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MILITARY STANDARD

POLYMER MATRIX COMPOSITES

FSC 9330

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DEPARTMENT OF DEFENSE

Washington, D. C. 20301

Polymer Matrix Composites

MIL-STD-1944

1. This Military Standard is approved for use by the Army Materials and Mechanics Research Center, Department of the Army and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, US Army Materials and Mechanics Research Center, ATTN: AMXMR-SMS, 405 Arsenal St., Watertown, MA 02172-2719 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD.

Military Standard 1944 was prepared for the Department of Defense (DoD) in accordance with standard procedure and in compliance with policies and requirements of the Defense Standardization and Specification Program (DSSP). This standard is intended to promote the standardization of polymeric composite materials and process engineering. This document has been extensively coordinated with government and industry to achieve consensus to the maximum extent. During preparation this document was coordinated with the Army, the Navy, the Air Force, NASA, the MIL-HDBK-17 Coordination Group, the ASTM D 30 Composites committee, the ASTM D 20 Plastics committee, the Aerospace Industries Association (AIA), more than 300 individual scientists and engineers in the aerospace and composites industries, and was also presented at the 30th National SAMPE Symposium/Exhibition.

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Note: Detailed requirements contained in this standard are grouped arbitrarily for ease of reference (e.g., chemical, physical, mechanical, etc.). Because some properties and test methods may be designated thermophysical, thermochemical, physicochemical, thermomechanical, etc., there is some overlap in categories which is unavoidable. The asterisk is intended to indicate sectionalized requirements. The purpose of a sectional format is to separately identify individual requirements or groups of requirements.

1. SCOPE

1.1 Scope. This standard prescribes technical requirements and quality assurance provisions which are used for the specification of polymer matrix composite materials. The scope of this standard encompasses the following:

a. Materials and processing terminology which is applicable to polymer matrix composite materials
b. Test methods for the material properties of resins, fibers, prepregs and laminated composite materials
c. Specifications for resins, fibers, prepregs, and laminated composite materials
d. Qualification procedures for polymer matrix composite materials

1.2 Application. This standard is intended to be used as a guide to standard test methods, material and process specifications, and qualification procedures for polymer matrix composite materials. This standard is also intended for use in the preparation of material and process specifications. This standard is applicable to thermoplastic and thermoset composites based on a wide variety of fiber reinforcements and forms including carbon, graphite, S2-glass, E-glass, quartz, aramid, boron and polycrystalline alumina, in woven fabric, unidirectional tape and roving. This standard applies to reinforced plastics and/or "advanced composite" materials (See also Appendix F). This standard is intended as a general guide and it is the responsibility of experienced engineering personnel to determine the applicability of its contents to a specific application.

1.3 Limitations. The preparing activity realizes that there are definitions, test methods, specifications and qualification procedures in use that are not contained in this standard. However, those that are contained herein have undergone coordination through an industry consensus process or through the DoD standardization process involved in the preparation of this standard. As a consequence, a certain degree of standardization has been achieved, and it is intended that MIL-STD-1944 will further enhance engineering standardization of polymer matrix composites. This standard does not address structural sandwich composites which are covered in MIL-HDBK-23 and MIL-STD-401, or nondestructive evaluation techniques which are covered in the DoD Standardization Area NDTI (Nondestructive Testing and Inspection) under separate documents.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this standard to the extent specified herein.

STANDARDS

MILITARY

MIL-STD-109	Quality Assurance Terms and Definitions
MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-490	Specification Practices
MIL-STD-810	Environmental Test Methods and Engineering Guidelines
MIL-STD-961	Military Specification and Associated Documents Preparation of
MIL-STD-962	Military Standards and Handbooks, Preparation of
MIL-STD-1587A(USAF)	Materials and Processes Requirements for Air Force Weapon Systems
MIL-STD-2089	Aircraft Nonnuclear Survivability Terms

HANDBOOKS

MIL-HDBK-17A	Plastics for Aerospace Vehicles - Part 1 - Reinforced Plastics
MIL-HDBK-139	Plastic, Processing of
DOD-HDBK-248A	Guide for Application and Tailoring of Requirements for Defense Materiel Acquisitions
MIL-HDBK-700	Plastics

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

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings and publications form a part of this standard to the extent specified herein.

U.S. ARMY

Army Materials and Mechanics Research Center (AMMRC)

AMMRC TR 82-27, "Studies of Tension Test Specimens for Composite Material," D.W. Oplinger, K.R. Gandhi, and B.S. Parker, April, 1982.

(Applications for copies of AMMRC publications should be addressed to the Army Materials and Mechanics Research Center, 405 Arsenal St., Watertown, MA 02172-2719.)

Army Regulations

AR 70-71 - Nuclear, Biological, and Chemical Contamination Survivability of Army Materiel

(Applications for copies of U.S. Army regulations should be addressed to Headquarters, Department of the Army, Washington, D.C.)

DARCOM (now Army Materiel Command)

DARCOM-P 706-314 - Engineering Design Handbook: Discontinuous Fiberglass Reinforced Thermoplastics

(Applications for copies of DARCOM publications should be addressed to the Defense Technical Information Center, Cameron Station, Alexandria, VA 22314.)

DEPARTMENT OF DEFENSE (DoD)

Advanced Composites Design Guide, Third Edition, Volume IV: Materials, January 1973, Chapter 4.0.5.

(Applications for copies of this guide should be addressed to the Air Force Materials Laboratory, Wright-Patterson Air Force Base, OH 45433.)

"Composites," Lessons Learned Bulletin, Directorate of Lessons Learned, Air Force Acquisition Logistics Center, WPAFB, OH, September 1984.

(Applications for copies of the lessons learned bulletin should be addressed to the Directorate of Lessons Learned, Air Force Acquisition Logistics Center (ATTN: AFALC/PTL), Wright-Patterson AFB, OH 45433.)

Defense Standardization Manual DoD 4120.3-M, Defense Standardization and Specification Program Policies, Procedures and Instructions, August 1978.

(Applications for copies of DoD 4120.3-M should be addressed to the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.)

Department of Defense Index of Specifications and Standards.

(Applications for copies of the DoDISS should be addressed to the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.)

DoD/NASA Structural Composites Fabrication Guide, Third Edition, Air Force Materials Laboratory (AFML), 1982. Published in 2 volumes.

Applications for copies of this guide should be addressed to the following activity:

Manufacturing Technology Division
Air Force Materials Laboratory
Air Force Wright Aeronautical Laboratories
Air Force Systems Command
Wright-Patterson Air Force Base, OH 45433

JCS Pub 1, Dictionary of Military and Associated Terms, Joint Chiefs of Staff, Washington, D.C., 3 September 1974.

Standardization Directory SD-6, "Provisions Governing Qualification (Qualified Products List)" (1 November 1979).

(Applications for copies of the SD-6 should be addressed to the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.)

"Standardization, Qualification, Certification," Proceedings of Colloquium/Workshop on Composite Materials and Structures, S.L. Channon Ed., Institute for Defense Analyses (IDA Record Document D-70), July 1984, p. S-6; Held at National Academy of Sciences, Washington, D.C. (May 8-10, 1984), Sponsored by Department of Defense, Office of Under Secretary of Defense for Research and Engineering.

(Applications for copies of the proceedings should be addressed to the Institute for Defense Analyses, 1801 N. Beauregard Street, Alexandria, VA 22311.)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

George C. Marshall Space Flight Center (MSFC)

MSFC Manual 8070.2F, Specifications and Standards, Approved Baseline List (October 15, 1984)

(Applications for copies of MSFC publications should be addressed to Systems Engineer, Specifications Program, Code EL03, George C. Marshall Space Flight Center, Huntsville, AL 35812.

Langley Research Center (LRC)

NASA RP-1092	Standard Tests for Toughened Resin Composites
NASA TM-85756	Effect of Impact Damage and Open Holes on the Compression Strength of Tough Resin/High Strain Fiber Laminates
NASA TM-86298	Standard Test Evaluation of Graphite Fiber/Resin Matrix Composite Materials for Improved Toughness

(Applications for copies of the NASA-Langley publications should be addressed to NASA, Langley Research Center, Hampton, VA 23665.)

Lyndon B. Johnson Space Center (LBJ)

JSC 02681	Nonmetallic Materials Design Guidelines and Test Data Handbook (January 1982)
JSC 08962 (Revision U)	Compilation of VCM Data of Nonmetallic Materials (September 1983)
SP-R-0022A	General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications (September 1974)

NASA RP-1014 An Outgassing Data Compilation of Spacecraft Materials

NASA RP-1061 Outgassing Data for Spacecraft Materials

(Applications for copies of NASA-LBJ publications should be addressed to NASA-LBJ Space Center, Houston, TX 77058.)

2.2 Other publications. The following documents(s) form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DoDISS.

ASTM STANDARDS

ASTM C 581 Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass Fiber Reinforced Structures Intended for Liquid Service

ASTM C 613 Standard Test Method for Resin Content of Carbon and Graphite Prepregs by Solvent Extraction

ASTM D 123 Standard Terminology Relating to Textiles.

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 A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials

ASTM D 257 Standard Test Methods for D-C Resistance or Conductance of Insulating Materials

ASTM D 276 Standard Methods for Identification of Fibers in Textiles.

ASTM D 543 Standard Test Method for Resistance of Plastics to Chemical Reagents

ASTM D 570 Standard Test Method for Water Absorption of Plastics

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 638 Standard Test Method for Tensile Properties 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

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 Specific Gravity and Density of Plastics by Displacement
ASTM D 883	Standard Definitions of Terms Relating to Plastics
ASTM D 885	Standard Methods of Testing Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made From Man-Made Organic-Base Fibers
ASTM D 907	Standard Definitions of Terms Relating to Adhesives
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D 1525	Standard Test Method for Vicat Softening Temperature of Plastics
ASTM D 1652	Standard Test Method for Epoxy Content of Epoxy Resins
ASTM D 2290	Standard Test Method for Apparent Tensile Strength of Ring or Tubular Plastics and Reinforced Plastics by Split Disk Method
ASTM D 2291	Standard Practice for Fabrication of Ring Test Specimens for Glass-Resin Composites
ASTM D 2343	Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics
ASTM D 2344	Standard Test Method for Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method
ASTM D 2393	Standard Test Method for Viscosity of Epoxy Resins and Related Components
ASTD D 2512	Standard Test Method for Compatibility of Materials with Liquid Oxygen (Impact Sensitivity Threshold and Pass-Fail Techniques)
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 2585	Standard Method for Preparation and Tension Testing of Filament-Wound Pressure Vessels
ASTM D 2586	Standard Test Method for Hydrostatic Compressive Strength of Glass-Reinforced Plastic Cylinders
ASTM D 2654	Standard Test Methods for Moisture Content and Moisture Regain of Textiles
ASTM D 2734	Standard Test Method for Void Content of Reinforced Plastics

ASTM D 2843	Standard Test Method for Density of Smoke from the Burning or Decomposition of Plastics
ASTM D 2863	Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D 2990	Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
ASTM D 3016	Standard Practice for Use of Liquid Exclusion Chromatography Terms and Relationships
ASTM D 3029	Standard Test Methods for Impact Resistance of Rigid Plastic Sheeting or Parts by Means of a Tup (Falling Weight)
ASTM D 3039	Standard Test Method for Tensile Properties of Fiber-Resin Composites
ASTM D 3171	Standard Test Method for Fiber Content of Resin-Matrix Composites by Matrix Digestion
ASTM D 3355	Standard Test Method for Fiber Content of Unidirectional Fiber-Resin Composites by Electrical Resistivity
ASTM D 3379	Standard Test Method for Tensile Strength and Young's Modulus For High-Modulus Single-Filament Materials
ASTM D 3410	Standard Test Method for Compressive Properties of Unidirectional or Crossply Fiber-Resin Composites
ASTM D 3417	Standard Test Method for Heats of Fusion and Crytallization of Polymers by Thermal Analysis
ASTM D 3418	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 Inplane Shear Stress-Strain Response of Unidirectional Reinforced Plastics
ASTM D 3529	Standard Test Method for Resin Solids Content of Carbon Fiber-Epoxy Prepreg
ASTM D 3530	Standard Test Method for Volatiles Content of Carbon Fiber-Epoxy Prepreg
ASTM D 3531	Standard Test Method for Resin Flow of Carbon Fiber-Epoxy Prepreg
ASTM D 3532	Standard Test Method for Gel Time of Carbon Fiber-Epoxy Prepreg

ASTM D 3544	Standard Guide for Reporting Test Methods and Results on High Modulus Fibers
ASTM D 3592	Standard Recommended Practice for Determining Molecular Weight by Vapor Pressure Osmometry
ASTM D 3593	Standard Test Method for Molecular Weight Averages and Molecular Weight Distribution of Certain Polymers by Liquid Size-Exclusion Chromatography (Gel Permeation Chromatography-GPC) Using Universal Calibration
ASTM D 3750	Standard Practice for Determination of Number-Average Molecular Weight of Polymers by Membrane Osmometry
ASTM D 3776	Standard Test Methods for Weight (Mass per Unit Area) of Woven Fabric
ASTM D 3800	Standard Test Method for Density of High-Modulus Fibers
ASTM D 3835	Standard Test Method for Rheological Properties of Thermoplastics with a Capillary Rheometer
ASTM D 3878	Standard Definitions of Terms Relating to High-Modulus Reinforcing Fibers and Their Composites
ASTM D 3951	Standard Practice for Commercial Packaging
ASTM D 4000	Standard Guide for Identification of Plastic Materials
ASTM D 4001	Standard Practice for Determination of Weight-Average Molecular Weight of Polymers by Light Scattering
ASTM D 4018	Standard Test Methods for Tensile Properties of Continuous Filament Carbon and Graphite Yarns, Strands, Rovings and Tows
ASTM D 4019	Standard Test Method for Moisture in Plastics by Coulometry
ASTM D 4065	Standard Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics
ASTM D 4102	Standard Test Method for Thermal Oxidative Resistance of Carbon Fibers
ASTM D 4255	Standard Guide for Testing Inplane Shear Properties of Composite Laminates
ASTM E 6	Standard Definitions of Terms Relating to Methods of Mechanical Testing
ASTM E 131	Standard Definitions of Terms and Symbols Relating to Molecular Spectroscopy
ASTM E 143	Standard Test Method for Shear Modulus at Room Temperature
ASTM E 168	Standard Recommended Practice for General Techniques of Infrared Quantitative Analysis

ASTM E 260	Standard Recommended Practice for General Gas Chromatography Procedures
ASTM E 355	Standard Recommended Practice for Gas Chromatography Terms and Relationships
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 595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ASTM E 662	Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials
ASTM E 682	Standard Practice for Liquid Chromatography Terms and Relationships
ASTM E 831	Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermodilatometry
ASTM F 814	Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials for Aerospace Applications

ASTM SPECIAL TECHNICAL PUBLICATIONS (STPs)

The ASTM STPs cited herein describe engineering practices, test methods, procedures, processes and characteristics of polymer matrix composites.

The documents cited in this section are for guidance and information.

