. Test methods such as ASTM D-635, ASTM D-2863, ASTM D-3801, ASTM E- 162 or equivalents may also be used to quantify burning characteristics of the material. The test procedure(s) selected should be appropriate for the anticipated end use of the material. The test method chosen or procedure used, the equipment used to initiate burning and to monitor samples, specimen preparation techniques and conditioning, and all test parameters (i.e., sample dimensions/configuration, specimen orientation, flame characteristics, time factors) and results should be fully documented and reported.

6.4.4.7.2 Combustion products/smoke. The products of combustion should be identified in accordance with the guidelines of MIL-HDBK-755 (sections 4-3.2 and 4-3.3). Toxic combustion products and the amounts generated per unit weight of original composite material should be specifically identified. Smoke generation characteristics should be determined in accordance with a test method such as ASTM F-814, ASTM E-906, ASTM E-662, ASTM D-2843, or equivalent. All test methods/procedures/equipment, sample preparation techniques and conditioning, and test parameters and results should be fully documented and reported.

6.4.5 Electrical properties.

6.4.5.1 Dielectric constant/permittivity. The dielectric constants/permittivities of the composite material should be determined and reported in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.1 1), MIL-HDBK-755 (section 5-3), and test method ASTM D-150 or equivalent for all principle directions.

6.4.5.2 Dielectric strength. The dielectric strengths of the composite material should be determined and reported in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.1 1), MIL-HDBK-755 (section 5-2), and test method ASTM D-149 or equivalent for all principle directions.

6.4.5.3 Dissipation factor/dielectric loss. The dissipation factors of the composite material should be determined and reported in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.1 1), MIL-HDBK-755 (section 5-4. 1), and test method ASTM D-150 or equivalent for all principle directions.

6.4.5.4 Surface resistivity/volume resistivity. The surface and volume resistivities of the composite material should be determined and reported in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 6.1 1), MIL-HDBK-755 (section 5-5), and test method ASTM D-257 or equivalent as functions of reinforcement orientation.

6.5 Generation of material allowables.

6.5.1 Specimen types/descriptions. The construction/configuration of the composite material test specimens should be based upon the needs of the particular test method/ procedure. Typical constructions/configurations are as follows:

a. Unidirectional lamina and/or laminates, in which the reinforcing fibers are oriented at a single angle relative to the direction of applied load (usually 0° or 90°). This configuration is primarily used to determine basic composite material properties.

b. Prescribed laminate lay-ups, including 0°/90°, ±45°, and 0°/±45°/90°. These configurations are also used to determine basic composite material properties, and there are a number of aircraft components which utilize similar constructions.

c. Specific end use laminate lay-ups, which are dictated by particular intended applications and could include odd-angle reinforcement orientations, unbalanced ply sequences, and hybrid constructions. Material properties determined from such samples are useful for specific designs, but have limited general application.

6.5.2 Screening; tests. The objective of the screening process should be to reveal key material property attributes and/or inadequacies in material system candidates through the use of a reduced test matrix. This process should identify the critical test and environmental conditions and any special considerations for a particular composite material system. Proper test selection and environmental conditioning will enable efficient and economical initial assessments of new composite materials and/or comparisons between material systems for intended applications. MIL-HDBK-17 (Volume I, section 2.8.1) should be used as a guideline for developing appropriate screening test matrices.

a. Mechanical property tests which may be typically included in screening test matrices are as follows. Environmental conditions (CTD, RTA, ETW) are defmed in paragraph 6.5.4.

(1) Lamina tests:

(a) 0” and 90” tension @ CTD, RTA, and ETW.

(b) 0” and 90° compression @ RTA and ETW.

(c) ±45° tension @ RTA and ETW.

(2) Laminate tests:

(a) Open-hole tension @ CTD, RTA, and ETW.

(b) Open-hole compression @ RTA and ETW.

(c) Filled-hole tension @ CTD.

(d) Filled-hole compression @ CTD, RTA, and ETW.

(e) Compression-after-impact @ RTA.

(f) Interlaminar shear @ CTD, RTA, and ETW.

(g) Interlaminar tension @ CTD, RTA, and ETW.

(h) Bearing tension @ CTD, RTA, and ETW.

(i) Bearing compression @ CTD, RTA, and ETW.

(j) Tension @ CTD, RTA, and ETW.

(k) Compression @ RTA and ETW.

b. Environmental/chemical resistance property tests should be included in screening tests as appropriate. These could include critical fluid resistance tests and NBC/ decontaminants resistance tests.

c. Other types of tests may also be appropriate as part of a screening test matrix, depending upon the intended application for the composite material. Tests would most likely include the determination of moisture absorption and its effect on glass transition temperature. Other thermal properties, such as thermal expansion coefficient or thermal stability, may be deemed to be important factors. Flammability/fire resistance might be a critical issue.

d. For screening tests, typically three specimens from a single batch of composite material, as defmed by MIL-HDBK- 17 (Volume I, section 1.7), should be used for each test configuration/environmental condition. Samples from more than one batch may be appropriate in certain cases, such as when significant batch-to-batch variations are suspected or when processing conditions are critical to final properties.

6.5.3 B-basis values. Complete characterization of the composite material should be accomplished by the generation of a data base of B-basis values, as described in MIL-HDBK-17 (Volume I, sections 2.2.1 and 8.2.1). B-basis values are defmed as those property values above which at least 90 percent of the population of values is expected to fall with a confidence level of 95 percent. The B-basis data base should include values for all of the critical mechanical properties described in section 6.4.2, and it should be suitable for determining design allowables for intended applications.

a. For mechanical property tests, a minimum of 30 specimens should be used for each test configuration/environmental condition. For physical, environmental resistance, thermal, or electrical property tests, appropriate numbers of specimens should be determined for each type of test. MIL-HDBK-17 (Volume I, section 8.3) provides guidelines on the minimum numbers of samples and measurements which should be used in order to produce meaningful data.

b. A minimum of three batches of composite material, as defined by MIL-HDBK-17 (Volume I, section 1.7), and preferably five batches, should be used to ascertain B-basis material properties. These batches should each be produced from different lots of matrix resin and different lots of reinforcement/filler material. A minimum of two test panels should be independently fabricated from each composite material batch in accordance with the appropriate process specifications for the material. At least one panel should be made under conditions which represent the minimal requirements of the process specifications (i.e., minimum time, temperature, and pressure to cure/fuse matrix, minimum post-cure treatment, etc.), in order to encompass the "worst case" situation in the material properties evaluation.

6.5.4 Test conditions. The B-basis material properties of the composite material should, at a minimum, be determined from samples at equilibrium with the following environmental test conditions. If intended applications are known to require composite material use at temperatures and/or relative humidity (RH) limits which differ from those listed here, then testing at such conditions should be used in the test program. Screening test material properties need to be determined only at those conditions which are specified in the appropriate reduced test matrix. All temperatures should be within ±3°C (±5°F).

a. Room temperature ambient (RTA): 24°C (75°F), 50% RH.

b. Cold temperature dry (CTD): –55°C (-67°F).

c. Elevated temperature wet (ETW): 82°C (180°F), 88% RH.

d. Elevated temperature dry (ETD): 104°C (220°F).

6.5.5 **Sample** conditioning. The environmental conditioning of specimens prior to testing should be done in accordance with the guidelines of MIL-HDBK-17 (Volume I, section 2.2.3), ASTM D-5229, ASTM D-618, or equivalent.

a. For CTD and ETD conditions, samples should first either be 1) equilibrated to RTA environmental conditions or 2) dried as described in paragraph 6.4.3.3a, then stored in sealed, moisture-impervious containers with a desiccant. Samples should be heated/cooled to the test temperature immediately prior to the test and maintained at this temperature during the test.

b. For ETW conditions, a two-step conditioning scheme is advisable, provided proper precautions are taken. Accelerated moisture conditioning may be used initially, in which samples with known initial moisture content are exposed to temperature and humidity in excess of ETW conditions until the approximate final desired moisture content (determined by the procedure of paragraph 6.4.3.3) is reached. The temperature in this conditioning phase should be selected such that the moisture absorption rate is maximized without having permanent deleterious effects on the composite material samples. In general, this will correspond to a temperature just below the material glass transition temperature. Relative humidity levels of 95-100% are customarily used. Following accelerated conditioning, samples should be allowed to equilibrate in the actual ETW environment, as described in paragraph 6.4.3.3. If desired, conditioned specimens may be stored in sealed, moisture-impervious containers. Samples should be reheated to the ETW test temperature immediately prior to testing, and ETW conditions should be maintained as closely as possible during testing.

c. The final moisture content of the composite specimens should be verified by accurately measuring weight changes of either the actual samples or appropriate representative samples (travellers). Such travellers should be in accordance with MIL-HDBK-17 (Volume I, section 2.2.3). They should be of identical construction and have the same history as the test specimens, and they should have been conditioned by exactly the same procedure and at the same time as the actual samples. Physical dimensions of the travellers should be such that their uptake of moisture is representative of the test samples.

