MIL-P-46179A
15 January 1986
SUPERSEDING
MIL-P-46179(MR)
3 December 1979

MILITARY SPECIFICATION

PLASTIC MOLDING AND EXTRUSION MATERIALS, POLYAMIDE-IMIDE (PAI)

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers polyamide-imide (PAI) thermoplastic materials intended for use up to 260°C (500°F).

1.2 Classification. The polyamide-imide materials shall be of the following types and classes (see 6.2).

Type I - Polyamide-imide resin, general purpose
Type II - Polyamide-imide resin, for bearing applications

Class 1 - 12% graphite; 3% Polytetrafluoroethylene (PTFE)
Class 2 - 20% graphite; 3% Polytetrafluoroethylene (PTFE)
Class 3 - 12% graphite; 8% Polytetrafluoroethylene (PTFE)

Type III - Polyamide-imide resin, glass fiber reinforced (GFR)

Class 1 - 30% GFR
Class 2 - 40% GFR

Type IV - Polyamide-imide resin, 30% carbon fiber reinforced

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 Laboratory Command, Materials Technology Laboratory, ATTN: SLCMT-MSR-ES, Watertown, MA 02172-0001 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

FSC 9330

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2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

FEDERAL

PPP-D-723 - Drums, Fiber
PPP-D-729 - Drums, Shipping and Storage, Steel 55-Gallon (208 Liters)

STANDARDS

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129 - Marking for Shipment and Storage

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

2.2 Other publications. The following document(s) form a part of this specification 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. Unless otherwise specified, the issues of documents not listed in the DODISS shall be the issue of the nongovernment documents which is current on the date of the solicitation.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM C 177 - Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Guarded Hot Plate
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 256 - Standard Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials
ASTM D 257 - Standard Test Methods for D-C Resistance or Conductance of Insulating Materials

ASTM D 570 - Standard Test Method for Water Absorption of Plastics
ASTM D 618 - Standard Methods of Conditioning Plastics and Electrical Insulating Materials For Testing
ASTM D 635 - Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position
ASTM D 648 - Standard Test Method for Deflection Temperature of Plastics Under Flexural Load
ASTM D 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 732 - Standard Test Method for Shear Strength of Plastics by Punch Tool
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 1708 - Standard Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens
ASTM D 2863 - Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D 3418 - Standard Test Method for Transition Temperatures of Polymers by Thermal Analysis
ASTM D 3951 - Standard Practice for Commercial Packaging
ASTM F 814 - Standard Method for Specific Optical Density of Smoke Generated by Solid Materials for Aerospace Applications

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

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

AMS 3670 - Polyamide-Imide Bar, Rod and Shapes Molded or Extruded
AMS 3670/1 - Unfilled Polyamide-Imide Bar, Rod, and Shapes
AMS 3670/2 - Polyamide-Imide Bar, Rod, and Shapes 20 Graphite-3 Polytetrafluoroethylene Filled
AMS 3670/3 - Polyamide-Imide Bar, Rod, and Shapes 12 Graphite-3 Polytetrafluoroethylene Filled

(Application for copies of SAE publications should be addressed to Society of Automotive Engineers, Inc. 400 Commonwealth Drive, Warrendale, PA 15096).

UNDERWRITERS' LABORATORIES (UL)

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

(Application for copies of UL Publications should be addressed to Underwriters' Laboratories, Inc., Publication Stock, 333 Pfingsten Road, Northbrook, IL 60062).

(Nongovernment standards and other publications are normally available from the organizations which prepare or which distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein (except for associated detail specifications, specification sheets or MS standards), the text of this specification shall take precedence. Nothing in this specification, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Material. The material shall consist of polyamide-imide (PAI) resin produced from trimellitic acid chloride and aromatic diamines.

3.2 Properties of PAI thermoplastic. Unless otherwise specified (see 6.2), the properties of the PAI thermoplastic materials shall be as specified in tables I through IV.

3.3 Color. Unless other specified (see 6.2), the color of the PAI materials shall be opaque greenish brown.

3.4 Form. Unless otherwise specified (see 6.2), the material form shall be pellets. When specified by the procuring activity, the form shall be in the size and shape specified (see 6.2). Polyamide-imide bar, rod, and shapes shall conform to the requirements specified in AMS 3670, 3670/1, 3670/2 or 3670/3 as applicable.