STP 836	Effects of Defects in Composite Materials
STP 813	Long Term Behavior of Composites
STP 797	Composite Materials: Quality Assurance and Processing
STP 787	Composite Materials: Testing and Design (6th Conference)
STP 775	Damage in Composite Materials
STP 772	Short Fiber Reinforced Composite Materials
STP 768	Composites for Extreme Environments
STP 749	Joining of Composite Materials
STP 734	Test Methods and Design Allowables for Fibrous Composites
STP 723	Fatigue of Fibrous Composite Materials

STP 704	Commercial Opportunities for Advanced Composites
STP 696	Nondestructive Evaluation and Flaw Criticality for Composite Materials
STP 674	Composite Materials: Testing and Design (Fifth Conference)
STP 658	Advanced Composite Materials - Environmental Effects
STP 636	Fatigue of Filamentary Composite Materials
STP 617	Composite Materials; Testing and Design (Fourth Conference)
STP 602	Environmental Effects on Advanced Composite Materials
STP 593	Fracture Mechanics of Composites
STP 580	Composite Reliability
STP 569	Fatigue of Composite Materials
STP 568	Foreign Object Damage to Composites
STP 546	Composite Materials: Testing and Design (Third Conference)
STP 524	Applications of Composite Materials
STP 521	Analysis of Test Methods for High Modulus Fibers and Composites
STP 497	Composite Materials: Testing and Design (Second Conference)
STP 460	Composites Materials: Testing and Design (First Conference)
STP 452	Interfaces in Composites
STP 279	Reinforced Plastics for Rockets and Aircraft

Compilation of ASTM Standard Definitions, 4th Edition, 1979.

(Applications for copies of ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

JET PROPULSION LABORATORY (JPL)

TS507035	Test Specification, Vacuum Outgassing of Polymers (Micro-VCM Technique), Detail Specification for

(Applications for copies of JPL publications should be addressed to the Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109.)

NATIONAL ACADEMY OF SCIENCES (NAS)

1. Publication NMAB 318-2, Test Methods, Specifications, and Standards: Fire Safety Aspects of Polymeric Materials (Volume 2), Technomic Publishing Co., Inc., 1979.

2. Publication NMAB 365, Organic Matrix Structural Composites: Quality Assurance and Reproducibility, National Academy Press, 1981.

3. Publication NMAB-396, Materials for Lightweight Military Combat Vehicles, National Academy Press, 1982, p. 25 & 85.

(Applications for copies of NMAB publications should be addressed to the National Materials Advisory Board, National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, D.C. 20418.)

SAE

ARP 1610 Physico-Chemical Characterization Techniques, Epoxy Adhesive and Prepreg Resin Systems

(Applications for copies of Aerospace Material Specifications (AMS) and Aerospace Recommended Practices (ARP) cited in this standard should be addressed to the SAE, 400 Commonwealth Drive, Warrendale, PA 15096.)

SOCIETY FOR THE ADVANCEMENT OF MATERIAL AND PROCESS ENGINEERING (SAMPE)

The documents cited in this section are for guidance and information.

1. Beckwith, S.W., "Elevated Temperature and Thermal Postcure Effects on Composite Material Fracture Toughness," 28th National SAMPE Symposium, Vol. 28, 1983, p. 301.

2. Morse, G.A., "Derivative Spectroscopy in Polymer Analysis: The Chemical Characterization of an Epoxy Resin," 16th National SAMPE Technical Conference, Vol. 16, 1984, p. 721.

3. Cobuzzi, C.A., King, J.J., and Castonguay, R.N., "HPLC Evaluation of MY 720 III," 28th National SAMPE Symposium, Vol. 28, 1983, p. 877.

4. Moss, Robert, "Using the Outgassing Test to Screen Materials for Contamination Potential," 28th National SAMPE Symposium, Vol. 28, 1983, p. 1045.

5. Chaudhari, M.A., Cobuzzi, C.A., and King, J.J., "Characterization of MY 720 VI," 16th National SAMPE Technical Conference, Vol. 16, 1984, p. 565.

6. Kranbuehl, D.E., Delos, S.E., and Jue, P.K., "Dynamic Dielectric Characterization of the Cure Process: LARC-160," 28th National SAMPE Symposium, Vol. 28, 1983, p. 608.

7. Maximovich, M.G., and Galeos, R.M., "Rheological Characterization of Advanced Composite Prepreg Materials," 28th National SAMPE Symposium, Vol. 28, 1983, p. 568.

8. Young, P.R., and Chang, A.C., "Prepreg Cure Monitoring Using Diffuse Reflectance-FTIR," 16th National SAMPE Technical Conference, Vol. 16, 1984, p. 136.

9. Smith, A.C., "Application of Mass Spectrometry to Process Control for Polymer Material in Autoclave Curing," SAMPE Quarterly, Vol. 14, No. 4 - July 1983, p. 1.

Symposium Proceedings

Volume 1	Filament Winding
Volume 8	Insulation-Materials & Processes for Aerospace & Hydrospace Applications
Volume 9	Joining of Materials for Aerospace Systems
Volume 10	Advanced Fibrous Reinforced Composites
Volume 11	Effects of the Space Environment on Materials
Volume 12	Advances in Structural Composites
Volume 13	Energistic Materials
Volume 14	Advanced Techniques for Materials Investigation & Fabrication
Volume 16	Materials '71
Volume 17	Materials Review for '72
Volume 25	The 1980's - Payoff Decade for Advanced Materials
Volume 26	Material and Process Applications - Land, Sea, Air, Space
Volume 27	Materials Overview of 1982
Volume 28	Materials and Processes - Continuing Innovations
Volume 29	Technology Vectors
Volume 30	Advancing Technology in Materials and Processes

Technical Conference Series

NSTC 1	Aircraft Structures & Materials Applications
NSTC 6	Materials on the Move
NSTC 7	Materials Review '75
NSTC 8	Bicentennial of Materials

NSTC 9 Materials & Processes - In Service Performance

NSTC 11 New Horizons - Materials and Processes for the Eighties

NSTC 13 Technology Transfer

NSTC 14 Material & Process Advances '82

NSTC 15 20/20 Vision in Materials for 2000

NSTC 16 Hi-Tech Review 1984

(Applications for copies of SAMPE publications should be addressed to the Society for the Advancement of Material and Process Engineering, SAMPE National Business Office, P.O. Box 2459, Covina, CA 91722.)

SOCIETY OF PLASTICS ENGINEERS (SPE)

1. Hagnauer, G.L. and Dunn, D.A., "Quality Assurance of Epoxy Resin Prepregs," Proceedings of the SPE 42nd Annual Technical Conference and Exhibition, 1984.

(Applications for copies of SPE publications should be addressed to The Society of Plastics Engineers, 14 Fairfield Drive, Brookfield Center, CT 06805.)

UNDERWRITERS LABORATORIES (UL)

UL 94 Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 746B Standard for Polymeric Materials - Long Term Property Evaluations

(Applications for copies of UL publications should be addressed to Underwriters Laboratories, Publications Stock, 333 Pfingsten Road, Northbrook, IL 60062.)

MISCELLANEOUS

The documents cited in this section are for guidance and information.

1. Gentle, E.J. and Reithmaier, L.W., Aviation Space Dictionary, 6th Edition, Aero Publishers, Inc., Fallbrook, CA, 1980.

2. High Temple Workshop V, "Abstracts and Presentation Viewgraphs," Naval Postgraduate School, Monterey, CA, March 4-8, 1985.

(Applications for copies of High Temple publications should be addressed to AFWAL/MLSE, Wright-Patterson, Air Force Base, OH 45433 or AFRPL/MKAT, Edwards Air Force Base, CA 93523.)

Note: "High Temple" is an abbreviation for High Temperature Plastic Laminate Evaluation.

3. Katz, H.S. and Milewski, J.V., Eds., Handbook of Fillers and Reinforcements for Plastics, New York, Van Nostrand Reinhold Co., 1978.

4. Lenoe, E.M., Oplinger, D.W. and Burge, J.J., Eds., Fibrous Composites in Structural Design, Plenum Press, New York, 1980.

5. Lubin, G., Ed., Handbook of Composites, New York, Van Nostrand Reinhold Co., 1982.

6. May, C.A., Ed., Resins for Aerospace, American Chemical Society, Washington, D.C., 1980.

7. Schwartz, S.S. and Goodman, S.H., Plastics Materials and Processes, New York, Van Nostrand Reinhold Co., 1982.

8. Weast, R.C., Ed., Handbook of Chemistry and Physics, 53rd Edition, The Chemical Rubber Co., Cleveland, OH, 1972-73.

(Nongovernment standards are generally available for reference from libraries. They are also distributed among nongovernment standards bodies and using Federal agencies.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

3. DEFINITIONS

3.1 Materials and processing terminology. The definitions contained in this standard are derived from various sources cited in Section 2.

Adhesives. See ASTM D 907.

Advanced composites. Composite materials applicable to aerospace construction and consisting of a high-stength, high-modulus fiber system imbedded within an essentially homogeneous matrix. (DoD/NASA)

Advanced filaments. Continuous filaments made from high-strength, high-modulus materials for use as constituents of advanced composites. (DoD/NASA)

Aerospace terminology. See Aviation Space Dictionary.

Aircraft survivability. See MIL-STD-2089.

Amorphous. Noncrystalline, or devoid of regular structure. (ASTM)

Anistropic. Having different properties in different directions.

Anisotropy. Dependence of properties on orientation of axes. No planes of symmetry.

Aramid fibers. A class of aromatic polyamide fibers. The class "aramid" presently includes Kevlar, Kevlar 29, Kevlar 49 and Nomex, all products of DuPont Company.

Areal weight. Weight (mass) per unit area of a single ply of dry reinforcement fabric.

Aspect ratio. In an essentially two-dimensional rectangular structure (e.g., a panel), the ratio of the long dimension to the short dimension. However, in compression loading, it is sometimes considered to be the ratio of load direction dimension to the transverse dimension. Also, in fiber micromechanics, it is referred to as the ratio of length to diameter.

Autoclave. A closed apparatus usually equipped with variable conditions of vacuum, pressure, and temperature; An autoclave is used for bonding, consolidating, or curing materials.

Autoclave molding. A process similar to the pressure bag technique. The layup is covered by a pressure bag, and the entire assembly is placed in an autoclave capable of providing heat and pressure for curing the part. The pressure bag is normally vented to the outside. (DoD/NASA)

B-Stage. An intermediate stage in the reaction of a thermosetting resin in which the material is partially advanced in its cure to a point to facilitate handling and processing. (DoD/NASA)

Balanced laminate. A composite laminate in which all lamina at angles other than 0^{o} and 90^{o} occur only in $\pm$ pairs (not necessarily adjacent), and is symmetrical about a centerline. (DoD/NASA)

Birefringence. A double-refraction phenomenon in which an unpolarized beam of light is divided into two beams with different directions and relative velocities of propagation. (ASTM)

Bleeder cloth. A nonstructural layer of material used in the manufacture of composite parts to allow the escape of excess gas and resin during cure. The bleeder cloth is removed after the curing process and is not part of the final composite. (DoD/NASA)

Breather. Porous material or fabric used to provide a gas evacuation flow path from the laminate to the vent port during cure.

Broadgoods. Uncured preimpregnated materials wider than 12 inches. These include woven cloths or fabrics of various constructions, and precollimated tapes made either in one operation or by combining several narrow widths. (DoD/NASA)

Buckling (composite). A mode of failure characterized generally by an unstable lateral deflection due to compressive action on the structural element involved. In advanced composites, buckling may take the form not only of conventional general instability and local instability but also a micro-instability of individual fibers. (DoD/NASA)

Bulk factor. The ratio of the thickness of uncured prepreg materials to their thickness when fully cured. Typical values range form 1.1 to 1.5 depending upon the fiber type and resin content. (DoD/NASA)

Bundle. A general term for a collection of esentially parallel filaments. (ASTM D 3878)

Carbon fibers. Refers to fibers that have a tensile modulus of elasticity of up to approximately 50 Msi (345 GPa) and a low degree of preferred orientation; "carbon fibers" are generally processed at temperatures lower than 1700°C (3092°F). See Graphite fibers.

Carbonization. The process of pyrolysis in an inert atmosphere at temperatures ranging from 1000-1500°C. All noncarbon elements are driven off in the process. (Lubin)

Catastrophic failure. Failure of a mechanical and unpredictable nature. (Lubin)

Catenary:

filament catenary - the difference in length of the filaments in a specified length of tow, end, or strand as a result of unequal tension; the tendency of some filaments in a taut horizontal tow, end, or strand to sag lower than others. (ASTM D 3878) roving catenary - the difference in length of the ends, tows, or strands in a specified length of roving as a result of unequal tension; the tendency of some ends, tows, or strands in a taut horizontal roving to sag lower than others. (ASTM D 3878)

Caul plates. Smooth metal plates, free of surface defects, of the same size and shape as a composite layup, used immediately in contact with the layup during the curing process to transmit normal pressure and to provide a smooth surface on the finished laminate. (DoD/NASA)

Ceramic fibers. Continuous fibers of metal oxides and carbides which are resistant to high temperatures (2000-3000°F). This class of fibers includes alumina, silicon carbide, quartz and high silica reinforcements.

Chromatography. See ASTM E 355 and E 682.

Cocure. The process of curing several different materials in a single step. Examples include the curing of various prepregs to produce hybrids, or the curing of composite materials and structural adhesives to produce sandwich structure or skins with integrally molded fittings. (DoD/NASA)

Collimated. Rendered parallel. (DoD/NASA)

Composite. 1. A material consisting of any combination of fibers, whiskers and particles in a common matrix. Composites are now established, widely used structural materials. Composite materials may be classified as follows:

a. Fibrous or filamentary composites - Fibers in a matrix
b. Laminated composites - See Laminate
c. Particulate composites - Particles in a matrix
d. Hybrid composites - See Hybrid

2. A composite material as described in this standard is defined by the following characteristics:

a. It is man made
b. It is a combination of at least two chemically distinct components with an interface separating them
c. Its components are of such a size as to be discernible and distinguishable from each other
d. It is created for the purpose of obtaining properties that would not be possible to achieve by any one of the components acting alone

Note: Generally, composite materials may also be divided into three groups based upon the matrix constituent.

a. Polymer matrix composites (PMC)
b. Metal matrix composites (MMC)
c. Ceramic matrix composites (CMC)

This standard only covers PMCs.

Composite armor. See MIL-STD-2089.

Compressive strength. The maximum compressive stress which a material is capable of sustaining. (See ASTM E 6)

Conductive composites. Composite materials which have a volume resistivity equal to or less than 500 ohm-cm and which are used for static dissipation, current conducting circuitry or EMI/RFI shielding applications.

Constitutive property. A property which depends on the constitution or structure of the molecule. (HCP)

Continuous-filament yarn. Yarn formed by twisting two or more continuous filaments into a single, continuous strand. (DoD/NASA)

Core stabilization. A process to rigidize honeycomb core materials to prevent distortion during machining or curing. (DoD/NASA)

Coupling agent. Any chemical substance designed to react with both the reinforcement and matrix phases of a composite material to form or promote a stronger bond at the interface. Coupling agents are applied to the reinforcement phase from aqueous or organic solution, from the gas phase, or added to the matrix as an integral blend.