The test specimens or travellers should be weighed both just before and just after the material property test is done to monitor any changes which may occur during testing.

6.5.6 Statistical treatment. Materials property data for the composite should be subjected to statistical treatment in accordance with MIL-HDBK-17 (Volume I, sections 8.5 through 8.8). B-basis values should be identified as such. All statistical treatment of data should be fully documented and reported.

6.5.7 Composite material data report. The property data generated by the contractor should be compiled into a complete report on the composite material characterization. The data included in this report should be in accordance with the guidelines of MIL-HDBK - 17 (Volume I, section 8.1.2). Suitable data may be forwarded for inclusion in Volume II of MIL-HDBK- 17.

6.5.7.1 Format. Documentation of the composite material property evaluations should be presented in contractor format. Data presentation should be in accordance with the guidelines of section 6.4 of this ADS handbook, MIL-HDBK-17 (Volume I, section 8.4), and ASTM E-1434, AFGS-8722 1, MIL-A-8868, or equivalent.

6.5.7.2 Sample preparation summary. The contractor should provide a sample preparation summary as part of the overall data report. This summary should include a description of the methods which were used to characterize/qualify and verify the constituent materials, as well as the procedures which were used to fabricate and nondestructively inspect test specimens. The contractor should be prepared to supply detailed information on these items if requested. The methods and procedures which were used to fabricate test panels and to produce actual test samples of the composite material should be fully documented and reported. Appropriate process specifications should be identified, particularly those which apply to constituent material handling and composite material lay-up/consolidation procedures. Tooling/molds and all other equipment used in the composite fabrication process should be described. The curing/fusing cycle, including temperature and pressure profiles, and any post-cure treatments should be documented. The quality control methods which were employed to ensure proper composite material fabrication should be fully documented and reported. Proper handling and storage methods of all materials should be documented. All nondestructive evaluation (NDE) methods should be fully described and the results reported. Any anomalies which were found during the NDE of composite material specimens should be noted, and assurances should be given that all internal and external defects which could cause misleading or erroneous material test results were either accounted for or were not included in the fmal data base test samples.

6.5.7.3 Composite material property test results. Graphical presentations of mechanical properties (i.e., stress-strain curves) should be done in accordance with the best-fit guidelines of MIL-HDBK- 17 (Volume I, section 8.3.7) or equivalent, while graphical presentations of thermal properties should be done in accordance with the guidelines of MIL-HDBK- 17 (Volume I, section 8.3.5) or equivalent. The composite material data report should identify whether the testing program represents a limited (screening) or complete (B-basis) characterization of the composite material, and it should include a complete description of the composite material, test methods/procedures documentation, all of the measured material properties data as functions of direction (reinforcement orientation), size/shape, and environmental conditions, and appropriate statistical analyses. The materials properties data should be presented in a manner which facilitates data retrieval for aircraft design purposes.

6.6 Composite material design considerations. The use of composite materials in aircraft design and applications should be in accordance with the requirements of the U.S. Army Helicopter Structural Integrity Program (HSIP) and MIL-STD-1530. Composite design considerations and guidelines can be found in MIL-HDBK-17 (Volume III), MIL-HDBK-754, MIL-HDBK-755 (Chapter 2), DOD/NASA Advanced Composites Design Guide, USAAVSCOM TR-85-D- 12, AMCP 706-202, AFGS-8722 1, MIL-A-8867, MIL-A-8866, FAA AC 20-107A, MIL-STD-1587, SD-24, AR-56, and ADS-5 1-HDBK.

6.6.1 Material selection methodology. The goal of composite material selection methodology should be to meet Army/ATCOM aircraft requirements. A rational approach should be used, enabling a successful transition to full scale development and production. The specific material selection criteria are directly dependent upon the application requirements. Committing to a material which does not meet all of the critical characteristics can be catastrophic. For this reason, all possible efforts should be made to ensure that operational requirements are met with the least possible risk. To accomplish this, an evolutionary rather than a revolutionary approach to materials selection and development should be used. A "building block" methodology, such as that described in section 3.2.1.2 of MIL-A-8867C, should be used to determine composite material design allowables and knockdowns for both static and fatigue performance.

6.6.2 Risk minimization. The cost and schedule risk associated with changing a primary material selection after the initiation of full scale development can be extreme. The relative maturity of the selected material has a direct effect on this risk. The magnitude of the characterization, testing, and evaluation needed to qualify composite materials for primary structure applications dictates that all of the following be considered in the material selection process: 1) material property/performance criteria, 2) processing and producibility requirements, 3) sourcing and supply requirements, 4) maintainability and supportability requirements, and 5) cost objectives relative to program goals. The selected composite material should represent the optimum available combination of properties and characteristics which best meet the overall requirements.

6.6.3 Material screening process. Preliminary composite material characterization provides a basis for initial screening and comparison. From the initial screening, leading candidates should be further characterized and screened to provide a sufficient database from which to make a final selection. During this phase, all conditions which could possibly eliminate materials from implementation should be examined. If a material cannot meet a critical characteristic or requirement, it should be eliminated from the process so that resources can be focused on the remaining candidates. Generally, several alternative composite materials should remain at the end of the screening process. This controls risk and provides options for the fmal selection.

6.6.4 Final material selection. The fmal composite material selection should be based upon an extensive comparison of the attributes and deficiencies of each candidate. This comparison will evaluate those materials which meet the minimum requirements and which offer competitive material properties, availability, producibility, supportability, and cost. Sufficient preliminary data should be available to adequately evaluate these areas. The evaluation process should consider the optimum combination of properties and characteristics for the application. Aircraft weight is often the predominant factor driving the selection process, and it is directly affected by a wide variety of factors, including design allowables and producibility. Material performance drives the amount of material which should be used to meet the predicted loads under the worst-case conditions, while producibility entails optimum tailoring of structure at minimum cost. Material quality and uniformity directly impact design allowables as well as final part quality and integrity.

6.6.5 Material acceptability. The composite material which is finally selected should provide an acceptable level of aircraft performance and supportability. All factors which affect required strength, rigidity, and structural reliability should be taken into account. Such factors include, but are not limited to, static, repeated, transient, vibratory, and shock loads, stress concentrations, impact damage, crack propagation, manufacturing processes and defects, environmental/climatic operating conditions, aerodynamic characteristics, and the effects of fatigue loads on composite endurance limit and ultimate strength. Documented analytical methods should be used to develop reinforcement/matrix strength and rigidity relationships for structural composite material consistent with required aircraft operating and environmental conditions. Particular attention should be given to the nature and direction of loads, especially those at structural joints, discontinuities, and cutouts, so as to advantageously utilize desirable directional properties of the composite material. The design and construction of the composite should ensure that anticipated fatigue loads will not reduce structural strength and rigidity below levels necessary for adequate performance during the required lifetime of the structure. The effects of repeated exposure to anticipated climatic conditions should be accounted for in the composite design. Composite material processes should be verified as adequate to produce the desired reinforcement/matrix composition and properties, and conformance with applicable process and contractual specifications should be determined. The type, quantity, and distribution of allowable material defects should be identified, and tolerance limits for such defects should be established, based on the required structural strength and rigidity characteristics and on fracture mechanics.

6.6.6 Material verification/certification. Design development tests of composite structures should be used to verify material analyses and to evaluate design details. Such tests are a part of the overall structural certification procedure for the aircraft, and they are particularly important when components are considered to be safety-of-flight parts. The complexity of these evaluations ranges from coupon tests through element/component tests and finally to full-scale tests of critical areas. Both static and fatigue tests should be done in a design development test program. The actual number and types of tests necessary will depend upon the particular design application. Guidelines for the certification testing methodology of composite structures can be found in NADC-86132-60 and NADC-87042-60.

6.6.7 Material performance criteria. The following paragraphs detail the various Criteria and trade studies which should be used to ensure the selection of optimum composite materials and the proper design of composite components for Army aircraft applications.

6.6.7.1 Material properties. Composite material performance in aircraft applications is primarily dependent upon the physical, mechanical, environmental resistance, and thermal properties described in section 6.4. These properties are interrelated and, in most cases, directionally dependent, and material behavior and responses to the service environment should be fully understood and accounted for in the design of the composite structure (i.e., compensated/knockdown properties). In general, mechanical tests at the extremes of environmental exposure drive the material selection process. Paragraph 6.5.2 outlines screening tests which provide a representative sample of dominant material properties and which allow logical initial material selections to be made. Additional tests may be necessary to narrow the field of material candidates, depending upon the intended application. Once initial selections are made, testing as described in section 6.5.3 should be used to generate more detailed databases and establish an adequate level of confidence in the maturity and stability of the composite material system.

6.6.7.1.1 Analytical composite properties. When composite laminate properties are established from single ply (lamina) properties through analytical techniques, such as those described in MIL-HDBK-17 (Volume III, Chapter 4), the minimum material properties for the composite laminate should be substantiated by the performance of a sufficient number of appropriate tests of the composite laminate to permit computation of B-basis allowables. Correction factors should be determined and utilized when actual laminate test data indicate that values computed from lamina properties are not sufficiently conservative.