3.5 Workmanship. The material shall be free of contamination and color and form shall be uniform from container to container within each lot (see 4.2.2.1.1).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items must meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of assuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to acceptance of defective material.

4.2 Sampling for inspection and acceptance. Sampling for inspection shall be performed in accordance with the provisions set forth in MIL-STD-105 unless otherwise specified. An inspection lot for examination and tests shall consist of all material of the same type and class submitted for delivery at one time under one contract.

4.2.1 Inspection of materials and components. In accordance with 4.1, the supplier is responsible for insuring that materials and components used were manufactured, tested and inspected in accordance with the requirements of referenced subsidiary specifications and standards to the extent specified. In the event of conflict, this specification shall govern. A supplier's certificate of compliance with 3.1 shall be furnished.

4.2.2 Inspection of material.

4.2.2.1 *Examination of the material*. Examination of the material shall be made in accordance with the classification of defects, inspection levels and acceptable quality levels (AQLs) set forth below. The lot size, for purpose of determining the sample size in accordance with MIL-STD-105, shall be expressed in units of 100 lb (45 kg) for examination in 4.2.2.1.1, and in units of shipping containers for examination in 4.2.2.1.2.

4.2.2.1.1 Examination of the material for defects in appearance and workmanship. The sample unit for this examination specified in table V shall be approximately one pound (0.45 kg).

4.2.2.1.2 Examination of the packaging. An examination shall be made in accordance with Table VI to determine that packing and marking comply with section 5 requirements. The sample unit for this examination shall be one shipping container fully packed, selected just prior to the closing operation. Shipping containers fully prepared for delivery shall be examined for closure defects.

4.2.2.1.3 Inspection levels and acceptable quality levels (AQLs) for examinations. The inspection levels for determining the sample size and the acceptable quality level (AQL) expressed as defects per 100 units shall be as follows:

Examination paragraph	Inspection level	AQL
4.2.2.1.1	II	2.5
4.2.2.1.2	S-2	2.5

4.2.3 Testing. The PAI materials shall be tested for the properties listed in tables I through IV, as applicable. Testing shall be in accordance with the test methods specified in table VII for each lot submitted for inspection. The lot size, for the purpose of determining the sample size for testing, shall be expressed in units of 100 lb (45 kg) of material. The sample unit of product shall consist of sufficient material to prepare all required specimens. The inspection level shall be S-1, with an AQL. The results for each test shall be the averaged results of the specimens, unless only one specimen is required for testing.

4.2.3.1 Classification of tests. All tests shall be classified, as follows:

a. Lot acceptance tests (see 4.2.3.2).
b. Periodic lot check tests (see 4.2.3.3).

4.2.3.2 Lot acceptance tests. Lot acceptance tests shall be made on each lot of material and shall be the basis for acceptance or rejection of the lot, except when periodic lot check tests are required. Lot acceptance tests shall consist of testing for tensile strength, tensile elongation and specific gravity.

4.2.3.3 Periodic lot check tests. Periodic lot check tests shall be made on the first lot of material furnished under this specification, and on any subsequent lot specified by the procuring activity (see 6.2). If not specified by the procuring activity, periodic lot check tests shall be repeated at least once every year. Periodic lot check tests shall consist of the tests for the properties in tables I through IV, specified by the procuring activity (see 6.2). When periodic lot check tests are made, they shall be included in the basis for acceptance or rejection of the lot.

4.3 Test methods. (See table VII).

4.3.1 Preparation of specimens. Unless otherwise specified (see 6.2), test specimens shall be prepared by injection molding. Specimens shall be post-cured for 24 ± 0.1 hours at 168 ± 2°C (335 ± 5°F), followed by 24 ± 0.1 hours at 243 ± 2°C (470° ± 5°F), followed by 60 ± 0.1 hours at 257 ± 2°C (495° ± 5°F).

4.3.2 Test conditions. Unless otherwise specified (see 6.2), all tests shall be performed at 23° ± 2°C (73.4° ± 3.6°F) and 50 ± 5 percent relative humidity. Specimens shall be conditioned in accordance with procedure A of ASTM D 618. Prior to conditioning, specimens shall be dried for 24 ± 0.1 hours at 166° ± 5°C (330° ± 9°F).