Crazing. The development of a multitude of very fine cracks in the matrix material. (DoD/NASA)

Creep. The time-dependent part of strain resulting from stress. (ASTM D 883)

Cryogenics. The discipline that involves the properties and use of materials at extremely low temperatures.

Cryogenic temperature. The temperature range that is of interest in cryogenics is not defined precisely; however, most researchers consider a gas to be cryogenic if it can be liquefied at or below -240°F. The most common cryogenic fluids are air, argon, helium, hydrogen, methane, neon, nitrogen, and oxygen.

Crystallinity. A regular arrangement of the atoms of a solid in space. In most polymers, this state is usually imperfectly achieved. The crystalline regions (ordered regions) are submicroscopic volumes in which there is more or less regularity of arrangement of the component molecules. In these regions there is sufficient geometric order to enable definite X-ray diffraction patterns to be obtained. (ASTM D 23)

Cure (noun). The overall transformation from a low molecular weight resin/hardener system to a crosslinked network by chemical reaction.

Cure (verb). To change the properties of a polymeric system into a more stable, usable condition by the use of heat, radiation, or reaction with chemical additives. (ASTM D 883)

Debulking. Compacting of laminates under moderate heat and vacuum to insure seating on the tool, to prevent wrinkles and to remove volatiles and air.

Delamination. Separation of the layers of material in a laminate. (DoD/NASA)

Density. Concentration of matter, measured by the mass per unit volume. (HCP)

Dielectric constant. See ASTM D 150.

Dielectric strength. See ASTM D 149.

Dissipation factor. See ASTM D 150.

End. An untwisted bundle of continuous filaments. A term commonly used in referring to fiberglass or aramid fibers. (ASTM D 3878)

End item. A final combination of end products, component parts, and/or materials which is ready for its intended use, e.g., ship, tank, mobile machine shop, aircraft. (JCS Pub 1)

Fabric. A material constructed of interlaced yarns, fibers, or filaments, usually a planar structure. Nonwovens are sometimes included in this classification. (DoD/NASA) See Woven fabric.

Fabric batch. Fabric woven from one warp loom setup of both warp and fill yarns or from more than one warp loom setup provided that all fiber and fabric properties are uniform and acceptable throughout.

Fabric prepreg batch. Prepreg containing one fabric batch impregnated with one batch of resin in one continuous operation.

Fatigue. The failure or decay of mechanical properties after repeated applications of stress. (Fatigue tests give information on the ability of a material to resist the development of cracks which eventually bring about failure as a result of a large number of cycles.) (Lubin)

Fiber (or fibre). A general term used to refer to filamentary materials; a general term for a filament of finite length. (ASTM D 3878) The terminology contained in ASTM D 3878 shall be used to describe high-modulus reinforcing fibers.

Fiber content. The amount of fiber present in a composite. This is usually expressed as a percentage volume fraction or weight fraction of the composite. (DoD/NASA) See Fiber volume.

Fiber, continuous. A polycrystalline or amorphous body that is continuous within the sample or component and that has ends outside of the stress field under consideration. Minimum diameter is not limited but maximum diameter may not exceed 0.25 mm (0.010 in). (ASTM D 3039)

Fiber direction. The orientation or alignment of the longitudinal axis of the fiber with respect to a stated reference axis. (DoD/NASA)

Fiber, discontinuous. A polycrystalline or amorphous body that is discontinuous within the sample or component, or that has one or both ends inside the stress fields under consideration. Minimum diameter is not limited but maximum diameter may not exceed 0.25 mm (0.010 in). (ASTM D 3039)

Fiber, finish. Surface coating applied to fibers to facilitate handling or provide better wetting and compatibility of fiber and matrix, or both. (ASTM D 4102) See Sizing.

Fiber lot. Fiber that is produced in one single continuous operation and is separately identified by the supplier.

Fiber volume. The volume of fiber in a cured composite. Typical values for boron/epoxy are 50 $\pm$ 2% and 55-67% for graphite/epoxy based upon the fiber type. (DoD/NASA)

Filament. A variety of fibers characterized by extreme length, such that there are normally no filament ends within a part except at geometric discontinuities. Filaments are used in filamentary composites and are also used in filament winding processes, which require long continuous strands. (DoD/NASA)

Filament winding. An automated process in which continuous filament (or tape) is pulled through a resin bath and wound on a removable mandrel in a pattern. Preimpregnated materials also are used. Typical products of the aerospace industry include rocket motor cases and pressure vessels. (DoD/NASA)

Filament wound. Pertaining to an object created by the filament-winding method of fabrication. (DoD/NASA)

Filamentary composites. A major form of advanced composites in which the fiber constituent consists of continuous filaments. Filamentary composites are defined here as composite materials composed of lamina in which the continuous filaments are in nonwoven, parallel, uniaxial arrays. Individual uniaxial lamina are combined into specifically oriented multiaxial laminates for application to specific envelopes of strength and stiffness requirements. (DoD/NASA)

Fill. Yarn oriented at right angles to the warp in a woven fabric. (DoD/NASA)

Filler. A second material added to a basic material to alter its physical, mechanical, thermal, or electrical properties. Sometimes used specifically to mean particulate additives. (DoD/NASA)

Flash. Excess material which forms at the parting line of a mold or die, or which is extruded from a closed mold. (DoD/NASA)

Form. Composite materials are available in many forms both with and without resin. Examples of common forms include:

a. Roving
b. Unidirectional tape
c. Woven fabrics
d. Mat
e. Bulk molding compounds
f. Sheet molding compounds

Fracture. Rupture of the surface without complete separation of laminates. (Lubin)

Fracture toughness. The fracture toughness of a material is often expressed as the critical stress intensity factor (K_{Ic}). The critical stress intensity factor (K_{Ic}) is a measure of a material's resistance to crack growth. (SAMPE Reference #1)

Gas chromatography. See ASTM E 355.

Gelation. Point in the curing cycle at which a dramatic increase in viscosity occurs due to initial network formation.

Gelcoat. A quick-setting resin used in molding processes to provide an improved surface for the composite; the first resin applied to the mold after the mold-release agent. (DoD/NASA)

Gel point. The stage at which a liquid begins to exhibit psuedoelastic properties. (This stage may be conveniently observed from the inflection point on a viscosity-time plot). Also called "gel time". (Lubin)

Gel time. See Gel point.

Glass. The fibrous form of glass, as used in the filaments, woven fabric, yarns, mats and chopped fibers. (DoD/NASA)

Glass transition. The reversible change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one. (ASTM D 883)

Glass transition temperature (T_g). The approximate midpoint of the temperature range over which the glass transition takes place. (ASTM D 883)

Glass cloth. Conventionally woven glass fiber material. (DoD/NASA) See Scrim.

Graphite fibers. Refers to fibers that have been heat-treated at temperatures in excess of 1700°C (3092°F), possess high degrees of preferred orientation, and have high tensile moduli of elasticity on the order of 50 Msi (345 GPa). The term "graphite fiber" should be abandoned in favor of the more technically correct term of "carbon fiber", regardless of heat treatment, purity, crystalline structure, or modulus. See Carbon fibers.

Graphitization. A process performed in the preparation of carbon and graphite fibers from polyacrylonitrile (PAN) or other precursor fibers which involves heat treatment under nitrogen at 1200-2800°C.

Hand layup. A process in which components are applied to the mold, and the composite is built up and worked by hand. (DoD/NASA)

Handling life. The out-of-refrigeration time over which the material maintains its handleability.

Hardness. Property of substances determined by their ability to abrade or indent one another. (HCP)

High modulus fibers. See Fiber.

High temperature resins. Linear or crosslinked, aromatic/heterocyclic polymers that have a high glass transition temperature (Tg) and can withstand continuous exposure in air at temperatures above 600°F (316°C) without exhibiting a significant loss of structural integrity. See Resin.

Homogeneous. Descriptive term for a material of uniform composition throughout; a medium which has no internal physical boundaries; a material whose properties are constant at every point, i.e., constant with respect to spatial coordinates (but not necessarily with respect to directional coordinates). (DoD/NASA)

Horizontal shear. A low-cost test to measure the interlaminar shear of a laminate by 3-point loading. (DoD/NASA) (Also called apparent shear or short beam shear)

Hybrid. A laminate containing two or more fiber types designed to obtain properties not readily available from a single material or to reduce the use of higher cost materials; one or more compatible resin systems may be used. (DoD/NASA) There are five major types of hybrid composite:

a. Random - the fibers are randomly mixed throughout the resin and composite with no preferential concentration of either fiber

b. Intraply - the fibers are combined in a regular fashion in each ply of the composite, either through woven cloth or hybrid tapes; however, each ply can be different

c. Interply - the composite consists of discrete layers of one fiber only (e.g., a graphite tube with outer layers of glass-epoxy)

d. Selective reinforcement (e.g., bonded-on stiffeners)

e. The so-called "super hybrids" that consist of resin-composite plies, metal-composite plies, and metal foils stacked in a specified sequence

Reference: Lubin, Handbook of Composites, p. 255.

Impact strength. The ability of a material to withstand shock loading; the work done in fracturing a test specimen in a specified manner under shock loading. (Lubin)

Impregnate. To apply resin onto fibers or fabrics by any of several processes; hot melt, solution coat, or hand layup.

Index of refraction. The ratio of the velocity of light in a vacuum to its velocity in the substance. (HCP)

Interface. The boundary between the individual, physically distinguishable constituents of a composite. (DoD/NASA)

Interlaminar. Descriptive term pertaining to some object (e.g., voids), event (e.g., fracture), or potential field (e.g., shear stress) referenced as existing or occurring between two or more adjacent lamina, between the plies.

Interlaminar shear. Shearing force tending to produce a relative displacement between two lamina in a laminate along the plane of their interface. (DoD/NASA)

Interpenetrating polymer network (IPN). A combination of two polymers in network form, at least one of which is synthesized and/or crosslinked in the immediate presence of the other. In full IPNs both components are crosslinked;

the phases of both materials are continuous and thus interpentrate each other. A semi-IPN is defined as a material system with two continuous phases; however, only one of the phases is crosslinked. (SAMPE)

Isotropic. Having uniform properties in all directions. The measured properties of an isotropic material are independent of the axis of testing. (DoD/NASA)

Lamina. A single ply or layer in a laminate made of a series of layers. (DoD/NASA)

Laminate. A composite which contains two or more reinforcement plies and which is either cured as a unit or secondarily bonded following the cure of one or more plies.

Laminate, angle-ply. Consists of an arbitrary number of layers identical in thickness and material and having alternating directions of +x and -x.

Laminate, cross-ply. Consists of an arbitrary number of layers of the same material and thickness but with alternating orientations of 0° and 90°.

Laminate orientation. The configuration of a crossplied composite laminate with regard to the angles of crossplying, the number of lamina at each angle, and the exact sequence of the individual lamina. (DoD/NASA)

Laminate, orthotropic. A ply geometry of laminate that must be arranged so that the gross inplane elastic properties of the laminate possess three mutually perpendicular planes of symmetry parallel to the side of this specimen. (ASTM D 3479)

Laminate, symmetric. A stacking sequence of plies below the laminate midplane that must be a mirror image of the stacking sequence above the midplane. (ASTM D 3479)

Layup. A process of fabrication which involves the stacking of plies of material in a specified orientation and sequence.

Layup area. The fabrication areas where prepreg is cut, plied, assembled or kitted.

Lessons learned. Recorded experience of value from past weapons systems that should be applied to current and future acquisition programs. Lessons learned for composites are described in the "AFALC Lessons Learned Bulletin."

Liquid chromatography. See ASTM E 682.

Lot. All material produced in a single production run from the same batch of raw materials under the same fixed conditions and submitted for inspection at one time.

Macromechanics (composite). Concepts, math-models and equations used to transform ply properties from its material axes to composite structural axes.

Mandrel. A form fixture of male mold used for the base in the production of a part by layup or filament winding. (DoD/NASA)

Master roll. Continuous length of material impregnated at one time which may be divided into various sub-rolls.

Material specification. This type of specification is applicable to a raw material (such as monomer reactant) or a semi-fabricated material (such as prepreg) which are used in the fabrication of a product. Normally, a material specification applies to production but may be prepared to control the development of a material. (MIL-STD-490)

Material system. A specific composite material made from specifically identified constituents in specific geometric proportions and arrangements, and processed to numerically defined properties. (DoD/NASA)

Materiel. All items necessary for the equipment, maintenance, operation, and support of military activities without distinction as to their application for administrative or combat purposes; excludes ships or naval aircraft. (JCS Pub 1)

Matrix. See Resin.

Mechanics. Science dealing with the properties and behavior of materials and structures.

Mechanical life. The out-of-refrigeration time over which a material remains capable of attaining cure, mechanical properties, and morphological integrity if layed up and compacted within its handling life.

Mechanical testing. See ASTM E 6 for detailed definitions pertaining to mechanical testing.

Micromechanics (composite). Concepts, math-models and equations used to predict unidirectional composite (ply) properties from constituent material properties, geometric configuration and fabrication process variables.

Modulus of elasticity. The ratio of stress to corresponding strain below the proportional limit. (See ASTM E 6)

Moisture content. The amount of water in a material determined under prescribed conditions and expressed as a percentage of the mass of the moist material, that is, the original mass comprising the dry substance plus any water present. (ASTM D 2654)

Moisture regain. The amount of water in a material determined under prescribed conditions and expressed as a percentage of the mass of the water-free specimen. (See ASTM D 2654)

Mold release agent. A lubricant applied to mold surfaces to facilitate release of the molded article. (DoD/NASA)

Molded edge. An edge which is not physically altered after molding for use in final form, and particularly one which does not have fiber ends along its length. (DoD/NASA)

Molding. The forming of a polymer or composite into a solid mass of prescribed shape and size by the application of pressure and heat. (DoD/NASA)

Molecular weight. The sum of the atomic weights of all the atoms in a molecule. (HCP)

NBC contamination. A term that includes both the individual and collective effects of residual radiological, biological, and chemical contamination. The elements of the abbreviation "NBC" are defined as follows:

a. Nuclear (N) - Residual radiological contamination consisting of fallout, rainout, and neutron-induced gamma activity.

b. Biological (B) - All the general classes of microorganisms and toxins that can be used as biological warfare agents. These classes include bacteria, rickettsia, viruses, fungi, and microbial toxins.

c. Chemical (C) - All known chemical warfare agents. These include blood agents such as VX, GB, or thickened GD, and blister agents such as HD. (AR 70-71)

NBC contamination survivability. The capability of a system and its crew to withstand an NBC-contaminated environment, including decontamination, without losing the ability to accomplish the assigned mission. (AR 70-71)

Open time. The time that a prepreg material can be left at ambient temperature without adversely affecting the molding characteristics of the resin. (DoD/NASA)

Organic matrix composites. Synonymous with polymer matrix composites.

Outgassing. The evolution of gas from a material in a vacuum.

PAN fibers. Fibers derived from a polyacrylonitrile precursor.