6.6.7.1.2 Compensated properties. The design allowables for a given environmental condition should be established by reducing the baseline allowables as necessary. To account for the degradation of material properties due to combined temperature and moisture effects and to determine the magnitude of the design allowable reduction, one of the following testing procedures should be used:

a. A test article can be environmentally preconditioned to the worst-case combination of temperature and moisture content, then actually tested under those conditions.

b. Critical test conditions based upon a consideration of potential failure modes in the intended application can be selected, and quantitative compensation/knockdown factors can be derived from the composite material database through a comparison of properties measured at nominal and at ETW conditions, as described in MIL-A-8867C, section 3.3.4.5.1. The validity of these compensation factors should be substantiated by appropriate tests.

6.6.7.1.3 Scale-up considerations. The effects of thickness, width, and shape on composite material properties should be considered. Large, thick, and/or curved composite structures can have inherent behavior different than test results of nominally-sized/shaped coupons might predict. Also, factors such as edge effects, residual stresses and strains, ply stacking sequence effects, and the effects of hole size relative to laminate thickness and width should be evaluated as part of the composite component design in order to ensure optimum performance.

6.6.7.1.4 Mechanical characteristics. Aircraft design with composite materials is often driven by several critical mechanical properties which greatly affect the design of composite structure. Because the tensile strength of composites is generally superior to any other of their inherent mechanical properties, compression and shear often drive the composite selection. Various compression tests are usually necessary to establish preliminary environmental effects, open-hole effects, and damage resistance and tolerance, as described in paragraphs 6.4.2.2 and 6.4.2.7.1. In addition, shear tests should be conducted to characterize resin and resin-dominated properties, as described in paragraph 6.4.2.4. Interlaminar strength (paragraph 6.4.2.7.2) is critical to the ability of a structure to meet out-of-plane loads. These out-of-plane loads are difficult to predict during design and analysis of flight conditions. Shear and compression properties often balance the relative toughness of a composite material. As toughness increases, shear strength increases and compression strength and shear modulus decrease. Fiber strain-to-failure should also be considered, since this has a direct effect on damage tolerance. A balance which best suits the structural application should be obtained. Composite strain and modulus in both tension and compression drive structural design, and they are the primary bases for materials selection comparison analyses.

6.6.7.1.5 Environmental resistance characteristics. The effects of all anticipated natural and induced environments on the composite structure or component should be considered in its design, in accordance with the guidelines of FAA AC 20-107A and ADS-27. Typical environmental conditions/hazards associated with aircraft applications are described in section 6.4.3 and in DOD/NASA Advanced Composites Design Guide (Chapter 1.9). These include weathering (temperature, moisture, ultraviolet radiation, salt spray, icing), mechanical hazards (wind, rain, and sand/dust erosion/abrasion, hail and foreign object impact, shock, vibration and sonic/acoustic exposure), chemical/NBC exposure, and electrical/electromagnetic hazards. Methods for properly protecting composite materials are described in DOD/NASA Advanced Composites Design Guide (Chapter 1.9), and these or similar precautions should be incorporated into the design of composite components. Component testing to verify environmental resistance should be in accordance with the test methods of MIL-STD-8 10, RTCA/DO-160, or equivalent, as appropriate.

6.6.7.1.5.1 Chemical resistance. Composite materials used in aircraft applications should ideally be resistant to the absorption or adverse effects of typical aircraft fluids, cleaners, and solvents, such as those listed in paragraph 6.4.3.2.1. Coefficients of expansion due to moisture (hygroscopy) and/or aircraft fluids should be accounted for in the composite component design. Composite materials should not be susceptible to any adverse effects of fungus, as described and verified by MIL-STD-8 10 (Method 508), RTCA/DO- 160 (Section 13.0), ASTM G-21, or equivalent. Anticipated aircraft primers, finishes, and/or protective coatings (per MIL-F-7179, TM 55-1500-345-23, or equivalent) for the intended application should also be verified as being compatible with the composite material.

6.6.7.1.5.2 NBC/laser resistance. Aircraft components made with composite materials should meet the requirements of ADS- 11 and AR 70-7 1. Properties of such materials should be determined as described in paragraph 6.4.3.2.2, and components should demonstrate resistance to nuclear blast pressure, thermal shock, radiation, biological and chemical agents, and laser energy. Potential hazards of agent absorption and desorption should be **minimized**, and components should be resistant to the decontaminating agents used by the Army.

6.6.7.1.5.3 Corrosion resistance. Aircraft composite components should meet the corrosion prevention guidelines of this ADS handbook (Chapter 7) and of TM l-1500-344-23. Particular attention should be given to areas, such as joints and fittings, where dissimilar materials are in contact and galvanic potentials may arise. For example, composite- materials containing carbon/graphite inherently promote corrosion if not properly designed or isolated. Sufficient electrical insulation should be provided between incompatible materials to eliminate the possibility of corrosion even in harsh environmental conditions. Where applicable, corrosion prevention compounds and/or protective coatings should be specified.

6.6.7.1.5.4 Water/fluid integrity. Aircraft structures and components made from composite materials should be designed to resist the penetration and/or transmission of water or aircraft fluids. This is particularly important when composites are used as skins and panels which are designed to protect an interior structure or compartment, or when they form the walls of tanks or reservoirs. The composite material should have sufficiently low permeability to the fluid, it should have adequate thickness, it should be free of significant voids, and cut edges should be avoided or protected. Any joints and/or fittings should be adequately sealed. Component fluid integrity should verified by appropriate tests, such as those for rain and leakage resistance in MIL-STD-8 10 (Methods 506 and 5 12), RCTA/DO- 160 (Section 10.0), MIL-W-6729, or equivalent, and those required by the certification and quality assurance provisions of individual component specifications.

6.6.7.1.6 Thermal characteristics. Composite materials should usually be designed for material properties exhibited at temperature extremes. The effects of temperature should be characterized and evaluated as thermal spikes, constants, and cycles which are representative of actual flight conditions. Thermal and fatigue degradation should be considered as part of the selection criteria.

a. The variations in thermal expansion between fibers and matrices can cause microcracking during either thermal cycling or thermal spikes. Differential coefficients of thermal expansion between adjacent materials, due to either different material compositions or reinforcement orientations, can result in thermally-induced or residual stresses which may be detrimental to aircraft component performance.

b. As a general guideline, composite materials should exhibit a wet glass transition temperature (paragraph 6.4.4.4.1) of at least 28°C (50°F) greater than the service temperature requirement or the maximum design temperature of the structural component in order to be deemed suitable for the application.

6.6.7.1.6.1 Flammabilitv. Flammability requirements for composite materials used in aircraft applications should be in accordance with FAR Part 25 and FAA AC 20-107A. Flammability properties should be determined as described in paragraph 6.4.4.7.1. In general, nonflammable and self-extinguishing materials are required in aircraft.

6.6.7.1.7 Electrical/electromagnetic characteristics. The electrical properties of composite materials can be important to the design of composite components, and they should be determined as described in paragraph 6.4.5. Electromagnetic environment effect (E^3) factors which should be considered in the design include the effects of electromagnetic interference (EMI) on aircraft equipment, nuclear electromagnetic pulse, and lightning. Since composite materials generally have low conductivity, proper shielding should be incorporated into the composite design when necessary, and electrical continuity in accordance with MIL-B-5087 or equivalent should be maintained when required without promoting galvanic corrosion. EM1 effects on equipment should be determined in accordance with MIL-STD-46 1, MIL-STD-462, and MIL-E-605 1, or equivalents. Radar cross section and reflection/transmission is also dependent upon the electrical characteristics of the composite material. A design balance will most likely be necessary to optimize low radar observability and any other required radar characteristics while providing sufficient electrical shielding.

6.6.7.1.7. 1 Lightning protection. Composite material structures and components should be adequately protected from the adverse effects of lightning, in accordance with DOD-STD- 1795, FAA AC 20-107A, and MIL-B-5087, or equivalents. Electrically-conductive meshes, foils, and/or coatings should be used when necessary, and sufficient electrical continuity between components and at joints should be ensured. Testing to determine the effects of lightning should be in accordance with RCTA/DO-160 (Section 23.0) or equivalent.

6.6.7.2 Processabilitv and producibility. Material processability and producibility should be considered early in the design of composite components. Potential composite materials should undergo extensive processing and manufacturing studies to ensure that production requirements can be met with minimum risk and to establish limits of design and manufacturing flexibility. Guidelines for composite material processing and production can be found in DOD/NASA Structural Composites Fabrication Guide, MIL-HDBK-17 (Volume III), MIL-HDBK-754, MIL-STD-1587, and MIL-P-9400.