5. PACKAGING

5.1 Packing. Packing shall be level A or Industrial as specified (see 6.2).

5.1.1 Level A. Unless otherwise specified, the material shall be packed in one of the following types of containers:

a. Fiber drums conforming to PPP-D-723, type II, grade A, or type III, grade A in quantities of 200 lb (90 kg), maximum.

b. Metal drums conforming to PPP-D-729, type III or type IV, in quantities of 400 lb (181 kg), maximum.

Insofar as practical, drums shall be of uniform shape and size, with minimum cube and tare consistent with the protection required. Drums shall contain identical quantities and shall be closed in accordance with the applicable container specification. Fiber drums shall be furnished with a 0.004 in (4 mil) thick polyethylene liner properly heat sealed.

5.1.2 Industrial. The material shall be packed in accordance with ASTM D 3951.

5.2 Marking. In addition to any special marking required by the contract or purchase order, shipping containers shall be marked in accordance with MIL-STD-129, with the exception that industrial marking in accordance with ASTM D 3951 applies for industrial packaging only.

6. NOTES

6.1 Intended use. Applications for polyamide-imide materials can be categorized into five areas.

a. Electrical devices
b. Bearings and wear surfaces
c. Mechanical seals and seats
d. Aircraft and aerospace components
e. General mechanical devices

6.1.1 Electrical devices. Electrical connectors, burn-in sockets, integrated circuit processing equipment, oil well dielectrics and electric arc welding equipment are examples of the use of PAI resins in electrical applications. PAI materials perform over temperatures ranging from -62°C (-80°F) to 204°C (400°F) and have good dielectric properties.

6.1.2 Bearing and wear surfaces. Some PAI resins are used as a matrix for wear compounds. Graphite powder and PTFE are incorporated into these resins to reduce the coefficient of friction. PAI materials are used for clutch buttons, turbine engine parts (e.g., bushings, washers/spacers and nuts), thrust washers, bearings, compressor rod packing, bushings and seals for hydraulic motors, and ball bearings.

6.1.3 Mechanical seals and seats. Seals of PAI are used in hydraulic and pneumatic systems to control leakage at high pressures and elevated temperatures. PAI materials are specified for hydraulic cylinder wear rings, hydraulic and pneumatic motor seals, compressor valve plates, valve seats, back-up rings and tup seals.

6.1.4 Aircraft and aerospace components. PAI resins are intended for use in a variety of aircraft and aerospace hardware. Some examples are:

a. Antennas
b. Radomes
c. Electronic enclosures
d. Support brackets and frames
e. Mechanical fasteners and rivets
f. Fuel system components
g. Hydraulic system components
h. Compressor system components
i. Jet engine components
j. Rocket engine components
k. Wear strips
l. Space structures
m. Connector shells

Amorphous thermoplastic polyamide-imide (PAI) has potential as a matrix material for advanced composite structural applications. See reference: Cole B., "Torlon-C Graphite Composites," 30th National SAMPE Symposium, Vol. 30, p. 799 (1985).

6.1.5 General mechanical devices. PAI materials are used to make hydraulic pistons and potentiometer shafts. Parts made of PAI are also used in ultrasonic transducers and pump vanes.

6.2 Ordering data. Acquisition documents should specify the following:

a. Title, number and date of this specification.
b. Type and class of PAI material (see 1.2).
c. Properties of PAI material, if other than specified in 3.2.
d. Color, if other than specified in 3.3.
e. Form, if other than specified in 3.4
f. Periodic lot check tests, if required (see 4.2.3.3).
g. Preparation of specimens, if other than in 4.3.1.
h. Test conditions, if other than in 4.3.2
i. Level of packing required (see 5.1).

6.3 Changes from previous issue. Asterisks (or vertical lines) are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

6.4 ASTM D4000. Polyamide-imide plastics may also be specified using ASTM D4000, "Standard Guide for Identification of Plastic Materials."

Custodian:

Army -- MR

Review activities:

Army --AV, AL, AT
Navy -- AS
Air Force -- 20
DLA -- GS

User activities:

Navy -- SH

Preparing activity:

Army -- MR

Project No. 9330-B081

(KBWP# ID-0456A/DISK-0135B. FOR AMTL USE ONLY)

TABLE I. Physical properties.