Peel ply. A removable fabric ply molded onto the surface of a laminate to provide a chemically clean surface for bonding or painting when it is removed. (DoD/NASA)

Pitch fibers. Fibers derived from pitch precursor. While not as strong as low-modulus PAN fibers, they are processable to high moduli and are useful for some stiffness-critical applications.

Plastics. See MIL-HDBK-700, ASTM D 883 and D 4000.

Plied yarn. Two or more yarns collected together with or without twist. (ASTM D 3878)

Polymer. A substance consisting of molecules characterized by the repetition (neglecting ends, branch junctions, and other minor irregularities) of one or more types of monomeric units. (ASTM D 883)

Polymerization. A chemical reaction in which the molecules of monomers are linked together to form polymers. (ASTM D 883)

Porosity. A condition of trapped pockets of air, gas, or void within a solid material, usually expressed as a percentage of the total nonsolid volume to the total volume (solid + nonsolid) of a unit quantity of material. (DoD/NASA)

Precursor. Organic fiber from which carbon fibers are prepared via pyrolysis. Polyacrylonitrile (PAN), rayon, and pitch are commonly used. (ASTM D 4102)

Prefit. A process to check the fit of mating detail parts in an assembly prior to adhesive bonding to insure proper bond lines. Mechanically fastened structures are also prefit sometimes to establish shimming requirements. (DoD/NASA)

Prepreg. In the composites industry, the intermediate product which consists of fibers or fabrics which have been preimpregnated with resin. Prepregs are ready-to-mold combinations of resin and reinforcement which have been partially cured ("B-staged") and can be maintained in this condition for extended periods of time prior to final curing. Prepregs are designated as "standard" or "net resin" prepregs:

a. Standard prepreg - contains more resin than is desired in the finished part; excess resin is bled off during cure
b. Net resin prepreg - contains the same resin content that is desired in the finished part; no resin bleed

Prepreg batch. Prepreg containing reinforcements impregnated with one batch of resin in one continuous operation.

Prepreg lot. Prepreg from one batch submitted for acceptance at one time which is produced as a continuous product on one apparatus from one resin batch and from one single fabric or fiber lot.

Prepreg tack. Stickiness of a prepreg.

Process specification. This type of specification is applicable to a service which is performed on a product or material. Examples of processes are the polymerization of monomer reactants to produce resin and the autoclave curing of prepreg to produce laminates. Process specifications cover manufacturing techniques which require a specific procedure in order that a satisfactory result may be achieved. Where specific processes are essential to fabrication or procurement of a product or material, a process specification is the means of defining such specific processes. Normally, a process specification applies to production but may be prepared to control the development of a process. (MIL-STD-490)

Pultrusion. A process for producing continuous lengths of shapes with a constant cross-section by pulling resin-impregnated fibers through a heated die where curing occurs.

Qualification. The entire process by which products of manufacturers and distributors are examined and tested and then identified on a list of qualified products (i.e., QPL). (SD-6)

Quality assurance. See MIL-STD-109.

Quartz fibers. Fibers produced from high purity (99.95% SiO_2) natural quartz crystals.

Reinforced plastic. A plastic with high strength fillers imbedded in the composition, resulting in some mechanical properties superior to those of the base resin. (ASTM D 883)

Note: The reinforcing fillers are usually fibers, fabrics, or mats made of fibers.

Resin. A solid or pseudosolid organic material often of high molecular weight, which exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally. In a broad sense, the term is used to designate any polymer that is a basic material for plastics. (ASTM D 883) In reinforced plastics, the material used to bind together the reinforcement material; the "matrix." (Lubin)

Resin batch. The quantity of resin made from the same batches or lots of base ingredients in an identical mixing process.

Resin content. The amount of matrix present in a composite, either by percent weight or percent volume. (DoD/NASA)

Resin rich area. An area containing more than the maximum allowable resin content.

Resin starved area. An area with less than the minimum allowable resin area content, usually characterized by excess voids and/or loose fibers.

RF Curing. A process to rapidly cure organic resins by radio frequency (RF) energy rather than thermal energy. (DoD/NASA)

Rheology. The study of the deformation and flow of matter.

Roll. Any subsection of a prepreg lot.

Roving. A number of ends, tows, or strands collected into a parallel bundle with little or no twist. (ASTM D 3878)

Sandwich construction. A structural panel concept consisting in its simplest form of two relatively thin, parallel sheets of structural material bonded to and separated by a relatively thick, lightweight core. (DoD/NASA)

Scrim. A reinforcing fabric woven into an open mesh construction, used in the processing of tape or other B-state material to facilitate handling. (DoD/NASA)

Selvage. The woven ends portion of a fabric parallel to the warp. (ASTM D 13)

Semicrystalline polymers. Those capable of forming at least two-dimensional intermolecular order as prepared or as developed by suitable thermal treatments. The amount and degree of perfection of the ordering or crystallization depends on the spatial relationship of the atoms in the molecules, as well as the thermal or other treatment. (ASTM D 20)

Separator cloth. A fabric, coated with Teflon or similar release agent, placed between the composite layup and the bleeder system to facilitate subsequent bleeder system removal from the laminate after its cure. (DoD/NASA)

Shear strength. The maximum shear stress which a material is capable of sustaining. (See ASTM E 6)

Shelf life. The length of time a material, substance, product, or reagent can be stored under specified environmental conditions and continue to meet all applicable specification requirements and/or remain suitable for its intended function. (DoD/NASA)

Shell tooling. A mold or bonding fixture consisting of a contoured surface shell supported by a substructure to provide dimensional stability. (DoD/NASA)

Short beam shear strength (SBS). The interlaminar shear strength of a parallel fiber reinforced plastic material as determined by three-point flexural loading of a short segment cut from a ring-type specimen. (Lubin)

Silica (i.e, high silica). High purity glass of 95% plus purity SiO_2.

Sizing. The process of applying a material to a surface to fill pores and thus reduce the absorption of the subsequently applied adhesive or coating or to otherwise modify the surface. Also, the surface treatment applied to glass fibers used in reinforced plastics. Material used is often called size. (MIL-HDBK-700)

Specific gravity. The ratio of the mass of a body to the mass of an equal volume of water at 4°C or other specified temperature. (HCP)

Specific modulus. Modulus-to-density ratio.

Specific strength. Strength-to-density ratio.

Specification. A document prepared specifically to support acquisition which clearly and accurately desbribes the essential technical requirements for purchased materiel. (DoD 4120.3-M)

Spectroscopy. See ASTM E 131.

Standard. A document that establishes engineering and technical requirements for processes, procedures, practices and methods that been adopted as standard. (DoD 4120.3-M)

Standardization. The process by which the Department of Defense achieves the closest practicable cooperation among the Services and Defense agencies for the most efficient use of research, development, and production resources, and agrees to adopt on the broadest possible basis the use of common or compatible technical procedures and criteria. (JCS Pub 1)

Standardized product. A product that conforms to specifications resulting from the same technical requirements. (JCS Pub 1)

Staple. Discontinuous filaments; also known as strand - same as end or tow. (ASTM D 3878)

Stoichiometric. Pertaining to weight relations in chemical reactions. (HCP)

Strand. Same as end or tow. (ASTM D 3878)

Surface resistivity. See ASTM D 257.

Symmetrical laminate. A composite laminate in which the ply orientation is symmetrical about the midplane. (DoD/NASA)

Tape. A prepreg of finite width consisting of resin impregnated unidirectional fibers.

Tensile strength. The maximum tensile stress which a material is capable of sustaining. (See ASTM E 6)

Textiles. See ASTM D 123.

Thermal expansion. The coefficient of linear expansion or expansivity is the ratio of the change in length per degree C to the length at $0^{o}C$. (HCP)

Thermal index. A relative thermal index of a material is an indication of the material's ability to retain a particular property (physical, electrical, etc.) when exposed to elevated temperatures for an extended period of time. It is a measure of the material's thermal endurance. (UL 746)

Thermoplastic. A plastic that repeatedly can be softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be shaped by flow into articles by molding or extrusion for example. (ASTM D 883)

Thermoset. A plastic that, after having been cured by heat or other means, is a substantially infusible and insoluble. (ASTM D 883)

Tow. An untwisted bundle of continuous filaments. A term commonly used in referring to carbon or graphite fibers. (ASTM D 3878)

Tracer yarns. Yarns of a distinctive color woven into the fabric to aid visual identification of warp and fill yarn direction.

Typical basis. The typical property value is an average value. No statistical assurance is associated with this basis. (DoD/NASA)

Unidirectional. Reinforcing fibers in one direction in the plane of the composite.

Vacuum bag molding. A process in which the layup is cured under pressure generated by drawing a vacuum in the space between the layup and a flexible sheet placed over it and sealed at the edges. (DoD/NASA)

Viscosity. All fluids possess a definite resistance to change of form and many solids show a gradual yielding to forces tending to change their form. This property, a sort of internal friction, is called viscosity; it is expressed in dyne-seconds per cm^2 or poises. (HCP)

Void. An empty, unoccupied space in an assembly. Voids are associated with bridging, resin-starved areas, and processing conditions.

Volume resistivity. See ASTM D 257.

Warp. The longitudinal oriented yarns in a woven fabric (See Fill); a group of yarns in long lengths and approximately parallel. (DoD/NASA)

Wet strength. The strength of a composite measured after exposing the test specimen to water or water vapor.

Whisker. A single filamentary crystal. Whisker diameters range from 1 to 25 microns with aspect ratios between 100 and 15,000. (DoD/NASA)

Work life. The period during which a compound, after mixing with a catalyst, solvent, or other compounding ingredients, remains suitable for its intended use. (DoD/NASA)

Woven fabric. A planar structure produced by interlacing two or more sets of yarns, fibers, rovings, or filaments where the elements pass each other essentially at right angles and one set of elements is parallel to the fabric axis. (ASTM D 123)

Wrinkle. A condition where one or more plies of prepreg are formed into a ridge.

X-Axis. In composite laminates, an axis in the plane of the laminate which is used as the 0^{o} reference for designating the angle of a lamina. (DoD/NASA)

Y-Axis. In composite laminates, the axis in the plane of the laminate which is perpendicular to the X-axis. (DoD/NASA)

XY plane. In composite laminates, the reference plane parallel to the plane of the laminate. (DoD/NASA)

Yarn. A twisted bundle of continuous filaments. (ASTM D 3878)

Yarn lot. In general, a quantity of yarn formed during a continuous unit of production having the same process and uniform characteristics throughout.

Z-Axis. In composite laminates, the reference axis normal to the plane of the laminate. (DoD/NASA)

Note: The definitions contained in Section 3 are pertinent to the material processing and specification of polymer matrix composites and are not intended to be an all-inclusive list. Additional or more detailed definitions of various terms may be found in the documents cited in this standard.

3.2 Symbols and acronyms. This section contains symbols and acronyms which are commonly used in the plastics and composites fields and the aerospace industry.

3.2.1 Materials.

3.2.1.1 Plastics. Standard symbols for generic families of plastics are listed in ASTM D 4000.

3.2.1.2 Composites.

AFRP - Aramid Fiber Reinforced Plastic
CFRP - Carbon Fiber Reinforced Plastic
CMC - Ceramic Matrix Composites
FRP = Fiber Reinforced Plastic
GFRP - Glass Fiber Reinforced Plastic
GR/EP - Graphite/Epoxy
GR/PI - Graphite/Polyimide
MMC - Metal Matrix Composites
PMC - Polymer Matrix Composites
RP - Reinforced Plastic
RPC - Reinforced Plastic Composites

3.2.1.3 Miscellaneous.

BMI - Bismaleimide
DDS - 4,4'-diaminodiphenylsulfone
DICY - Dicyandiamide
LARC-160 - A high temperature polyimide matrix resin developed by Lewis Research Center
M&P - Materials and Processes
PBI - Polybenzimidazole
PMR-15 - A high temperature polyimide matrix resin (designed PMR for polymerization of monomer reactants) which has been polymerized to a nominal molecular weight of 1500.
TGDDM - Tetraglycidyl-4,4'-diaminodiphenylmethane
TGMDA - Tetraglycidylmethylenedianiline

3.2.2 Material properties.

CLTE - Coefficient of Linear Thermal Expansion

DTUL - Deflection Temperature Under Load

HDT - Heat Distortion Temperature

ILSS - Interlaminar Shear Strength

K_{Ic} - Fracture Toughness

LOI - Limiting Oxygen Index

M_n - Number Average Molecular Weight

M_w - Weight Average Molecular Weight

MWD - Molecular Weight Distribution

SBS - Short Beam Shear Strength

T_g	-	Glass Transition Temperature
T_m	-	Melting Temperature
TOS	-	Thermal Oxidative Stability
TWL	-	Total Weight Loss
VCM	-	Volatile Condensible Materials

3.2.3 Analytical methods.

AA	-	Atomic Absorption
DDA	-	Dynamic Dielectric Analysis
DMA	-	Dynamic Mechanical Analysis
DR-FTIR	-	Diffuse Reflectance - FTIR
DSC	-	Differential Scanning Calorimetry
DTA	-	Differential Thermal Analysis
ESCA	-	Electron Spectroscopy Chemical Analysis
FTIR	-	Fourier Transform Infrared Spectroscopy
GC	-	Gas Chromatography
GC-MS	-	Gas Chromatography - Mass Spectrometry
GLC	-	Gas Liquid Chromatography
GPC	-	Gel Permeation Chromatography
HPLC	-	High Performance Liquid Chromatography
IR	-	Infrared Spectroscopy
LC	-	Liquid Chromatography
MS	-	Mass Spectrometry
NDT	-	Nondestructive Testing
NDTE	-	Nondestructive Testing and Evaluation
NMR	-	Nuclear Magnetic Resonance
PGC	-	Pyrolysis Gas Chromatography
SEC	-	Size Exclusion Chromatography
SEM	-	Scanning Electron Microscopy
TGA	-	Thermogravimetric Analysis
TMA	-	Thermomechanical Analysis
UV	-	Ultraviolet Spectroscopy Analysis

4. GENERAL REQUIREMENTS

4.1 Laminate orientation code. The Standard Laminate Code described in the Advanced Composites Design Guide shall be used to describe a specific laminate.

4.2 Standardization documents. Department of Defense standardization documents for polymer matrix composites shall be prepared in accordance with DoD 4120.3-M.

4.2.1 Military specifications. Military specifications for polymer matrix composites shall be prepared in accordance with MIL-STD-490 and MIL-STD-961.

4.2.2 Military standards. Military standards for polymer matrix composites shall be prepared in accordance with MIL-STD-962 and this standard.

4.2.3 Military handbooks. Military handbooks for polymer matrix composites shall be prepared in accordance with MIL-STD-962. In accordance with MIL-STD-962 (Paragraph 3.2), Military Handbook 17 shall be used in the preparation of specifications and standards for polymer matrix composites to the maximum extent practicable.

4.3 Acquisition. Program managers, procurement and engineering personnel shall use the specifications listed in Appendices A through D to the maximum extend practicable if essential requirements are met. Preparation of overlapping and duplicate documents shall be avoided.