6.6.7.2.1 Processing feasibility considerations. Compatibility with the shop floor environment is essential to the successful production of composite components. The ability to use manual and/or automated manufacturing processes should be evaluated to predict material utilization and production costs. Evaluations should include raw material handling requirements (acceptance procedures, storage, shelf lives, out-time), available facilities (environmental controls, cleanliness considerations), processing/lay-up/molding/ winding factors (uncured/unfused resin characteristics, tack, drape/boardiness, ply cutting and placement, reinforcement alignment/uniformity, ply build-ups/drop-offs, consolidation/debulking), solvent effects, tooling and equipment requirements, matrix curing/post-curing/fusion factors (temperature and pressure requirements, application methods/rates, and sensitivity to variations), machining/drilling/trimming operations, bonding/assembly operations, scrap rework and reprocessing feasibility, sealing and finishing processes, and inspectability of interim steps and the fmal component. Materials should have an adequate processing window, sufficient to allow families of parts to be processed during the same process cycle while ensuring that design allowable material properties are achieved. Methods for improving manufacturing efficiency by minimizing processing steps, such as by co-curing and/or co-bonding, should be investigated and implemented when feasible. Studies should. be done to evaluate the effects of processing variations on the properties of the final part and to ensure that manufacturing consistency is achievable.

6.6.7.2.2 Health/safety risks. The selected composite materials and all associated materials and processes should not pose significant health or safety threats to workers/ operators or to the environment. Such hazards should be avoided through the use of nontoxic/nonflammable materials whenever possible and through the use of reasonable protective equipment and precautions. All materials and processes should be in compliance with OSHA and EPA requirements.

6.6.7.2.3 Processing: validation/verification. Some full scale parts representative of the intended application should be included in the test matrix to properly validate the composite material manufacturing processes and to verify form, fit, and function with the overall aircraft structure. Final part quality and acceptability limits should be fully evaluated, including surface quality, microcracking, wrinkles, porosity/voids/ delaminations, foreign matter inclusions, reinforcement misalignment/waviness/washout, reinforcement breakage, resin richness/starvation, glass transition temperature, warpage, and cured ply thickness. Component performance, as dictated by the critical characteristics of the intended part, should be established as a function of potential manufacturing variations, and the maximum allowable defects should be defmed by type, quantity, and distribution. Repeatable cured-ply thickness is important from a fit-up and moldline conformance standpoint, and component interchangeability should be verified where applicable.

6.6.7.2.4 Tooling/fabrication feasibility. Tooling and fabrication materials and concepts should be evaluated to ensure that production is feasible and that part quality is repeatable. Appropriate process cycles and equipment should be developed to maintaii consistent heating/cooling rates, thermal distribution, dimensional tolerance and stability, vacuum retention, and any other important factors.

6.6.7.2.5 Processing quality control. Material and process specifications should be 'developed for composite materials prior to their use in aircraft applications. The material supplier should be able to demonstrate the stability of their material during development and manufacturing to justify selection. The overall processing and producibility characteristics of the composite material should be summarized and related to design, manufacturing, and supportability considerations prior to any fmal material selection and usage.

6.6.7.3 Adhesive/sealant bonding characteristics. The design of adhesive bonds/joints and the selection of adhesives and sealants for composite materials should be in accordance with the guidelines of MIL-HDBK-69 1, MIL-HDBK-454 (Requirement 23), MIL-HDBK-725, and appropriate contractor or commercial/industrial specifications.

6.6.7.3.1 Bondability/suitable adhesives. Adhesives and sealants intended for use with composite materials should be fully characterized and qualified in accordance with appropriate Government, contractor, or commercial/industrial specifications. Material properties similar to those listed in section 6.4 should be ascertained to develop databases for each adhesive and sealant under consideration. Appropriate primers compatible with both the intended adhesive/sealant and the adherend(s) should also be evaluated. The suitability of an adhesive or sealant for a particular composite material and application should be verified through appropriate tests. These include, but are not limited to, lap shear tests (ASTM D- 1002, ASTM D-3 163, ASTM D-3 164, ASTM D-3 165, ASTM D-3528, or equivalent), peel tests (ASTM D-903, ASTM D-178 1, ASTM D-1876, ASTM D-3 167, or equivalent), cleavage tests (ASTM D-3807, SAE J 1882, or equivalent), impact tests (ASTM D-950 or equivalent), tensile tests (ASTM D-897, ASTM D-952, ASTM

D-2095, or equivalent), compressive tests (ASTM D-905 or equivalent), flexure tests (ASTM D-l 184 or equivalent), creep tests (ASTM D-2990 or equivalent), and fatigue tests (ASTM D-3 166 or equivalent). Cure requirements of adhesives and sealants should be evaluated to ensure that the required conditions do not adversely affect the composite material.

6.6.7.3.2 Adhesive durability. Durability tests, such as ASTM D-896, ASTM D-l 15 1, ASTM D-l 183, ASTM D-1828, ASTM D-2918, ASTM D-2919, or equivalents, should be done to establish the effects of environment (temperature, moisture, aircraft fluids, etc.) and anticipated load spectra on the adhesive/sealant material and its bonding properties. Bond criticality assessments should be made to determine which bonds are important to the composite component structure, particularly when safety-of-flight is involved. For parts in which safety-of-flight is an issue, full scale environmental testing of actual adhesive bonds should be done to verify design acceptability. For non-safety-of-flight parts, representative coupon testing of adhesive bonds is adequate to validate performance.

6.6.7.3.3 Surface preparation/processing guidelines. Adherend surface preparation is important for the successful adhesive bonding of composite materials. Such preparations should ensure that detrimental surface contaminants are not pre sent and that surfaces are amenable to adhesive bonding, in accordance with the guidelines of MIL-HDBK-69 1, ASTM D-2093, or appropriate contractor or commercial/industrial specifications. Adhesive bonding processes should be done in accordance with MIL-A-83377 or equivalent. Adhesive storage, handling, mixing/preparation, application, and precautions should be in accordance with the recommended procedures of the adhesive manufacturer and with the appropriate contractor processing specifications. Quality control measures should be implemented to verify the acceptability of adhesive materials prior to use and to ensure that bonding requirements are met. Proper environmental conditions (temperature and humidity) and cleanliness should be maintained whenever adhesive bonding operations are performed.

6.6.7.4 Reliability/maintainability/supportability. Composite materials selected for Army aircraft applications should be highly durable, compatible, and supportable under actual service conditions, as demonstrated by appropriate testing or by actual service experience with the material. Guidelines for designing composite components with regard to reliability, maintainability, and supportablilty can be found in MIL-HDBK- 17 (Volume III, Chapters 6 and 8), USAAVSCOM TR-85-D-12, and DOD/NASA Advanced Composites Design Guide (Chapter 1.10).

6.6.7.4.1 Material durability. Durability of materials is measured in terms of mean time between maintenance actions and the extent of required actions. This performance aspect can be characterized up front through appropriate tests which simulate the operational environment, as described in paragraph 6.6.7.1.5, and potential ground handling and combat damage. Visible damage tolerance criteria should be established as a guideline to minimize maintenance actions, ideally without significant weight penalty.

6.6.7.4.2 Material compatibility. Compatibility between the composite material and other materials selected for the aircraft should be established to ensure that the overall material system will be fully integrated and that maintenance will be minimized. Compatibility tests include fluid resistance, corrosion prevention schemes, electrical compatibility, and sealant and adhesive bonding, as described in paragraphs 6.6.7.1.5.1, 6.6.7.1.5.3, 6.6.7.1.7, and 6.6.7.3, respectively.

6.6.7.4.3 Material supportability. Supportability of composite material aircraft components is essential. As such, composite components should be supportable at all levels of maintenance. Unit level maintenance is preferable to intermediate level, which is in turn preferable to depot level. Components should be repairable or replaceable as efficiently as possible, and any routine maintenance operations should not require undue effort. The design goal should be to minimize the amount of time, equipment/facilities, and personnel skill/training required for maintenance actions while maintaining the required performance level of the component and the aircraft.

6.6.7.4.4 Repairability/repair methods. Guidelines for the development of repair methods for composite structures and components can be found in USAAVSCOM TR-85-D-12 and AFWAL Advanced Composite Repair Guide. Guidelines for adhesive bonded repairs of aircraft structures are contained in MIL-HDBK-337. The goal of composite repairs should be to return defective or damaged components to their designed or original level of performance and appearance (or at least to the minimum design requirements for the application) without creating any adverse effects. Factors to be considered include restoration of structural integrity (strength, stiffness, stability), environmental resistance, functional performance, aerodynamic smoothness, safety, cosmetic appearance, and service life/durability. Emergency temporary repairs may also be occasionally required for composite structures, particularly in combat situations when battle damage has occurred, and the capability and speed of performing such repairs should be considered in composite component design.

a. Compatibility with current repair technology and support equipment should be a strong consideration during material selection. Material repair and maintenance should be evaluated and demonstrated to provide a high level of confidence that, if selected, the composite material will be fully supportable. Considerations for material repairs include proper damage assessment, allowable repair limits, the removal at&replacement of finishes/coatings, preparation of damaged areas (damage removal, cleaning, drying, etc.), specific repair materials (configurations, compatibility), repair kit design (consumable and reusable items, practicality and versatility, storage requirements, and useful life expectancy), adhesive bonding repair versus mechanical fastener repair options, weight and balance factors, any time requirements for repairs (i.e., maximum aircraft downtimes, out-time/pot life restrictions), the development of suitable repair procedures and operations, costs, safety/health precautions, ‘and the skill/training, equipment, and facilities required for accomplishing the repair procedures.

b. Repair methods should be validated by appropriate materials tests to verify that the specified repairs are adequate from both structural and environmental viewpoints. Nondestructive inspection (NDI) and/or testing techniques should be investigated, developed, and specified as part of the repair procedure to the extent that composite material damage can be accurately characterized and repairs can be verified as having been properly and acceptably done. Possible NDI methods are described in MIL-HDBK-337.