5. DETAILED REQUIREMENTS

5.1 Resin.

5.1.1 Chemical.

5.1.1.1 *Composition and polymerization*. Material specifications shall include the following requirements on the resin matrix:

a. Monomer reactants and solvents used in polymerization and their purity
b. Manufacturing requirements for monomer reactants
c. Stoichiometry of monomer reactants for polymerization
d. Type of polymeric resin
   (1) *Addition or condensation*
   (2) Chemical description (e.g., PMR-15, LARC-160, etc.)

5.1.1.2 Infrared spectroscopy (IR). Polymers used in polymer matrix composites may be identified by their characteristic infrared spectra. Infrared spectroscopic analysis shall be conducted in accordance with ASTM E 168. Infrared analysis may be useful for determining the concentration of a curing agent or the extent of reaction.

5.1.1.3 Ultraviolet spectroscopy (UV). Ultraviolet derivative spectroscopy may be used to evaluate epoxy resins for quality control purposes (SAMPE Reference #2).

5.1.1.4 Liquid chromatography (LC). Analysis by liquid chromatography may be used as a means of quality control in prepreg manufacturing or for procurement purposes. The polymeric resin used in a prepregging process or the prepreg itself may be analyzed to obtain a chromatogram of the material. The chromatogram is analogous to a "chemical fingerprint." Minute differences in chromatograms may indicate material processing changes or the presence of chemical impurities. Epoxy resin may be characterized by HPLC (SAMPE Reference #3). Standard practice for liquid chromatography is described in ASTM E 682.

5.1.1.5 Liquid exclusion chromatography (LEC). Polymers used in polymer matrix composites may be characterized by liquid exclusion chromatography. Analysis by LEC is useful for determining the molecular weight and molecular weight distribution of a polymeric resin. Analysis by LEC shall be conducted in accordance with ASTM D 3016.

5.1.1.6 Gas chromatography (GC). General gas chromatographic procedures shall be conducted in accordance with ASTM E 260.

5.1.1.7 Epoxy content. The epoxy content of epoxy resins shall be determined by ASTM D 1652.

5.1.2 Physical.

5.1.2.1 Glass transition temperature, (T_g). Both a dry T_g and a wet T_g shall be specified for the polymeric resins used in polymer matrix composites. Moisture behaves as a plasticizer and will lower the T_g of polymeric resins. The T_g of a dry resin may be determined in accordance with ASTM D 3418 which uses differential scanning calorimetry. A wet T_g

should not be determined by this method because heating will dry the sample and will produce erroneous results. A wet or dry T_g may be determined by dynamic mechanical analysis (DMA) in accordance with ASTM D 4065 or by thermomechanical analysis (TMA). For comparison purposes, it is recommended that both Tg's be determined on the same basis, whether statically or dynamically.

5.1.2.2 Specific gravity. The specific gravity of a polymeric resin shall be determined in accordance with ASTM D 792.

5.1.2.3 Viscosity vs. temperature. Rheological properties of thermoplastic resins may be determined by ASTM D 3835. The viscosity of epoxy resins and related components shall be determined by ASTM D 2393.

5.1.2.4 Molecular weight. The molecular weight of polymeric resins may be determined by the following methods:

a. ASTM D 3016 - Liquid exclusion chromatography
b. ASTM D 3592 - Vapor pressure osmometry
d. ASTM D 3750 - Membrane osmometry
e. ASTM D 4001 - Light scattering

5.1.2.5 Molecular weight distribution (MWD). Gel permeation chromatography (GPC) in accordance with ASTM D 3593 may be used to determine the MWD of macromolecules.

5.1.2.6 Outgassing (aka Offgassing).

5.1.2.6.1 Outgassing test methods. The test methods cited herein shall be used for determining the outgassing properties of polymeric composites:

a. ASTM E 595 - Screening technique for determining volatile content of materials in a vacuum environment; total mass loss (TML) and collected volatile condensable materials (CVCM) are measured by this method (See also SAMPE Reference #4.)

b. SP-R-0022A - Establishes outgassing requirements and test guidelines for polymeric materials used in spacecraft applications; TML and VCM are measured

c. JSC 02681, Revision J - This handbook describes three offgassing screening tests

   1. Odor test
   2. Carbon monoxide test
   3. VCM test

d. JPL TS507035 - Test method for TML and VCM

5.1.2.6.2 Outgassing test data. Outgassing test data is compiled in NASA JSC 08962, NASA RP-1014 and NASA RP-1061.

5.1.3 Thermal.

5.1.3.1 Vicat softening temperature. The Vicat softening temperature of thermoplastics shall be determined by ASTM D 1525.

5.1.3.2 Heats of fusion and crystallization. The heat of fusion and heat of crystallization of polymers shall be determined by DSC analysis in accordance with ASTM D 3417.

Note: DSC analysis may be used for characterization of epoxy resins (SAMPE Reference #5).

5.1.3.3 Transition temperatures. First-order transition (e.g., T_m) and glass transition (T_g) temperatures shall be determined by DSC or DTA in accordance with ASTM D 3418.

5.1.3.4 Reporting thermoanalytical data. Thermoanalytical data obtained by DTA, TGA or TMA shall be reported in accordance with the format of ASTM E 472.

5.1.3.5 Thermal index. The relative thermal indices of polymeric materials shall be determined in accordance with UL 746B.

5.1.4 Mechanical.

5.1.4.1 Fracture toughness. The plane-strain fracture toughness (K_{Ic}) of a neat resin may be determined by ASTM E 399.

5.1.5 Electrical. Resin age, composition and curing characteristics may be determined using dynamic dielectric analysis (DDA) (SAMPE Reference #6).

5.1.6 Miscellaneous. The day and time that the resin is prepared and the day and time that the resin is prepregged shall be reported by the manufacturer to the procuring activity. Excessive lag times between resin preparation and prepregging may be deleterious.

5.2 Fiber.

5.2.1 Physical.

5.2.1.1 Types of fibers. Typical fibers which are used as reinforcements in composite laminates are listed in table I.

TABLE I. Fiber properties. 1/

Category	Type	Supplier	Ultimate Tensile Strength, ksi	Tensile Modulus, psi x 10^6	Density g/cm^3
Alumina (Al_2O_3)	FP-1	Dupont	200	55	3.7
	FP-2	Dupont	250	55	3.7
	SiO_2	Dupont	275	55	3.7
	Nextel	3M	250	22	2.7
Aramid	Kevlar 29	Dupont	500	13	1.44
	Kevlar 49	Dupont	550	19	1.45
Boron (W)	4.0 mil	Avco	510	58-60	2.57
	5.6 mil	Avco	510	58-60	2.49
	8.0 mil	Avco	510	58-60	2.46
Boron carbide			300-400	40-55	2.0
Boron nitride			300	30-50	1.8
Glass	"E"	Owens/Corning	500	10.5	2.54
	"S"	Owens/Corning	650	12.4	2.49
Carbon	Celion	Celanese	550	34	1.78
(Low-Cost High-	Celion ST	Celanese	630	34	1.78
Strength)	AS1	Hercules	450	34	1.80
" "	AS2	Hercules	400	33	1.80
	AS4	Hercules	520	34	1.80
	AS6	Hercules	600	35	1.83
LHS (PAN)	XAS	Hysol Grafil	500	34	1.79
	XAS 1	Hysol Grafil	550	34	1.79
	XAS 2	Hysol Grafil	600	34	1.79
	XAS 3	Hysol Grafil	700	37	1.82
	Microfil 55		525	55	1.78
	T-300	Union Carbide	400	33	1.76
	T-500	Union Carbide	500	35	1.79
	T-600	Union Carbide	600	35	1.80
	T-700	Union Carbide	660	36	1.81
	F3	Great Lakes	450	33	1.78

TABLE I. Fiber properties. (cont'd)

Category	Type	Supplier	Ultimate Tensile Strength, ksi	Tensile Modulus, psi x 10^6	Density g/cm^3
Carbon Intermediate Modulus (IM) (PAN)	Celion 940X	Celanese	700	41	1.78
	IM6	Hercules	635	40	1.73
	IMS	Hysol Grafil	450	42	1.76
	IM 7	Hercules	670	40	1.78
Carbon High Modulus (HM) (PAN)	Celion G50	Celanese	360	50	1.78
	HMS-4	Hercules	425	52	1.79
	HMU	Hercules	400	55	1.84
	HMS	Hercules	400	52	1.86
	Microfil 55		525	55	1.78
	T-50	Union Carbide	350	57	1.81
	F5	Great Lakes	450	50	1.85
Carbon Ultra-High Modulus (UHM) (PAN)	Celion GY70	Celanese	270	75	1.99
	Celion GY80	Celanese	270	83	1.99
Carbon (Pitch)	P-25W	Union Carbide	200	23	1.90
	P-55S	Union Carbide	250	55	2.0
	P-75S	Union Carbide	300	75	2.0
	P-100	Union Carbide	325	105	2.15
	P-120	Union Carbide	325	120	2.18
Quartz	Astroquartz	J.P. Stevens AAI Products	130	10	2.20
Silicon carbide (SiC)	5.6 mil (W)	Avco	550	60	3.07
	4.0 mil (W)	Avco	550	60	3.30

1/ Ultimate tensile strength, tensile modulus and density are three properties which should be specified to characterize a fiber. Additional fiber properties may be obtained from suppliers by requesting Product Data Sheets. The values in this table should be considered nominal values, not certifiable minimums, and should not be used for specification purposes.

Caveat: Proprietary names are stated only to identify current materials and should not be construed as an official endorsement, either expressed or implied, which excludes other materials which may satisfy specification requirements.

5.2.1.2 Fiber density. The density of high-modulus fibers may be determined by ASTM D 276, D 792, D 1505 or D 3800. These standards describe three basic methods for determining fiber density: density-gradient column, pycnometer, and techniques based on Archimedes principle.

5.2.1.3 Fiber melting point. The melting point of a high-modulus fiber may be determined by ASTM D 276 which requires heating a fiber between two cover glasses and observing the melting point with a magnifying lens.

5.2.1.4 *Fiber identification by infrared spectroscopy*. *Aramid, glass and* other fibers may be identified by infrared spectroscopy by ASTM D 276.

5.2.1.5 Refractive indices and birefringence. The refractive indices and birefringence of aramid, glass and other fibers may be determined by ASTM D 276.

5.2.1.6 Moisture content and moisture regain. The moisture content and moisture regain of fibers, both natural and man-made, and in all forms from bulk fiber or filament to finished fabrics, may be determined by ASTM D 2654.

5.2.1.7 Thermal oxidative stability (TOS). The thermal oxidative resistance of carbon fibers shall be determined by ASTM D 4102.

5.2.1.8 Fiber finish. Fiber finish may be determined by ASTM D 4102.

5.2.2 Mechanical. The tensile properties of fiber reinforcements shall be determined by the following methods as applicable:

a.	ASTM D 885	-	Aramid yarns
b.	ASTM D 2343	-	Aramid roving; Glass fiber strands, yarns, and rovings
c.	ASTM D 3379	-	High-modulus single filament materials
d	ASTM D 3544	-	Guide for reporting tension test results
e.	ASTM D 4018	-	Continuous filament carbon and graphite yarns, strands, rovings and tows

5.3 Prepreg.

5.3.1 Physical description of reinforcement. The physical description of the reinforcement used in a composite shall be described using the standard definitions of ASTM D 3878.

5.3.2 Resin content. *The resin content of carbon and graphite prepregs may* be determined by Soxhlet extraction in accordance with ASTM C 613. The resin content of carbon fiber-epoxy prepregs shall be determined in accordance with ASTM D 3529. The resin content of other prepregs shall be determined as specified in a detailed specification or contract.

5.3.3 Fiber content. The fiber content of some prepregs may be determined by ASTM D 3171. This test method is based on the digestion of the matrix resin by liquid media, which do not attack the fibers excessively. Digestion methods are not satisfactory for graphite/Kevlar composites because Kevlar (aramid) fibers are subject to oxidation by the digesting reagents.

5.3.4 Volatiles content. The volatiles content of carbon fiber-epoxy prepreg tape and sheet may be determined by ASTM D 3530. The volatiles content of carbon and graphite prepregs may also be determined by ASTM C 613.

5.3.5 Moisture content. The moisture content of prepregs may be determined by coulometry in accordance with ASTM D 4019.

5.3.6 Areal weight. The areal weight (mass per unit area) of impregnated woven fabrics may be determined by ASTM D 3776. Areal weight for unidirectional tape shall be determined as specified in a detailed specification or contract.

5.3.7 Gel time. The gel time of carbon fiber-epoxy prepreg tape and sheet may be determined by ASTM D 3532.

5.3.8 Resin flow. The resin flow of carbon fiber-epoxy prepreg tape or sheet materials may be determined by ASTM D 3531.

5.3.9 Fiber wetting. The filaments in a prepreg shall be completely wetted by the resin. No cured resin particles shall be permitted when determined visually using magnification as necessary.

5.3.10 Alignment. In unidirectional prepreg tape, the filament bundles shall be parallel to the longitudinal direction of the prepreg within an angle of 0.5° when examined visually using appropriate aids to measure angular alignment.

5.3.11 Gaps. Any gaps within or between tows in unidirectional tape shall comply with the following when determined visually using adequate scales:

a. No gap shall exceed 0.04 inches in width
b. The length of any gap greater than 0.02 inches shall not exceed 12 inches
c. Gaps in line with each other and no more than one inch apart shall be considered as one gap, regardless of number
d. Gaps with excessive width or length shall be considered defective and must be replaced

5.3.12 Splices. Prepreg splices shall be permitted on any roll of tape where processing is continuous without change in fiber or resin batch. Such splice shall be marked by tape as a nonconforming area.

5.3.13 Width. The prepreg width shall be as specified in a detailed specification. Width tolerance for unidirectional tape shall be $\pm$ 0.050 inch.

5.3.14 Edges. Maximum acceptable waviness of any 12-inch length of tape shall be 0.030 inch from the edge when measured with appropriate straight edge.

5.3.15 Length. The length of each individual roll of prepreg shall be provided together with sequence in production and batch identification as supporting data to prepreg certification. The maximum length of prepreg on any single roll shall be as specified in a detailed specification or contract.

5.3.16 Packaging. Prepregs shall be packaged in accordance with ASTM D 3951.

5.3.17 Shelf life. A prepreg shall have a minimum shelf life of 6 months at 0°F.

5.3.18 Work life. A prepreg shall have a minimum work life of 10 days.

5.3.19 Rheological characterization. Advanced composite prepreg materials may be characterized by rheological techniques using a dynamic mechanical spectrometer (SAMPE Reference #7). Flow, gel time and dynamic viscosity characteristics may be determined to aid in establishing processing parameters.

5.3.20 Cure monitoring by diffuse-reflectance FTIR. Graphite fiber reinforced polymeric matrix prepregs containing thermosetting resins may be chemically characterized by prepreg cure monitoring using diffuse-reflectance Fourier transform infrared spectroscopy (SAMPE Reference #8). This technique has been used to characterize bismaleimide, epoxy and polyimide (i.e., LARC-160) resins.

5.3.21 Cure monitoring by mass spectrometry. Mass spectrometry analysis of gas samples collected during the cure of prepreg materials is a useful technique for process control (SAMPE Reference #9). Mass spectrometry is useful for characterizing the chemical composition of different resin systems and their cure mechanisms. This information may be used in material or process specifications to aid in production.

5.3.22 Quality assurance of epoxy resin prepregs (Instrumental methods of analysis). SPE Reference #1 contains a compilation of instrumental methods of analysis which are useful for the material characterization and quality assurance of epoxy resin prepregs. These methods are recommended for inclusion in material specifications for polymer matrix composite materials. Aerospace Recommended Practice (ARP) 1610 also describes various chemical and physical characterization techniques for the quality assurance of epoxy resin prepregs.

5.4 Laminate (composite).

5.4.1 Physical.

5.4.1.1 Specific gravity and density. The specific gravity and density of composite laminates shall be determined by ASTM D 792.

5.4.1.2 Void content. The void content of composite laminates shall be determined by ASTM D 2734.

5.4.1.3 Fiber content. The fiber content of resin-matrix composites other than aramid, may be determined by matrix digestion in accordance with ASTM D 3171. The fiber content of unidirectional fiber-resin composites containing electrically conductive fibers may be determined by electrical resistivity in accordance with ASTM D 3355.

5.4.1.4 Resin content. The resin content of glass fabric or filament reinforced resin-matrix composites may be determined by ASTM D 2584.

5.4.1.5 Glass transition temperature, (T_g). See 5.1.2.1.

5.4.1.6 Water absorption. The water absorption of composite laminates shall be determined by ASTM D 570.

5.4.1.7 Thermal conductivity. The thermal conductivity of composite laminates shall be determined as specified in a detailed specification or contract.

5.4.1.8 Coefficient of linear thermal expansion (CLTE). The CLTE of composite laminates shall be determined by ASTM D 696 or E 831.

5.4.1.9 Hardness. The indentation hardness of composite laminates may be determined using a Barcol Impressor in accordance with ASTM D 2583.

5.4.1.10 Flammability. The flammability characteristics of polymeric composite laminates may be determined by the following methods as applicable:

a. ASTM D 635 - Rate of burning
b. ASTM D 2843 - Smoke density
c. ASTM D 2863 - Limiting oxygen index (LOI)
d. ASTM E 662 or ASTM F 814 - Specific optical density (SOD); both D_4 and D_{max}
e. UL 94 - Burning behavior

Other test methods, standards and specifications pertinent to the flammability of polymeric composite materials are described in National Academy of Sciences Publication NMAB 318-2 and NASA JSC 02681, Revision J.

5.4.1.11 Ply thickness. Cured ply thickness shall be determined as specified in a detailed specification or contract.

5.4.1.12 Liquid oxygen (LOX) compatibility. The compatibility and relative sensitivity of polymeric composites under impact energy shall be determined by ASTM D 2512.

5.4.2 Mechanical.

5.4.2.1 Tensile strength and modulus. The tensile properties of polymer matrix composites may be determined by the following methods:

a. ASTM D 638 - The tensile properties of neat plastic resins may be determined by this method. The method of preparation of specimens for testing (e.g., machined from plate or molded to net shape) shall be specified in the detailed specification. The use of the dog-bone specimens is not recommended for testing reinforced plastics. The combination of low strain-to-failure materials and the stress concentrations inherent in these specimens produces a large percentage of failures outside the gage section and may lead to erroneous results.

b. ASTM D 2290 - The apparent tensile strength of parallel-fiber-reinforced rings may be determined by this method. The ring specimens used in this test shall be fabricated in accordance with ASTM D 2291.

c. ASTM D 2585 - The apparent tensile parameters of filament-wound pressure vessels may be determined by this method.

d. ASTM D 3039 - The tensile properties of polymer matrix composites reinforced by oriented continuous or discontinuous high-modulus fibers may be determined by this method.

e. AMMRC TR 82-27 - This optional method for determining tensile properties employs a "streamline" specimen developed at AMMRC.

As a caveat it should be recognized that there are problems associated with each tensile test method described herein and none is universally accepted. These test methods are currently used by different activities and it is the responsibility of appropriate engineering personnel to determine their applicability.

5.4.2.2 Compressive strength and modulus. The compressive properties of chopped fiber (i.e., discontinuous) reinforced plastic/composites may be determined by ASTM D 695. The compressive properties of resin-matrix composites reinforced by oriented continuous high-modulus fibers shall be determined by ASTM D 3410. The hydrostatic compressive strength properties of filament-wound glass reinforced plastic cylinders may be determined by ASTM D 2586.

5.4.2.3 Flexural strength and modulus. The flexural properties of resin-matrix composites reinforced by oriented continuous high-modulus fibers shall be determined by ASTM D 790.

5.4.2.4 Shear strength and modulus. The shear properties of polymer matrix composites may be determined by the following methods:

a. ASTM D 2344 - Apparent interlaminar shear strength (short-beam method)
b. ASTM D 3518 - $\pm$ 45° off-axis test
c. ASTM D 4255 - Rail shear test
d. ASTM E 143 - Torsional tube shear test

As a caveat it should be recognized that there are problems associated with each ASTM Standard shear test method and that none will yield the "true" shear modulus or strength. The word "apparent" for describing the Short-Beam Shear test is highly justified. The $\pm$ 45° Off-Axis test (ASTM D 3518) is relatively simple and economical but is subject to free edge effects and statically indeterminate normal stresses in the principal shear planes. Similarly, the Rail Shear test (ASTM D 4255) is subject to significant normal stresses in the test section which are dependent upon how the load is applied, the stiffness of the rails, and the properties of the laminate.

5.4.2.5 Tensile fatigue strength. The tension-tension fatigue properties of oriented, high-modulus fiber, resin-matrix composites shall be determined by ASTM D 3479.

5.4.2.6 Creep and creep-rupture. The tensile, compressive, and flexural creep and creep-rupture of polymer matrix composite materials shall be determined by ASTM D 2990.

5.4.2.7 Impact strength. The drop weight impact strength of structural composites shall be determined by ASTM D 3029.

5.4.2.8 Compression after impact. Graphite/epoxy laminates shall be tested for compression after impact in accordance NASA RP-1092 (ST-1).

5.4.2.9 Edge delamination tension. Graphite/epoxy laminates shall be tested for edge delamination in accordance with NASA RP-1092 (ST-2).

5.4.2.10 Open-hole tension. Graphite/epoxy laminates shall be tested for open-hole tension in accordance with NASA RP-1092 (ST-3).

5.4.2.11 Open-hole compression. Graphite/epoxy laminates shall be tested for open-hole compression in accordance with NASA RP-1092 (ST-4).

5.4.2.12 Hinged double cantilever beam. Graphite/epoxy laminates shall be tested by the hinged double cantilever beam method in accordance with RP-1092 (ST-5).

5.4.2.13 NASA Technical Memorandums. The test methods ST-1 through ST-5 cited above are further described in NASA Technical Memorandums 85756 and 86298.

5.4.3 Electrical.

5.4.3.1 Dielectric constant. The dielectric constant of a composite laminate shall be determined by ASTM D 150.

5.4.3.2 Dielectric strength. The dielectric strength of a composite laminate shall be determined by ASTM D 149.

5.4.3.3 Dissipation factor. The dissipation factor of a composite laminate shall be determined by ASTM D 150.

5.4.3.4 Surface resistivity. The surface resistivity of a composite laminate shall be determined by ASTM D 257.

5.4.3.5 Volume resistivity. The volume resistivity of a composite laminate shall be determined by ASTM D 257.

5.4.4 Chemical. The chemical resistance of a composite laminate may be determined by ASTM D 543 or C 581 as applicable.

5.5 Cure cycles. Process specifications shall include layup/bagging procedures and the time-temperature-pressure conditions for the fabrication of test panels and preparation of specimens.

5.6 Qualification.

5.6.1 Purpose of qualification. Qualification of polymer matrix composite materials has the following objectives:

a. To provide control over the consistency and quality of materials
b. To establish equivalency among suppliers to promote multiple sourcing and standardization

5.6.2 Qualification provisions. Qualification of polymer matrix composite materials shall be achieved in accordance with the provisions of the OUSDRE SD-6, "Provisions Governing Qualification."

5.6.3 Qualification tests. This section contains recommended qualification tests for polymer matrix composite materials which are intended for use in military applications. These recommended tests are based on a consolidation of current government and industry qualification practices (See IDA Record Document D-70.) Temperature and environmental exposure conditions are not precisely defined for two reasons. First, engineering data bases for PMCs have not been standardized and are still undergoing dynamic development. Secondly, temperature and environmental exposure requirements for PMCs vary for each application. Precise temperature and environmental exposure test conditions for material qualification should be established in accordance with MIL-STD-210 and MIL-STD-810 based on the intended use of the material.

5.6.3.1 Qualification of resins. Resin qualification should include the following tests:

a. Infrared spectroscopy (IR)
b. Liquid chromatography (LC)
c. Differential scanning calorimetry (DSC)
d. Viscosity profile/flow-characteristics

5.6.3.2 Qualification of fibers. Fiber qualification should include the following tests:

a. Tensile strength
b. Tensile modulus
c. Density

5.6.3.3 Qualification of prepregs. Prepreg qualification should include the following tests:

a. Resin content
b. Volatiles content
c. Rheological characterization
d. Areal weight
e. Gel time

5.6.3.4 Qualification of composite laminates. Laminate qualification should include the following tests:

a. Ply thickness
b. Void content
c. Density
d. Fiber volume
e. Flammability
f. Surface resistivity (electrical)
g. Tension
h. Compression
i. Shear
j. Open-hole tension
k. Open-hole compression
l. Compression after impact

5.7 Materials and processes (M&P). In accordance with MIL-STD-962A (Paragraph 4.1), the purpose of the publications cited herein is to provide designers and users with data and descriptions essential to the selection and application of materials and processes in the development and production of services and materiel for the military.

5.7.1 SAMPE publications.

5.7.1.1 Symposium proceedings. Documents in this series contain papers which have been presented at prior National SAMPE Symposia and cover a wide range of materials and process technology (See Section 2).

5.7.1.2 Technical conference series. Volumes in this series contain papers which have been presented at various technical conferences which deal with specific subject matter related to a narrow segment of the materials and process technology (See Section 2).

5.7.2 ASTM publications. In addition to the ASTM standards previously cited in this standard, ASTM publications include Special Technical Publications (STP's) which describe various engineering test methods and characteristics of polymer matrix composites (See Section 2).

5.7.3 NASA publications. Appendix E contains a compilation of selected NASA publications which cover various materials and processing aspects of polymer matrix composites. See also MSFC Manual 8070.2F.

5.7.4 Military publications. The following military publications contain useful information relating to reinforced plastic/composite materials and processes:

a. MIL-HDBK-139 - Describes the processing of plastics

b. MIL-HDBK-700 - Describes the engineering properties of plastics

c. DARCOM pamphlet P 706-314 - Contains engineering design property data for discontinuous fiberglass reinforced thermoplastics

d. MIL-STD-1587A (USAF) - Contains U.S. Air Force requirements for materials and processes used on military weapon systems

e. MIL-HDBK-17B (under development) - This document will contain engineering property data and guidelines for composite materials used for aircraft and aerospace applications

f. DoDISS - Department of Defense Index of Specifications and Standards

g. DoD/NASA Structural Composites Fabrication Guide

h. Advanced Composites Design Guide

5.7.5 NMAB publications. See NMAB 365 and 396.

5.7.6 Miscellaneous publications. Publications (Number 2-7) cited in Section 2 (Miscellaneous) encompass various aspects of resin chemistry, material processing, composite laminating, mechanical testing and structural design of many polymer matrix composite systems which have been developed for aerospace applications.

5.8 NBC contamination survivability. Army Regulation 70-71 establishes Army policy and procedures for the development and acquisition of materiel to insure its survivability and sustainability on the nuclear, biological, and chemical (NBC)-contaminated battlefield. Program managers and military contractors shall conform to AR 70-71 wherever polymer matrix composites are used in U.S. Army materiel.

6. NOTES (Not Applicable)

Custodians:

Army - MR
Air Force - 20

Review Activities:

Army - ME, AT, AV
Air Force - 70, 84, 99

User Activities:

Army - MI, SM
Air Force - 79

Preparing Activity:

Army - MR

Project No. 9330-B124

(WP ID-#6345A/DISK-0429A, FOR AMMRC USE ONLY)

APPENDIX A

Specifications for Resins

This appendix includes specifications for plastic resins which are used for the fabrication of reinforced plastics and composite materials.

MILITARY SPECIFICATIONS

MIL-R-7575C (28 Apr 77)	Resin, Polyester, Low-pressure Laminating
MIL-R-9299C (3 Dec 68)	Resin, Phenolic, Laminating
MIL-R-9300B (15 Jan 68)	Resin, Epoxy, Low-pressure Laminating
MIL-R-21607D(SH) (5 Aug 76)	Resins, Polyester, Low-pressure Laminating, Fire-retardant
MIL-R-25042B (12 Sep 67)	Resin, Polyester, High Temperature Resistant, Low-pressure Laminating
MIL-R-25506C (13 Mar 84)	Resin Solution, Silicone, Low-pressure Laminating
MIL-P-46120B(MR) (11 Jul 83)	Plastic Molding and Extrusion Material, Polysulfone
MIL-P-46129A(MR) (15 May 75)	Plastic Molding and Extrusion Material, Polyphenylene Oxide, Modified
MIL-P-46131B (17 Nov 75)	Plastic Molding and Extrusion Material, Polyphenylene Oxide, Modified, Glass Fiber Reinforced
MIL-P-46179(MR) (3 Dec 79)	Plastic Molding and Extrusion Material, Polyamide-Imide
MIL-P-46183 (20 Jun 84)	Plastic Molding and Extrusion Material, Polyetheretherketone (PEEK)
MIL-P-46184 (1 Nov 82)	Plastic Molding and Extrusion Material, Polyetherimide (PEI)
MIL-P-46185 (10 Jun 83)	Plastic Molding and Extrusion Materials, Polyethersulfone
MIL-R-47025 (19 Apr 74)	Resin, Casting, Fire-retardant, Epoxy Base

MIL-M-47026(MI) (19 Apr 74)	Molding Compound, Phenolic Resin, Quartz Reinforced
MIL-C-47028(MI) (19 Apr 74)	Compound, Molding, Silica Fiber, Phenolic Impregnated
MIL-P-82650(OS) (30 Oct 78)	Plastic Molding Material, Glass, Phenolic
MIL-R-83330 (15 Jul 71)	Resin, Heat Resistant, Laminating (Polyimide)

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3616	Resin, Polyimide, Laminating and Molding - High Temperature Resistant, 370°C or 700°F, Unfilled, Addition Polymer (Jan 77)
AMS 3618	Resin, Polyimide, Thermosetting - High Heat (290°C) Resistant (Nov 70)
AMS 3619A	Resin, Polyimide, Laminating - High Temperature Resistant, 315°C (600°F) (Oct 79)
AMS 3701	Epoxy Resin, Tetraglycidyl Methylenedianiline (TGMDA), 10,000-14,000 Centipoise Viscosity (Jul 84)
AMS 3702	Epoxy Resin, Tetraglycidyl Methylenedianiline 14,000-18,000 Centipoise Viscosity (Jul 84)

ASTM SPECIFICATIONS

ASTM D 706	Standard Specification for Cellulose Acetate Molding and Extrusion Compounds.
ASTM D 707	Standard Specification for Cellulose Acetate Butyrate Molding and Extrusion Compounds.
ASTM D 1562	Standard Specification for Cellulose Propionate Molding and Extrusion Compounds.
ASTM D 3935	Standard Specification for Polycarbonate (PC) Unfilled and Reinforced Materials.
ASTM D 4000	Standard Guide for Identification of Plastic Materials.
ASTM D 4066	Standard Specification for Nylon Injection and Extrusion Materials (PA).