6.6.7.5 Survivabilitv. Some survivability issues related to the use of composite materials in aircraft applications have been previously described, including low radar observability (paragraph 6.6.7.1.7), NBC/laser resistance (paragraph 6.6.7.1.5.2), battle damage repair (paragraph 6.6.7.4.4), flammability (paragraph 6.6.7.1.6. 1), and lightning protection (paragraph 6.6.7.1.7.1). Other factors which should be considered in composite component design include damage tolerance and crashworthiness. One additional consideration should be the infrared observability of the composite component. If the selected material does not have inherent low infrared reflectivity, proper protective measures should be incorporated into the component&sign.

6.6.7.6 Sources and supply. As part of the qualification program of a composite material for Army aircraft applications, the contractor should ensure that the supply of the material meets all quality, repeatability, cost, and schedule requirements.

6.6.7.6.1 Control of material variations. Consistent material composition and characteristics are important from a design perspective in that they are related to the establishment of the statistical variance associated with the design allowables. If defective material is produced and used in aircraft structure, structural integrity may be compromised and design margins may be exceeded during service. Aerospace grade composite materials should meet strict quality standards through all stages of matrix, reinforcement, and prepreg manufacture and delivery. Reinforcement manufacture should be a highly automated and controlled process. Matrix resin formulation and synthesis should be controlled to maintain consistent physical and mechanical properties. Prepregging technology should maintain high quality levels to control factors which can affect composite mechanical properties and producibility, such as reinforcement wetout, tension, and alignment, areal weight, and resin content. A composite material supplier should establish the ability to strictly control each critical material processing step for the entire lifetime of the production program, and it should be able to meet stringent supply requirements with a high level of confidence.

6.6.7.6.2 Second-source materials. A second source for any composite material to be used in aircraft applications should be established by the contractor, in order to ensure material availability and to promote competitive acquisition. This second source should have the capability of producing material which is identical to that chosen for the application but which is manufactured at independent facilities. Second-source materials should meet all of the appropriate Government, contractor, and commercial/industrial specifications and match the qualification requirements of the original material, fully supporting the design allowables, packaging requirements, life requirements, and physical requirements for the intended application. Any change in the material manufacturing process or formulation will necessitate a requalification of the second-source material.

6.6.7.7 Cost criteria. Advanced composite material costs can be broken down into material procurement costs, fabrication/assembly costs, and maintainability/supportability costs. Material procurement costs include materials acquisition, storage, and incoming material inspection testing. The cost of fabricating advanced composites is usually significantly greater than the material procurement costs. Fabrication and assembly costs include all those associated with procedures and operations, quality control/inspection, tooling, capital depreciation, overhead requirements, and labor required to produce the finished product. A detailed breakdown of costs associated with the manufacturing of parts should be done to compare the cost advantages and disadvantages of various candidate materials, product forms, and processes. Scrap and rework rates should also be included in the fabrication cost analysis. Maintainability and supportability costs include those associated with required maintenance,’ repairs, and/or replacement of the component over the lifetime of the aircraft. A design or materials choice may be possible which minimizes such costs. Guidelines for optimizing composite material components through a design-to-cost process can be found in DOD/NASA Advanced Composites Design Guide (Chapter 1.8).

6.7 Control of composite material processing.

6.7.1 Production controls. Manufacturing and fabrication of composite materials and components for Army aircraft applications should be in accordance with FAA AC 21-26 and appropriate Government, contractor, and commercial/industrial specifications. A production plan should be developed, detailing the manufacturing methods, controls, cost estimates, and specifications which will be used. Such specifications should include appropriate materials specifications/documentation (qualification, conformance, and procurement requirements), tooling and process specifications, and requirements for the manufacturing environment. Processing conditions and procedures should be equivalent to those used to produce specimens for material allowables and qualification tests. Guidelines for composite fabrications can be found in section 6.6.7.2 and in DOD/NASA Structural Composites Fabrication Guide, MIL-HDBK-17 (Volume III, section 2.5), and MIL-HDBK-139. Statistical process controls (SPC) should be incorporated in order to minimize batch-to-batch variations in materials, lay-up, and/or cure cycles, thereby ensuring production consistency and helping to minimize production costs.

6.7.2 Quality controls. Quality assurance and control of composite material manufacturing should be in accordance with FAA AC 2 l-26, MIL-HDBK-17, and MIL-I-6870, or equivalent, and with appropriate contractor or commercial/industrial specifications. Guidelines for quality control of composite materials can be found in DOD/NASA Advanced Composites Design Guide (Chapter 1.11) and MIL-HDBK-17 (Volume III, Chapter 3), including incoming materials certifications, tool proofing, process verifications, and nondestructive testing and inspections of composite components and structures. Appropriate documentation should be maintained as a record of successful completion of each composite manufacturing step.

6.7.2.1 Process control specimens. Whenever feasible, removable test coupons should be an integral part of critical composite component design to provide a means for evaluating component integrity and to verify the acceptability of the manufacturing cycle. Alternatively, representative test samples (travellers) should accompany components through all processing steps. Both destructive and nondestructive tests may be appropriate for such coupons, depending upon specification requirements. Process control specimens should be designed and test methods should be selected such that the critical quality characteristics of the composite component ‘will be monitored and that acceptable performance of the component will be ensured.

CHAPTER 7

CORROSION PREVENTION AND CONTROL

7.1 Introduction. The purpose of this chapter is to provide guidelines for the establishment of Corrosion Prevention and Control (CPC) programs for Army aviation systems. It describes what should be the managerial and technical goals of Army contractors in the design validation, development, and production phases of Army aviation systems relative to corrosion prevention and control.

7.2 Corrosion Prevention and Control program objective. The objective of CPC programs should be to minimize the life cycle cost of all Army aviation systems due to corrosion. This handbook:

a. Provides a mechanism for the implementation of sound materials selection practices and finish treatments during the design, development, production, and operational cycles of Army aviation systems.

b. Provides guidelines for the organization and implementation of a Corrosion Prevention and Control plan, finish specifications, and corrosion prevention maintenance procedures applicable to specific Army aviation systems.

7.3 Corrosion Prevention and Control program application. The detailed Corrosion Prevention and Control plan, finish specifications, and corrosion prevention maintenance procedures should apply to all elements of the design and procurement of Army aviation systems, including spare parts and components.

7.4 General Corrosion Prevention and Control program guidelines. A Corrosion Prevention and Control program for the development of specific Army aviation systems should be implemented through a contractor-prepared Corrosion Prevention and Control plan, contractor-prepared finish specifications, contractor-prepared system-peculiar corrosion prevention maintenance procedures, and a Government/contractor Corrosion Prevention Action Team (CPAT).

7.4.1 Corrosion Prevention and Control program documentation. The following documents should be prepared by the contractor during implementation of the Corrosion Prevention and Control program for each specific Army aviation system:

7.4.1.1 Corrosion Prevention And Control plan. The contractor should prepare a Corrosion Prevention and Control plan which describes the contractor's approach to Corrosion Prevention and Control measures that will be implemented for the purpose of minimizing or eliminating potential corrosion on the aircraft system being procured. This includes the installation of Government furnished equipment and contractor-designed associated ground equipment. The plan should also include:

a. A designation of the contractor organizational element that will be responsible for management of the Corrosion Prevention and Control plan.

b. The establishment of a materials review effort between ATCOM and the contractor to optimize materials selection for a particular application prior to design configuration and fabrication of any part or component.

c. The establishment of a test program to determine/verify the effectiveness of corrosion protection.

7.4.1.2 Finish specification. The contractor should prepare a finish specification which describes the specific corrosion protection finishes or techniques to be used on the various substrates of all components and assemblies to protect them against corrosion in the environments to which they will be exposed. This document should be prepared in accordance with MIL-F-7179 or equivalent.* The requirements contained in the finish specification should be included in all applicable production drawings.

7.4.1.3 System-peculiar corrosion prevention maintenance procedures. The contractor should prepare system-peculiar corrosion control procedures which detail the maintenance methods to be utilized by personnel in the unit, intermediate, and depot levels. Maximum use should be made of the Aircraft Weapons Systems Cleaning and Corrosion Control manual TM l-1500-344-23 and the Avionics Cleaning and Corrosion Prevention/Control manual TM l-1500-343-23. Through field inspections and CPAT feedback, this procedure should be updated as required. The procedure should also:

a. Base corrosion inspections on calendar time rather than on flight hours.

b. Identify corrosion-prone areas.

c. Establish corrosion limits that require replacement of parts, components, and assemblies.

7.4.2 Schedule for submission.

7.4.2.1 Corrosion Prevention And Control Plan. The initial draft of the Corrosion Prevention and Control plan should be submitted to ATCOM as a part of the proposal package. The plan should be submitted sixty days after contract award or in accordance with the Contract Data Requirements List (DD Form 1423). Revision of this document should be accomplished as required.

7.4.2.2 Finish specification. The finish specification should be submitted sixty days after contract award or in accordance with the DD Form 1423. Revision of this document should be accomplished as required to record any changes in materials and processes being used for corrosion prevention and control. Through design reviews, analysis of field reports, and field inspections, data should be collected and analyzed for required revisions to this document.

7.4.2.3 System-peculiar corrosion prevention maintenance procedures. A draft of the system-peculiar corrosion prevention maintenance procedures should be submitted prior to the critical design review or in accordance with the DD Form 1423. Revision of these procedures should be accomplished as required.

7.5 Implementation of the Corrosion Prevention Action Team.

7.5.1 Membership. The team should be chaired by an ATCOM representative and include engineering representatives from the contractor. The team should include members from ATCOM and the contractor organization as follows:

a. The contractor members of the CPAT should be the authoritative representatives necessary to ensure that proper materials, processes, and treatments are selected and are subsequently properly applied and maintained from the initial design state to the final deliverable hardware.

b. The ATCOM members of the CPAT should be as designated by the ATCOM Director of Maintenance. The Team should include representatives from:

(1) The Engineering, Maintenance, Readiness, and Material Management Directorates.

(2) The Program/Project/Product Manager Office(s).

(3) The Plant/Contractor Representative Office(s).

7.5.2 Duties. The primary function of the CPAT should be to ensure that the corrosion pervention goals of this handbook are attained. Periodic reviews of the design and facilities where parts are fabricated, processed, assembled, and readied for shipment should be held. Discrepancies should be documented and submitted for resolution.

7.6 Materials and processes selection considerations. The primary consideration in the design and construction of aviation systems should be the ability of the design to comply with structural and operational requirements. In addition, aviation components are expected to perform reliably and to require minimum maintenance over a specified lifetime. Therefore, in the selection of suitable materials and appropriate processing methods to satisfy structural requirements, consideration should also be given to those materials, processing methods, and protective treatments which minimize the rate of material deterioration and which reduce service failures due to corrosion of parts and assemblies in service. Deterioration modes which contribute to service failures include but are not limited to pitting corrosion, galvanic corrosion, exfoliation corrosion, stress corrosion, corrosion fatigue, thermal embrittlement, fretting fatigue, oxidation, hydrogen embrittlement, weathering, and fungus growth. In the entire design phase, attention should be given to precautionary measures which minimize deterioration of individual parts and assemblies as well as the entire system. Precautionary measures include proper selection of materials, limitations of design operating stresses, relief of residual stress levels, shot peening, heat treatments which reduce corrosion susceptibility, and protective coatings and finishes.

7.7 General design guidelines for corrosion prevention.

7.7.1 Exclusion of rain and airborne spray. The design of the system should prevent water leaking into, or being driven into, any part of the system interior, either on the ground or in flight. All windows, doors, panels, canopies, etc., should be provided with sealing arrangements such that the entry of water is minimized when these items are correctly closed. Fasteners should be installed into the airframe with a sealant, primer, or other suitable method such that leakage is prevented or minimized. Particular care should be taken to prevent wetting of equipment, heatproofmg materials, and soundproofing materials. The aircraft should satisfy the watertightness requirements of MIL-W-6729 or equivalent. Sharp interior comers and recesses should be avoided so that moisture and solid matter cannot accumulate to initiate localized attack. Sealed floors with suitable drainage should be provided for cockpits and cargo compartments. Adequate ventilation should be provided in all areas to prevent moisture retention and buildup.

7.7.2 Drainage. Drain holes should be provided to prevent collection or entrapment of water or other unwanted fluids in areas where exclusion is impractical. All designs should include considerations for the prevention of water or fluid entrapment and ensure that drain holes are located to effect maximum drainage of accumulated fluids. Actual aircraft configuration and attitude should be considered in addition to component design.

7.7.3 Dissimilar metals. The use of dissimilar metals (as defmed by MIL-STD-889 or equivalent) in contact should be limited to applications where similar metals cannot be used due to peculiar design requirements. When it is necessary to use dissimilar metals in contact, the metals should be protected against galvanic corrosion. Galvanic corrosion can be minimized by the interposition of a material which will reduce the overall electrochemical potential of the joint or by the interposition of an insulating or corrosion inhibiting material.

-7.8 Specific design guidelines for corrosion prevention of metallic materials.

7.8.1 Aluminum.

7.8.1.1 Allov selection. The stress corrosion cracking (SCC) resistance of aluminum alloys should be considered in their selection for structural applications in Army aviation equipment. Relative SCC ratings for high strength aluminum alloy products, based on standard tests (e.g., ASTM G-47 and ASTM G-64, or equivalents) and service experience, are provided in Table 1. An experience factor can be substituted for the ratings of those materials which have established service records. The ratings presented in Table 1 are for the short transverse test direction, as this is the most critical SCC condition in structural applications.

7.8.1.2 Sheet aluminum. All aluminum sheet used in external environments should be adequately protected from corrosion by cladding or by an appropriate surface finish/ treatment. Cladding should not be used where the design requires 1) surface metal removal by machining or chemical milling, 2) adhesive bonding, or 3) the use of alloys of the 5000 or 6000 series type.

7.8.1.3 Aluminum allov selection limitations. Mill-product forms of aluminum alloys 2020, 7079, and 7178 in all temper conditions should not be used for structural applications. The use of 7XXX-T6 aluminum alloys should be limited to a thickness not to exceed 4.80 mm (0.190 inch). The use of 2000 series aluminum alloys in the T3 and T4 tempers should be quantitatively justified.

TABLE 1. Corrosion characteristics of aluminum alloys.

Alloy and Temper	Rolled Plate	Rod and Bar	Extruded Shapes	Forgings
2014-T6	Poor	Poor	Poor	Poor
2024-T3, T4	Poor	Poor	Poor	
2024-T6		Good		Poor
2024-T8	Good	Excellent	Good	Intermediate
2124-T851	Good			
2219-T3, T37	Poor		Poor	
2219-T6, T8	Excellent	Excellent	Excellent	Excellent
6061-T6	Excellent	Excellent	Excellent	Excellent
7049-T73	Excellent		Good	Good
7149-T73			Good	Good
7049-T76			Intermediate	
7X75-T736				Good
7050-T736	Good		Good	Good
7050-T76	Intermediate		Intermediate	
7X75-T6	Poor	Poor	Poor	Poor
7X75-T73	Excellent	Excellent	Excellent	Excellent
7X75-T76	Intermediate		Intermediate	

7.8.1.4 Maximum metal removal. Maximum metal removal from surfaces on non-stress-relieved structural parts after final heat treatment should not exceed 3.80 mm (0.150 inch) per side. This limit does not apply if the final temper condition can be demonstrated to have a stress corrosion resistance of 175 MPa (25 ksi) or higher in the short transverse grain direction, as determined by a 20-day alternate immersion test in accordance with ASTM G-47 (Method 76) or equivalent. This requirement is applicable to 2000 and 7000 series alloys, but a 30-day test should be used on 2000 series alloys. Maximum metal removal requirements do not apply to mechanically stress-relieved products because of the low level of internal stresses resulting from mechanical stress-relieving.

7.8.1.5 Shot peening for stress corrosion resistance. The surfaces of all structural forgings, machined plate, and extrusions (where accessible after final machining and heat treatment) should be placed in compressionby shot peening or similar means, using a minimum of two coverage passes and in accordance with an appropriate Government, contractor, or industrial/commercial specification. Alloys having a stress corrosion resistance of 175 MPa (25 ksi) or higher in the short transverse direction and web areas under 2.0 mm (0.080 inch) thick, where no short transverse grain is exposed by machining, should not be shot peened. Those areas of forgings requiring lapped, honed, or polished surface finishes for functional engineering requirements should be shot peened prior to such subsequent surface finish operations. Aluminum forgings with a stress corrosion threshold less than 175 MPa (25 ksi) should, after shot peening, have essentially no residual surface tensile stresses in the final heat treated and machined condition. For aluminum alloys, surface removal during finish clean-up of shot peened surfaces, as required for fit-up, should not exceed 10 percent of the "A" intensity arc height.