APPENDIX A

ASTM SPECIFICATIONS

ASTM D 4067	Standard Specification for Reinforced and Filled Polyphenylene Sulfide (PPS) Injection Molding and Extrusion Materials.
ASTM D 4101	Standard Specification for Propylene Plastic Injection and Extrusion Materials.
ASTM D 4203	Standard Specification for Styrene-Acrylonitrile (SAN) Injection and Extrusion Materials.

APPENDIX B

Specifications for Fiber Reinforcements

This appendix includes specifications for fiber reinforcements in various forms such as yarn, rovings and mats, which are fabricated into composite components.

MILITARY SPECIFICATIONS

MIL-Y-1140H (13 Dec 72)	Yarn, Cord, Sleeving, Cloth, and Tape-Glass
MIL-C-9084C (9 Jun 70)	Cloth, Glass, Finished, For Resin Laminates
MIL-C-19663C(SH) (20 Aug 74)	Cloth, Woven Roving, For Plastic Laminates
MIL-M-43248C (21 Jun 82)	Mat, Reinforcing, Glass Fiber
MIL-R-60346C(MR) (18 Jun 81)	Roving, Glass, Fibrous (For Prepreg Tape and Roving, Filament Winding, and Pultrusion Applications)
MIL-F-81265(OS) (17 May 65)	Fiber, Asbestos
MIL-B-83353(USAF) (21 Dec 71)	Boron Monofilament, Continuous, Vapor Deposited
MIL-Y-83371(USAF) (5 May 72)	Yarns, Graphite, High Modulus, Continuous Filament
MIL-P-87116(USAF) (27 Jul 79)	Preform, Graphite, Fiber, 3D Orthogonal, 2-2-3, Fineweave
MIL-P-87117(USAF) (27 Jul 79)	Preform, Rigidized, Graphite Fiber 3D Orthogonal, 2-2-3 Fineweave, CVD Infiltrated
MIL-P-87118(USAF) (6 Apr 81)	Preform, Rigidization of, Graphite Fiber, 3D Orthogonal, 2-2-3, Fineweave, CVD Processing of
MIL-P-87119(USAF) (6 Apr 81)	Preform, Densification High Pressure Rigidized Graphite Fiber, 3D Fineweave, Orthogonal, Processing of
MIL-P-87122(USAF) (4 Mar 81)	Preform, Rigidized of Graphite Fiber, 3D Fineweave Pierced Fabric, Processing of

MIL-P-87123(USAF) (27 Jul 79)	Preform, Rigidized, Graphite Fiber 3D, Fineweave Pierced Fabric
MIL-Y-87125(USAF) (6 Dec 83)	Yarn, Graphite, 1000/3000 Filaments

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3823B	Fabric, Glass Cloth-Style 7781, Chrome-Silane Finish (Jul 77)
AMS 3824A	Cloth, Type "E" Glass, Finished for Resin Laminates (Jan 84)
AMS 3837A	Cloth, Type "S" Glass - 181 Style Fabric, Finish No. Hts-904 (Jul 79)
AMS 3846A	Cloth, Quartz - Finished for Resin Laminates (Apr 83)
AMS 3865B	Filaments, Boron - Tungsten Substrate, Continuous (Oct 84)
AMS 3890	Graphite Yarn, Non-Structural - 2 Ply Yarn, 720 Filaments (May 70)
AMS 3892A	Fibers, Carbon (Graphite), Tow and Yarn, For Structural Composites (Jul 84)
AMS 3892/1A	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF 400 (2760) Tensile Strength, 33 (228) Tensile Modulus (Jul 84)
AMS 3892/2A	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF 300 (2070) Tensile Strength, 50 (345) Tensile Modulus (Jul 84)
AMS 3892/3A	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF 400 (2760) Tensile Strength, 40 (275) Tensile Modulus (Jul 84)
AMS 3892/4A	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF 300 (2070) Tensile Strength, 75 (517) Tensile Modulus (Jul 84)
AMS 3892/5A	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF 220 (1515) Tensile Strength, 75 (517) Tensile Modulus (Jul 84)

AMS 3892/6	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF 325 (2240) Tensile Strength, 57 (395) Tensile Modulus (Jul 84)
AMS 3892/7	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF (OX) 400 (2760) Tensile Strength, 33 (228) Tensile Modulus (Jul 84)
AMS 3892/8	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF (OX) 400 (2760) Tensile Strength, 40 (275) Tensile Modulus (Jul 84)
AMS 3892/9	Tow or Yarn, Carbon (Graphite) Fibers, For Structural Composites, GF (OX) 500 (3445) Tensile Strength, 32,000,000 (221) Tensile Modulus (Apr 84)
AMS 3901A	Organic Fiber, (Para-Aramid), Yarn and Roving - High Modulus (Jan 85)
AMS 3901/1A	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 18,000,000 (125) Tensile Modulus, 195 Denier, 0.6% Finish (Jan 85)
AMS 3901/2A	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 17,500,000 (120) Tensile Modulus, 380 Denier, 0.6% Finish (Jan 85)
AMS 3901/3A	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 16,500,000 (115) Tensile Modulus, 1140 Denier, Finish 0.6% (Jan 85)
AMS 3901/4A	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 16,500,000 (115) Tensile Modulus, 1420 Denier, 0.6% Finish (Jan 85)
AMS 3901/5A	Roving, Organic Fiber (Para-Aramid), High Modulus, OR 450,000 (3100) Tensile Strength, 17,500,000 (120) Tensile Modulus, 7100 Denier, 0.6% Finish (Jan 85)
AMS 3901/6A	Roving, Organic Fiber (Para-Aramid), High Modulus, OR 500,000 (3450) Tensile Strength, 17,500,000 (120) Tensile Modulus, 4560 Denier, 0.6% Finish (Jan 85)
AMS 3901/7	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 16,500,000 (115) Tensile Modulus, 2130 Denier, 0.6% Finish (Jan 85)
AMS 3901/8	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 18,000,000 (125) Tensile Modulus, 195 Denier, 1.2% Finish (Jan 85)

AMS 3901/9	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 17,500,000 (120) Tensile Modulus, 380 Denier, 1.2% Finish (Jan 85)
AMS 3901/10	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 16,500,000 (115) Tensile Modulus, 1140 Denier, 1.2% Finish (Jan 85)
AMS 3901/11	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 16,500,000 (115) Tensile Modulus, 1420 Denier, 1.2% Finish (Jan 85)
AMS 3901/12A	Yarn, Organic Fiber (Para-Aramid), High Modulus, OY 390,000 (2690) Tensile Strength, 16,500,000 (115) Tensile Modulus, 2130 Denier, 1.2% Finish (Jan 85)
AMS 3902A	Cloth, Organic Fiber, High Modulus - For Structural Composites (Jan 77)

ASTM SPECIFICATIONS

ASTM D 578	Standard Specification for Glass Fiber Yarns
ASTM D 579	Standard Specification for Greige Woven Glass Fabrics
ASTM D 3317	High Modulus, Organic Yarn and Roving.

APPENDIX C

Specifications for Prepregs and Intermediate Products

This appendix includes specifications for prepregs and intermediate products which are fabricated into structural and nonstructural reinforced plastic or composite parts. This appendix also includes process specifications which define various fabrication procedures.

MILITARY SPECIFICATIONS

Epoxy

MIL-M-46069 (29 Jul 65)	Molding, Plastic, Glass/Epoxy Pre-mix
MIL-M-46861A(MI) (7 Mar 80)	Molding Material, Glass, Epoxy Coated
MIL-M-46862(MI) (8 Jan 76)	Molding Material, Glass, Epoxy Impregnated
MIL-P-46892A(MI) (21 Jul 80)	Plastic Molding Material, Epoxy, Glass Fiber
MIL-C-47177(MI) (6 Oct 77)	Casting Compound, Epoxy Resin with Aromatic Amine Curing Agent
MIL-C-47221A(MI) (23 Apr 82)	Compound, Molding, Epoxy Resin, Silicon Dioxide and Asbestos-Fiber Filled
MIL-C-47257A(MI) (4 Feb 80)	Compound, Epoxy, Filament Winding
MIL-B-83369(USAF) (21 Aug 72)	Boron Filament Reinforcement, Continuous, Epoxy Resin Impregnated
MIL-G-83410(USAF) (12 Feb 73)	Graphite Fiber Resin Impregnated Tape and Sheet, For Hand Layup

Phenolic

MIL-P-13436A (21 Dec 66)	Plastic Sheet, Filled Phenolic, Uncured
MIL-P-15035C (1 May 84)	Plastic Sheet, Laminated, Thermosetting, Cotton-Fabric-Base, Phenolic-Resin
MIL-P-15047C (11 Jun 71)	Plastic Material, Laminated Thermosetting Sheets, Nylon Fabric Base, Phenolic Resin
MIL-P-18324D (14 Jun 68)	Plastic Material, Laminated Phenolic, for Bearings (Water or Grease Lubrication)

MIL-P-25515C (4 Dec 68)	Plastic Material, Phenolic Resin, Glass-Fiber Base, Laminated
MIL-M-46891(MI) (18 Jul 80)	Molding Compound, Phenolic Resin, Asbestos Reinforced
MIL-G-47024(MI) (24 Feb 76)	Glass Roving, Phenolic Impregnated
MIL-M-47026(MI) (19 Apr 74)	Molding Compound, Phenolic Resin, Quartz Reinforced
MIL-C-47028(MI) (19 Apr 74)	Compound, Molding, Silica Fiber Phenolic Impregnated
MIL-T-47030(MI) (19 Apr 74)	Tape, Phenolic, Hi-Silica
MIL-T-60330(AR) (8 Feb 65)	Tape, Asbestos, Felt, Phenolic-Resin Impregnated
MIL-P-81255(OS) (18 Feb 76)	Plastic Molding Material, Asbestos Phenolic
MIL-A-81264(OS) (17 May 65)	Asbestos Felt or Mat, Resin Impregnated
MIL-P-82650(OS) (30 Oct 78)	Plastic Molding Material, Glass Phenolic

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3821A	Cloth, Type "E" Glass, "B" Stage Epoxy-Resin-Impregnated 7781 Style Fabric, Flame Resistant (Jan 84)
AMS 3827A	Cloth, Type "E" Glass, "B" Stage Polyester-Resin-Impregnated, 7781 Style Fabric, Flame Resistant (Jan 84)
AMS 3828A	Glass Roving, Epoxy Resin Preimpregnated, Type "E" Glass (Jul 83)
AMS 3829	Cloth, Type "E" - Glass, Style 7781 Fabric, Solution-Addition-Type PMR-15 Polyimide Resin Impregnated (Apr 82)
AMS 3831	Cloth, Type "E" Glass, "B" Stage Epoxy-Resin-Impregnated, 7781 Style Fabric, Flame Resistant, Improved Strength (Jan 84)

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3832A	Glass Roving, Type "S" Glass, Epoxy Resin Impregnated (Jul 79)
AMS 3834	Cloth, Type "E" Glass, "B" Stage Polyster-Resin-Impregnated, 7781 Style Fabric, Flame Resistant, Improved Strength (Jan 84)
AMS 3844	Cloth, Type "E" Glass, Style 7781 Fabric - Hot-Melt, Addition-Type, Polyimide Resin Impregnated (Jul 79)
AMS 3845A	Cloth, Type "E" Glass, "B" Stage Addition Cure Polyimide-Resin-Impregnated (Apr 85)
AMS 3845/1A	Cloth, Type "E" Glass, "B" Stage Polyimide-Resin-Impregnated, 181 Style Fabric, Low-Flow Addition-Cure Resin, For Press Cure 40-100 psi (276-690 KPa) or Vacuum/Autoclave Processing (Apr 85)
AMS 3845/2	Cloth, Type "E" Glass, "B" Stage Polyimide-Resin-Impregnated, 181 Style Fabric, High-Flow Addition-Cure Resin, For Press Cure 40-100 psi (276-690 KPa) or Vacuum/Autoclave Processing (Apr 85)
AMS 3847A	Cloth, Quartz - "B" Stage Polyimide Resin Impregnated, Style 581 Fabric, 315°C (600°F) (Apr 83)
AMS 3849	Cloth, Quartz, Style 581 Fabric - Hot-Melt, Addition-Type, Polyimide Resin Impregnated (Jul 79)
AMS 3867A	Boron Filament Tape, Epoxy-Resin-Impregnated (Oct 84)
AMS 3867/1A	Boron Filament Tape, Epoxy-Resin-Impregnated, Type B4.0 E375 (Oct 84)
AMS 3867/2A	Boron Filament Tape, Epoxy-Resin-Impregnated, Type B5.6 E375 (Oct 84)
AMS 3867/3A	Boron Filament Tape, Epoxy-Resin-Impregnated, Type B8.0 E375 (Oct 84)
AMS 3867/4	Boron Filament Tape, Epoxy-Resin-Impregnated, Type B4.0 E180 (Oct 84)
AMS 3867/5	Boron Filament Tape, Epoxy-Resin-Impregnated, Type B5.6 E180 (Oct 84)
AMS 3867/6	Boron Filament Tape, Epoxy-Resin-Impregnated, Type B8.0 E180 (Oct 84)

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3894C	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated (Apr 83)
AMS 3894/1A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 110,000 (758) Tensile, 27,000,000 (186) Modulus, 175 (350) (Apr 83)
AMS 3894/2A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 150,000 (1034) Tensile, 20,000,000 (138) Modulus, 175 (350) (Apr 83)
AMS 3894/3A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 150,000 (1034) Tensile, 19,000,000 (131) Modulus, 80 (180) (Apr 83)
AMS 3894/4A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 150,000 (1034) Tensile, 15,000,000 (103) Modulus, 80 (180) (Apr 83)
AMS 3894/5A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 110,000 (758) Tensile, 27,000,000 (186) Modulus, 80 (180) (Apr 83)
AMS 3894/6A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 150,000 (1034) Tensile, 15,000,000 (103) Modulus, 175 (350) (Apr 83)
AMS 3894/7A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 90,000 (620) Tensile, 40,000,000 (275) Modulus, 80 (180) (Apr 83)
AMS 3894/8A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 70,000 (483) Tensile, 36,000,000 (248) Modulus, 80 (180) (Apr 83)
AMS 3894/9A	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 70,000 (483) Tensile, 36,000,000 (248) Modulus, 175 (350) (Apr 83)
AMS 3894/10	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 210,000 (1450) Tensile, 20,000,000 (138) Modulus, 175 (350) (Apr 83)
AMS 3894/11	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 200,000 (1380) Tensile, 18,000,000 (124) Modulus, 80 (180) (Apr 83)
AMS 3894/12	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 200,000 (1380) Tensile, 18,000,000 (124) Modulus, 120 (250) (Oct 83)