7.8.1.6 Stress corrosion factor. High strength aluminum alloy parts should be designed, manufactured, assembled, and installed so that sustained residual tensile stresses are minimized to prevent premature failures due to SCC. Stretch stress-relieved or compression stress-relieved aluminum products should be used wherever possible.

7.8.2 High strength low allov steels.

7.8.2.1 Protective metallic coatings. High strength, low alloy steel parts and fasteners, 1250 MPa (180 ksi) ultimate tensile strength (UTS) and above, should be protected by a corrosion preventive metallic coating. Such coatings should be applied by a process which has been proven to be nonembrittling to the alloy/heat treatment combination. Surface coatings which are used in sliding or wear applications should have sufficient inherent hardness and durability or should be suitably treated to provide durability. Soft coatings, such as cadmium and aluminum, should not be used for sliding/wear applications. Metallic coatings should be chosen to be appropriate for the expected service temperature extremes, and such coatings should have no adverse affects on aircraft fluids such as fuels and lubricants. Cadmium-plated surfaces should not be used in applications where surface temperature exceeds 230°C (450°F). Cadmium should not be used on fuel or lubricating system components that can come into contact with the fuel or lubricating oils (synthetic or mineral based), due to the potential adverse effects which cadmium can have on these fluids. Cadmium-plated fasteners, if used in areas where direct contact with fuels or lubricants can occur, should be overcoated with a protective coating or sealant. The use of chromium plating for corrosion protection of alloy steel wear surfaces in interior environments is acceptable. For applications involving exposure to the exterior environment, chromium plating should be considered to provide acceptable corrosion protection of alloy steel wear surfaces only when the chrome plating is periodically lubricated (fluid or grease types only) or a 0.040 mm (0.0015 inch) minimum layer of nickel plating is applied under the chrome. All chrome-plated steel parts used in fatigue applications should be shot peened prior to plating. Chrome-plated surfaces should not be used in applications where service temperatures exceed 370°C (700°F). The use of dissimilar metallic coatings in contact should be avoided whenever possible, particularly for steels above 1250 MPa (180 ksi) UTS.

7.8.2.2 Stress corrosion factors. Alloy steel parts heat treated to 1250 MPa (180 ksi) UTS and above should be designed, manufactured, assembled, and installed such that sustained residual surface tensile stresses are minimized to prevent premature failures due to SCC. Whenever practicable, the use of press or shrink fits, tapered pins, clevis joints in which tightening of the bolt imposes a bending load on the female lugs, and straightening or assembly operations that result in sustained residual surface tensile stresses in these materials should be avoided. In cases where such practices cannot be avoided, parts should be protected by such methods as stress relief heat treatments, optimum grain-flow orientation, wet-installed (with a protective material) inserts and pins, or shot peening or similar surface working to minimize the hazard of SCC or hydrogen embrittlement damage.

7.8.3 Corrosion resistant steels.

7.8.3.1 Corrosion characteristics. Table 2 should be used as a guide in the selection of corrosion resistant steels for structural applications.

7.8.3.2 Surface treatments. All corrosion resistant steels should be passivated in accordance with an appropriate Government, contractor, or industrial/commercial specification, such as QQ-P-35, ASTM A-380, or equivalent. In addition, 400 series martensitic steels should be protected against corrosion by coatings or other suitable means.

7.8.3.3 Limitations. Corrosion resistant precipitation hardening steels should not be used in the H900 condition. Corrosion resistant maraging, Almar series, custom series, etc., steels should not be used in sustained load applications. Corrosion resistant 19-9DL and 43 1 steels should not be used for any aircraft applications. Series 400 martensitic grade corrosion resistant steels should not be used in the 1050 to 1250 MPa (150 to 180 ksi) strength range. Unstabilized austenitic steels may be used up to 370°C (700°F). Welded assemblies thereof should not be used unless they have been given a solution heat treatment after welding (except for the stabilized grades 321 and 347, ELC 304, and ELC 316).

TABLE 2. Corrosion characteristics of corrosion resistant steels,

Class	Alloy	General Corrosion Resistance	Stress Corrosion Resistance
Austenitic	301	Excellent	Excellent
	316(ELC)	Excellent	Moderate
	347	High	Excellent
	A286	High	Excellent
	321	High	Excellent
	304(ELC)	High	Excellent
	302	High	Excellent
	304	High	Excellent
	310	Excellent	Excellent
Martensitic	440C	Low to Moderate	Susceptibility varies significantly with composition, heat treatment, and product form
	420	Low to Moderate - Will develop superficial rust film with atmospheric exposure	
	410		
	416		
Precipitation Hardening	21-6-9	Moderate	Susceptibility varies significantly with composition, heat treatment, and product form
	PH13-8MO	Moderate	
	PH15-7MO	Moderate	
	PH14-8MO	Moderate	
	17-4PH	Moderate	
	15-5PH	Moderate	
	AM355	Moderate	
	AM350	Moderate	

7.8.4 Titanium.

7.8.4.1 Surface considerations. The surfaces of titanium mill-products (sheet, plate. bar, forging, and extrusion) should be 100 percent machined, chemically milled, pickled, or otherwise processed to remove all contaminated zones and layers formed while the material was at elevated temperature. This includes contamination which results from mill processing, heat treating, and elevated-temperature forming operations.

7.8.4.2 Fretting. Titanium alloys are highly susceptible to the reduction of fatigue life by fretting at interfaces between titanium or titanium alloys and other metals. In any design where fretting is suspected, tests should be made to determine whether such a condition will exist. Design considerations should be applied to minimize fretting in structural applications.

7.8.4.3 Special precautions. Titanium parts should not be plated with or come into contact with incompatible metals, such as cadmium. Cadmium plated clamps, fixtures, and jigs should not be used for the fabrication or assembly of titanium components or structures. Silver brazing of titanium parts should be avoided for elevated temperature applications.

7.85 Magnesium. Whenever magnesium alloys are used, parts should be adequately protected from corrosion, from damage due to abrasion, environmental conditions, or abuse, and from fluid/moisture entrapment. Such parts should be readily accessible for inspection, repair, and replacement. Magnesium use should be restricted to noncorrosion-prone areas where adequate protection systems can be maintained with ease and high reliability. Magnesium alloys should not be used in primary flight control systems, for landing gear wheels, for primary structures, or for areas subject to abuse, to foreign object damage, or to abrasion.

7.8.6 Bervllium. In applications where beryllium is the selected material, parts should be adequately protected against corrosion by suitable protective coatings. Tests should be conducted to determine the suitability of the corrosion protection under conditions simulating the expected corrosive environment.

7.8.7 Mercury. Mercury and many compounds containing mercury can cause accelerated stress cracking of aluminum and titanium alloys. If devices containing mercury are used on installed equipment or during production where spillage can contact these alloys, suitable protective measures should be employed.

7.8.8 Depleted uranium. Depleted uranium should be suitably plated/coated to provide adequate corrosion protection. Nickel-plating per MIL-P-274 18 or equivalent plus one coat of MIL-P-23377 Type I or equivalent primer having a thickness of 0.015 to 0.025 mm (0.0006 to 0.0009 inch) has been found to be effective for this purpose.

7.9 Insulating blankets. Where thermal/accoustical insulating blankets are required, they should be either procured with a permanent ‘(e.g., baked-on) water-repellant binder system or suitably protected with sealant to prevent any moisture absorbed by the blanket from contacting any metal structure. The blankets should be attached to the aircraft frame members, and contact with metal aircraft skins should be avoided.

7.10 Electronic equipment. The contractor should ensure that electronic parts and components in Army aviation weapon systems are adequately protected from corrosion in accordance with appropriate Government, contractor, or industrial/commercial specifications, such as MIL-P- 11268, MIL-HDBK- 1250, or equivalent. The use of organic materials for the fabrication of avionic and electronic components, particularly hermetically-sealed microcircuits, should be quantitatively justified through property trade-off analyses.

7.11 Corrosion prevention during, manufacturing operations. Adequate precautions should be taken during manufacturing operations to maintain the integrity of corrosion prevention measures and to prevent the introduction of corrosion or corrosive elements.

7.11.1 Cleaning. Cleaning of the various types of metallic surfaces prior to the application of surface treatments and coatings should be as specified in appropriate Government, contractor, or industrial/commercial specifications, such as MIL-S-5002 or equivalent. Cleaning materials and processes should have no damaging effects (i.e., pitting, intergranular attack, or significant etching) on the metal surfaces. After cleaning, all parts should be completely free of corrosion products, scale, paint, grease, oil, flux, and other foreign materials, including other metals, and should be given the specific treatment as soon as practicable after cleaning. Particular care should be exercised in the handling of parts to assure that foreign metals are not inadvertently transferred, as may occur when steel is allowed to come into contact with zinc.

7.11.1.1 Cleaning after assembly. All closed compartments should be cleaned after assembly to remove debris such as metal chips, broken fasteners, and dust. Particular attention should be given to ensure that drain holes are not blocked.

7.11.1.2 Titanium contamination. Care should be taken to ensure that cleaning fluids and other chemicals are not used on titanium assemblies where entrapment can occur. Substances which are known to be contaminants and which can produce stress corrosion cracking at various temperatures include hydrochloric acid, trichlorethylene, carbon tetrachloride, chlorinated cutting oils, all chlorides, freons, and methyl alcohol.

7.11.2 Surface damage. Damage to any previously-applied surface treatment or protective finish should be repaired. Damage to surfaces which will become inaccessible because of mating with other parts should be repaired/touched-up prior to mating. Organic coatings used for repair should be the same as those on the undamaged areas.

7.11.3 Marking pencils. Marking pencils should have no corrosive or deleterious effects on the surfaces of aircraft parts or components. Ordinary lead pencils containing graphite should not be used to mark metal parts. Nongraphitic marking pencils which meet appropriate Government, contractor, or industrial/commercial specifications should be used.

7.11.4 Protection of parts during storage and shipment. All parts and assemblies should be given adequate protection to prevent corrosion and physical damage during temporary or long term storage and shipment.

7.12 Inorganic finishes. Cleaning, surface treatments, and inorganic finishes for metallic surfaces of Army aviation weapon systems parts and components should be in accordance with appropriate Government, contractor, or industrial/commercial specifications, such as MIL-S-5002 or equivalent. On parts or surfaces of parts which are located in corrosion susceptible areas or which form exterior surfaces of the system, chemical finishing should be used to provide maximum corrosion resistance.

7.12.1 Aluminum. Parts made from aluminum alloys should be anodized as necessary in accordance with appropriate Government, contractor, or industrial/commercial specifications. Nonclad parts made from 7000 series aluminum alloys should be sulfuric acid anodized in accordance with MIL-A-8625 (Type II) or equivalent. They may be chromic acid anodized, in accordance with MIL-A-8625 (Type I) or equivalent, provided that the anodized 7000 series test specimens meet the weight and corrosion resistance requirements of MIL-A-8625 (Type II) or equivalent. Nonclad parts made from 2000 series aluminum alloys should be anodized in accordance with MIL-A-8625 (Type I or II) or equivalent. Clad 2000 series, unclad or clad 6000 series, and clad 7000 series aluminum alloys may be anodized in accordance with MIL-A-8625 (Type I or II) or equivalent, or a chemical film in accordance with MIL-C-5541 or equivalent should be used as a minimum corrosion preventive coating. Aluminum alloy parts that are used in electrical applications requiring grounding to structure should be treated with a chemical film per MIL-C-5541 or equivalent. Fatigue-critical parts should not be sulfuric acid anodized. When adhesive bonding characteristics are deemed to be critical, phosphoric acid anodizing in accordance with an appropriate Government, contractor, or industrial/commercial process specification, such as ASTM D-3933 or equivalent, may be used.

7.12.2 Cadmium coatings. Cadmium coatings should be used only when no other coating method is acceptable. Such coatings should be applied in accordance with appropriate Government, contractor, or industrial/commercial specifications. For all steel parts, including fasteners, cadmium coatings should have a minimum thickness of 0.008 mm (0.0003 inch) and should be subsequently treated with a chromate conversion coating or equivalent. High strength steels having an ultimate tensile strength of 1250 MPa (180 ksi) and above should be coated with the titanium-cadmium process in accordance with MIL-STD-1500 or equivalent, the vacuum deposition process in accordance with MIL-C-8837 or equivalent, or a similar nonembrittling process.

7.12.3 Aluminum coatings. Ion vapor deposited (IVD) aluminum coatings, in accordance with appropriate Government, contractor, or industrial/commercial specifications such as MIL-C-83488 or equivalent, may be considered acceptable alternative coatings to cadmium for steel structures in Army aviation weapon systems. The contractor should verify that:

a. The IVD aluminum coating process meets current environmental cleanliness standards.

b. The IVD aluminum coating provides a high performance corrosion protective finish.

c. The performance of the part/structure is not adversely affected by the use of the IVD aluminum coating in lieu of cadmium plating.

7.12.4 Magnesium. Magnesium alloys should be treated in accordance with appropriate Government, contractor, or industrial/commercial corrosion prevention specifications, such as MIL-M-45202, MIL-M-3 17 1, or equivalent, prior to painting. Holes drilled subsequent to finish application should be treated in accordance with MIL-M-3 17 1 (Type VI) or equivalent.

7.12.5 Special plated part considerations. Cadmium- and silver-plated parts and fasteners should not be used in contact with titanium components if use temperatures are expected to exceed 230°C (450°F). Fasteners or components should not be plated with incompatible metals, such as titanium with cadmium. Cadmium-plated, aluminum,or other fasteners made or plated with susceptible metals should not be used in direct contact with conductive composite materials.

7.13 Organic finishes. All organic finishes and coatings should be consistent with the requirements of appropriate Government, contractor, or industrial/commercial specifications, such as MIL-F-7179 or equivalent. The organic finishes or finish systems used should provide the necessary protection against corrosion for all materials used in areas subjected to corrosive environments. Organic finishes, marking, and color schemes should be in accordance with TM 55-1500-345-23. The organic finish for Army aircraft should conform to MIL-C-46168, MIL-C-53039, or equivalent aliphatic polyurethane or to MIL-C-22750 or equivalent epoxy-polyamide, as applicable. It should provide appropriate resistance to chemical and biological agents and should be readily and effectively decontaminated after exposure to such agents. The finish should be resistant to all expected environmental conditions (fluids, temperature, weathering) and to cracking/ flaking, and it should have and maintain the required color, spectral reflectance, and specular reflectance. The finish should be applied over a compatible primer, such as MIL-P-23377, MIL-P-85582, MIL-P-53030, MIL-P-53022, or equivalent, which enhances finish durability and corrosion protection and which has suitable chemical/environmental resistance, reflectance, and strippability. Application of organic coatings should be in accordance with appropriate Government, contractor, or industrial/commercial application specifications and practices, such as MIL-C-53072 or equivalent. Justification data, including both laboratory and service experience, should be provided whenever finishes other than those described in this handbook are proposed.

7.14 Environmental sealing. Environmental sealing reduces or eliminates corrosion by excluding moisture and other corrosive substances from joints. It is important that the areas to be coated with sealant are adequately cleaned before sealant is applied. All joints and seams located in exterior or internal corrosive environments, including those in landing gear wells, control surface wells, attachment wells, and structures under fairings, should be sealed with materials which have suitable chemical resistance, corrosion inhibition, temperature resistance, and adhesive strength for the intended application, such as those which meet the requirements of MIL-S-8 1733, MIL-C-83982, MIL-S-8802, AMS 3276, or equivalents. MIL-S-8 1733 covers sealants which contain a soluble chromate content of 3 to 6 percent for corrosion inhibition and is the preferred type of sealant. For sealing high temperature areas, MIL-S-38249 or equivalent firewall sealant should be used. Removable panels and access doors should be sealed, either by mechanical seals or by a separable fay surface sealant such as MIL-S-8784 or equivalent. High-adhesion sealant such as MIL-S-8802 or equivalent may also be used for access door sealing if a suitable parting agent is used on one surface.

7.15 Fastener installation. Except as noted in paragraph 7.15.2, all permanently-installed fasteners used in areas up to 105°C (225°F) should be wet-installed with an appropriate sealant, such as a corrosion inhibiting sealant conforming to MIL-S-8 1733 or equivalent or an epoxy primer conforming to MIL-P-23377 or equivalent. In high temperature areas exceeding 105°C (225°F), MIL-P-23377 or equivalent epoxy primer or a sealant which is suitable for the thermal environment should be used. Fasteners in integral fuel tanks should be wet-installed with a sealant which has suitable chemical resistance, such as those conforming to MIL-S-8802, AMS 3276, or equivalent.

7.15.1 Removable fasteners. Quick release fasteners and removable fasteners penetrating exterior surfaces should be designed and installed so as to provide a seal which prevents moisture or fluids from entering. Holes for these fasteners should be protected from corrosion prior to installing the fastener by applying and curing a suitable material such as epoxy primer per MIL-P-23377 or equivalent. In system components that are sensitive to contamination from wear debris (e.g., in optical and avionic assemblies), wear-resistant fasteners should be used.

7.15.2 Fasteners in titanium. Titanium, monel, and stainless steel fasteners installed in titanium structures may be installed dry, unless sealing is required for liquid tightness or pressurization.

7.15.3 Monel and stainless steel fasteners. Monel fasteners or stainless steel fasteners should be appropriately protected when used in contact with aluminum components, such as by coating with cadmium or aluminum.

Certification Board Record

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AIR VEHICLE MATERIALS AND PROCESSES

General Type	Decision (check)	Certification
Specification		Performance
		Detail
Standard		Interface Standard
		Standard Practice
		Design Standard
		Test Method Standard
		Process Standard
Handbook	X	Handbook (non-mandatory use)
Alternative Action		

MEMBERS	Concur	Nonconcur	ADVISORS
Division	X		Secretariat
Directorate			
Center			
Standardization Executive	X		Proponent