APPENDIX C

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3894/13	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 131,000 (903) Tensile, 25,000,000 (172) Modulus, 175 (350) (Oct 83)
AMS 3894/14	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 90,000 (620) Tensile, 40,000,000 (275) Modulus, 175 (350) (Oct 83)
AMS 3894/15	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 200,000 (1380) Tensile, 21,000,000 (145) Modulus, 175 (350) (Oct 83)
AMS 3894/16	Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 200,000 (1380) Tensile, 21,000,000 (145) Modulus, 175 (350) (Oct 83)
AMS 3895	Broadgoods and Tape, Multi-Ply Graphite Fiber/Epoxy Resin Impregnated, Uniform Fiber (Oct 80)
AMS 3898/A	Interleaf Carrier Material, Composite Tape (Jan 85)
AMS 3898/1A	Interleaf Carrier Material, Composite Tape - Parchment, 0.004 in. (0.10 mm), Unperforated (Jan 85)
AMS 3898/2A	Interleaf Carrier Material, Composite Tape - Polyethylene Film, Unperforated, 0.0018 in. (0.046 mm) (Jan 85)
AMS 3898/3A	Interleaf Carrier Material, Composite Tape - Polyethylene Coated Paper, Unperforated, 0.0035 in. (0.089 mm) (Jan 85)
AMS 3898/4A	Interleaf Carrier Material, Composite Tape - Paper, 0.004 in. (0.10 mm), Perforated (Jan 85)
AMS 3898/5A	Interleaf Carrier Material, Composite Tape - Polyethylene Coated Paper, Perforated, 0.0035 in. (0.089 mm) (Jan 85)
AMS 3898/6	Interleaf Carrier Material, Composite Tape, Differentially Coated Paper, Unperforated, 0.0032 in. (0.080 mm) (Apr 84)
AMS 3898/7	Interleaf Carrier Material, Composite Tape, Differentially Coated Paper, Unperforated, 0.0042 in. (0.105 mm) (Apr 84)
AMS 3898/8	Interleaf Carrier Material, Composite Tape/Broadgoods, Kraft, Differentially Coated Paper, Unperforated, 0.0038 in. $\pm$ 0.0004 (0.0965 mm $\pm$ 0.0102) (Apr 84)

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3898/9	Interleaf Carrier Material, Composite Tape/Broadgoods, Kraft, Differentially Coated Paper, Unperforated, 0.0050 in. ± 0.0005 (0.125 mm ± 0.012) (Apr 84)
AMS 3903	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated (Jun 75)
AMS 3903/1	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 120,350 (177) (Jun 75)
AMS 3903/2	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 181,350 (177) (Jun 75)
AMS 3903/3	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 281,350 (177) (Jun 75)
AMS 3903/4	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 328,350 (177) (Jun 75)
AMS 3903/5	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 120,180 (82) (Jun 75)
AMS 3903/6	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 181,180 (82) (Jun 75)
AMS 3903/7	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 281,180 (82) (Jun 75)
AMS 3903/8	Cloth, Organic Fiber, High Modulus - Epoxy Resin Impregnated, OC Style 328,180 (82) (Jun 75)
AMS 3906	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup (Jun 75)
AMS 3906/1	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup GL-I-36 250 (121) (Jun 75)
AMS 3906/2	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup GL-III-36 - 250 (121) (Jun 75)
AMS 3906/3	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup GL-I-26 - 300 (149) (Jun 75)
AMS 3906/4	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup GL-III-26 - 300 (149) (Jun 75)

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3906/5	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup GL-I-36 - 300 (149) (Jun 75)
AMS 3906/6	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup GL-I-36 - 200 (93) (Jun 75)
AMS 3906/7	Glass Non-Woven Fiber Tape and Flat Sheet - Epoxy Resin Impregnated, For Hand and Machine Layup GL-III-33 - 200 (93) (Jun 75)

Material Specifications Prepared by Aircraft and Aerospace Companies for Military Applications

Reference: DoD/NASA Structural Composites Fabrication Guide

Section	Specification Title	Page	Source
B-1-1	Boron/Polyimide Pre-Preg Material	B-3	McDonnell Douglas
B-1-2	Graphite/Polyimide Pre-Preg Material	B-13	McDonnell Douglas
B-1-3	Advanced Composite Materials	B-25	General Dynamics (Ft. Worth)
B-1-4	Type HMS Graphite/Epoxy Prepreg Material	B-45	AFML-TR-72-205
B-1-5	Tape, Unidirectional High Modulus Graphite Filament	B-53	McDonnell Douglas
B-1-6	Boron Reinforced Preimpregnated Material	B-69	Grumman Aerospace
B-1-7	Graphite Flat Sheet, Epoxy Resin Impregnated Tow, Specification for	B-117	General Dynamics (Convair)
B-1-8	Graphite Flat Sheet, Epoxy Resin Impregnated Yarn, Specification for	B-149	General Dynamics (Convair)
B-1-10	Tape, Unidirectional, Graphite Fiber, Epoxy Resin Impregnated, 350°F Service Temperature	B-191	Lockheed-Georgia
B-1-11	Glass Fabric, Epoxy Resin-Impregnated High Temperature (350°) for Structural Applications	B-201	Lockheed-Georgia
B-1-12	Boron/Epoxy Pre-Preg Material	B-211	-
B-1-13	Graphite Reinforced, Epoxy Preimpregnated Material, Low-Pressure Molding	B-229	Grumman Aerospace
B-1-14	Structural Laminates, Graphite Fiber Base, Polyimide Resin	B-267	Grumman Aerospace
B-1-15	Graphite-Reinforced Polyimide Preimpregnated Material, Woven Fabric	B-285	Grumman Aerospace
B-1-16	Structural Laminates, Glass Fiber Base, Polyimide Resin	B-317	Grumman Aerospace
B-2-1	Reinforced-Epoxy Composite Parts or Components, Fabricated Using Thermal Expansion Molding	B-359	Lockheed-Georgia
B-2-2	Skins, Structural, Boron/Polyimide, Fabrication and Acceptance of	B-367	McDonnell Douglas

Section	Specification Title	Page	Source
B-2-3	Bonded Structure, Polyimide Matrix Composite, Fabrication and Inspection of	B-385	McDonnell Douglas
B-2-4	Skins and Substructural Shapes, Structural, Graphite/Polyimide, Fabrication and Acceptance of	B-399	McDonnell Douglas
B-3-1	Fabrication of Vacuum Bags	B-409	Grumman Aerospace
B-3-2	Cocuring Manufacturing Plans	B-419	-
B-4-1	Fabrication and Acceptance of Boron/Epoxy Structural Skins	B-445	-
B-4-3	Clean Room Requirements for Composite Structural Fabrication	B-489	-
B-4-5	Fabrication and Acceptance Procedure for Boron/Epoxy Skin-Aluminum Honeycomb Sandwich Material	B-521	-

Note: Material specifications prepared by private companies may be considered proprietary and may not be available.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NASA RP 1142 NASA/Aircraft Industry Standard Specification for Graphite Fiber/Toughened Thermoset Resin Composite Material

APPENDIX D

Specifications for Composite Laminates

This appendix includes specifications for composite laminates and related structures.

MILITARY SPECIFICATIONS

MIL-P-9400B (26 Apr 77)	Plastic Laminate and Sandwich Construction Parts, Aircraft Structural, Process Specification Requirements
MIL-P-17549D(SH) (31 Aug 81)	Plastic Laminates, Fibrous Glass Reinforced, Marine Structural
MIL-P-18177C (15 Dec 61)	Plastic Sheet, Laminated, Thermosetting, Glass Fiber Base, Epoxy Resin
MIL-S-25392B (8 May 68)	Sandwich Construction, Plastic Resin, Glass Fabric Base, Laminated Facings and Polyurethane Foamed-in-Place Core For Aircraft Structural Applications
MIL-P-25395A (23 Dec 63)	Plastic Materials, Heat Resistant, Low Pressure Laminated Glass Fiber Base, Polyester Resins
MIL-P-25421B (18 Jan 71)	Plastic Material, Glass Fiber Base-Epoxy Resin, Low Pressure Laminated
MIL-P-25515C (4 Dec 68)	Plastic Materials, Phenolic Resin, Glass-Fiber Base, Laminated
MIL-P-25518B (29 Sep 81)	Plastic Materials, Silicone Resin, Glass-Fiber Base, Low Pressure Laminated
MIL-P-25770A(MI) (27 Nov 61)	Plastic Materials, Asbestos Base, Phenolic Resin, Low or High Pressure Laminates
MIL-P-46103C (23 Jul 81)	Armor: Lightweight, Ceramic-Faced Composite, Procedure Requirements
MIL-A-46108B (8 Aug 83)	Armor: Transparent, Glass; Glass/Plastic; Plastic Laminates (General Specification)
MIL-A-46166(MR) (26 Apr 76)	Plastic Laminates, Glass Reinforced (For Use in Armor Composites)

MIL-P-47135(MI) (24 May 74)	Plastic Laminates, Glass Fabric Base Epoxy Resin, Structural Shapes
MIL-A-62473B(AT) (24 Jan 84)	Armor: Aluminum-Aramid, Laminate-Composite
MIL-A-62474B(AT) (25 Jun 84)	Laminate: Aramid-Fabric-Reinforced, Plastic
MIL-P-82540(OS) (1 Jul 68)	Plastic Materials, Polyester Resin, Glass Fiber Base, Filament Wound Tube

APPENDIX E

NASA Publications on Composite Materials

This appendix is a compilation of selected NASA publications on composite materials. (See also 2.1.2)

NASA Special Publications

NASA SP-227	Aerospace Structural Materials	1970
NASA SP-448	Risk to the Public from Carbon Fibers Released in Civil Aircraft Accidents	1980
NASA SP-5039	Structural Design Concepts: Some NASA Contributions	1967
NASA SP-5055	"Nonglassy" Inorganic Fibers and Composites	1966
NASA SP-5974(03)	Composite Materials: A Compilation	1976
NASA SP-8108	Advanced Composite Structures	1974

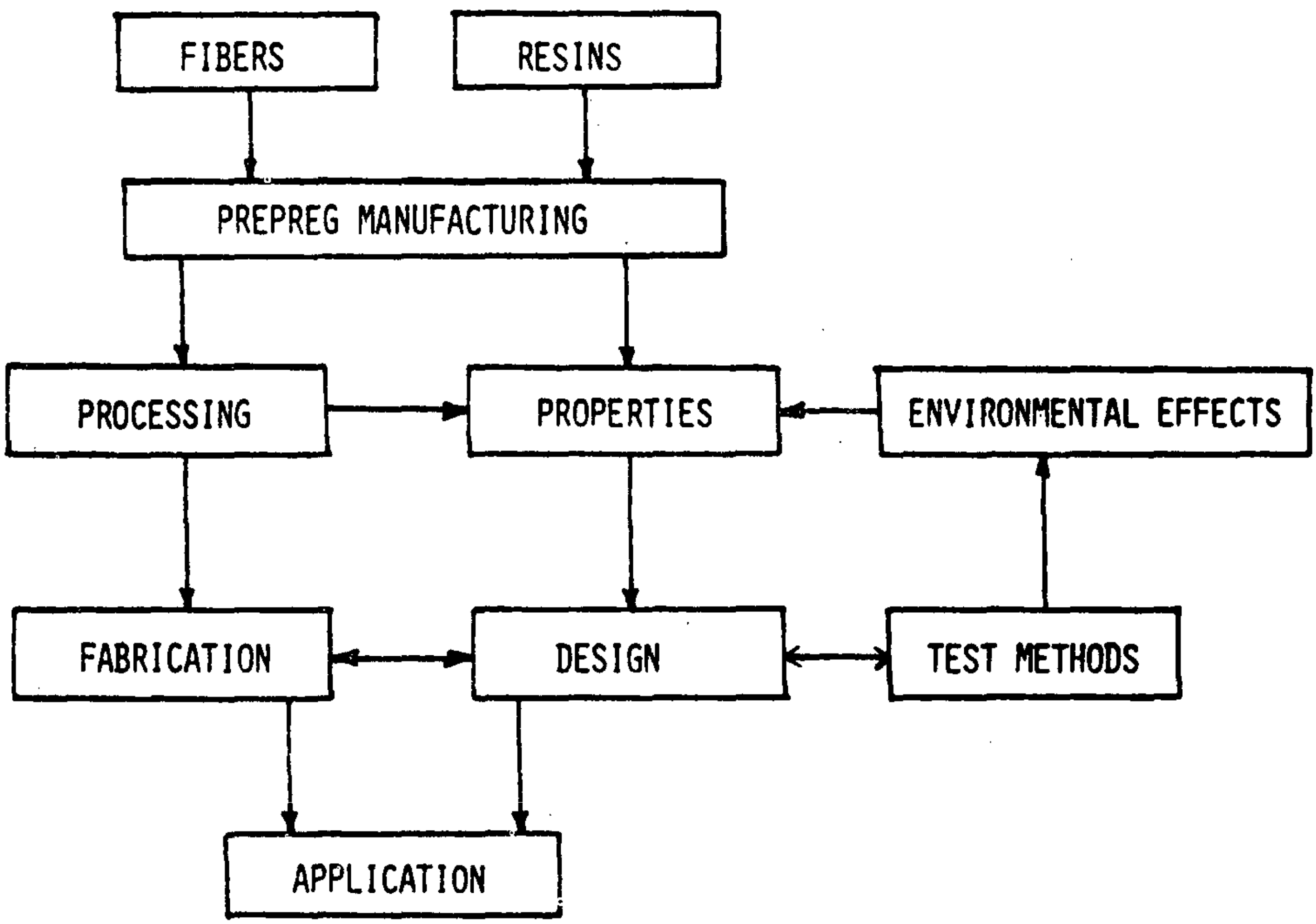
NASA Conference Publications

NASA CP-2074	Carbon Fiber Risk Analysis	1979
NASA CP-2079	Graphite/Polyimide Composites: Conference on Composites for Advanced Space Transportation Systems	1979
NASA CP-2119	Assessment of Carbon Fiber Electrical Effects	1980
NASA CP-2142	Selected NASA Research in Composite Materials and Structures	1980
NASA CP-2251	Advanced Materials Technology	1982

APPENDIX F

Application Guidance

The primary purpose of this standard is to provide designers and users with material requirements and processes which are essential to the selection and application of polymer matrix composite materials in the development and production of materiel for the military. The technological scope of this standard is depicted in the composites technology schematic contained herein and in Publication NMAB 365. Guidance for the application and tailoring of the requirements of this standard for defense materiel applications is described in Military Handbook DOD-HDBK-248A.



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