Property	Type I	Type II Class 1	Type II Class 2	Type II Class 3	Type III Class 1	Type III Class 2	Type IV
Specific gravity	1.41 ± 0.02	1.46 ± 0.02	1.50 ± 0.02	1.50 ± 0.02	1.61 ± 0.02	1.68 ± 0.02	1.48 ± 0.02
Water absorption % (by weight), max	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Glass transition temperature, Tg, °C(°F), min 1/	272 ± 2 (522 ± 5)	272 ± 2 (522 ± 5)	272 ± 2 (522 ± 5)	272 ± 2 (522 ± 5)	272 ± 2 (522 ± 5)	272 ± 2 (522 ± 5)	272 ± 2 (522 ± 5)

1/ The glass transition temperature shall be determined on dry, fully cured specimens.

TABLE II. Mechanical properties.

Property	Type I	Type II Class 1	Type II Class 2	Type II Class 3	Type III Class 1	Type III Class 2	Type IV
Tensile strength at break, MPa (psi), min 1/	159 (23,000)	124 (18,000)	114 (16,500)	97 (14,000)	172 (25,000)	172 (25,500)	163 (23,600)
Tensile elongation at break, % min	9	5	5	4	4	4	4
Flexural strength, MPa (psi), min	193 (28,000)	165 (24,000)	158 (23,000)	152 (22,000)	290 (42,000)	269 (39,000)	297 (43,000)
Flexural modulus, MPa (psi), min	3860 (560,000)	5860 (850,000)	5520 (800,000)	5030 (730,000)	9660 (1,400,000)	11,700 (1,700,000)	15,900 (2,300,000)
Izod impact strength notched, J/m (ft-lb/in), min 2/	117 (2.2)	53 (1.0)	64 (1.2)	53 (1.0)	64 (1.2)	64 (1.2)	37 (0.7)
Compressive strength, MPa (psi), min	165 (24,000)	145 (21,000)	124 (18,000)	103 (15,000)	199 (28,900)	248 (36,000)	203 (29,500)
Shear strength MPa (psi), min	103 (15,000)	89 (12,900)	62 (9,000)	63 (9,200)	110 (16,000)	124 (18,000)	97 (14,000)

1/ MPa x 145 = psi

2/ J/m x 18.73 x 10^{-3} = ft-lb/in

TABLE III. Thermal properties.

Property	Type I	Type II Class 1	Type II Class 2	Type II Class 3	Type III Class 1	Type III Class 2	Type IV
Deflection temperature at 1820 kPa (264 psi), °C (°F), min	260 (500)	260 (500)	260 (500)	260 (500)	260 (500)	260 (500)	260 (500)
Coefficient of linear thermal expansion, 10^{-6} cm/cm/°C (10^{-6} in/in/°F)	27-36 (15-20)	22-29 (12-16)	22-29 (12-16)	23-31 (13-17)	12-22 (7-12)	9-17 (5-9)	9-27 (5-15)
Thermal conductivity, W/m-K (Btu-in/h-ft^2-°F) 1/	0.21-0.28 (1.5-2.0)	0.50-0.58 (3.5-4.0)	-	-	0.32-0.40 (2.25-2.75)	-	0.43-0.57 (3.0-4.0)
Flammability							
UL rating	94V0	94V0	94V0	94V0	94V0	94V0	94V0
Smoke density 2/							
Smoldering (D_{max})	9	-	-	-	4	-	5
Flaming (D_{max})	220	-	-	-	50	-	90
Limiting oxygen index, min 3/	41	42	42	40	46	45	47

1/ 1 W/m-K = 6.933 Btu-in/h-ft^2-°F.

2/ D_{max} = Maximum specific optical density; Specimens were cut 3 x 3 in with thickness as supplied.

3/ Type A, Self-supporting samples, approximately 4.0 x 1/2 x 1/8 in. Test specimens were observed to glow after flaming combustion.

TABLE IV. Electrical properties.

Property	Type I	Type II Class 1	Type II Class 2	Type II Class 3	Type III Class 1	Type III Class 2	Type IV
Dielectric constant, max							
at 10^3 Hz	4.6	6.6	8.0	7.5	4.8	4.7	-
at 10^6 Hz	4.3	5.9	7.3	6.6	4.6	5.1	-
Dissipation factor, max							
at 10^3 Hz	0.033	0.046	0.074	0.046	0.028	0.050	-
at 10^6 Hz	0.039	0.053	0.079	0.089	0.064	0.055	-
Volume resistivity,							
ohm-cm, min	10×10^{15}	5×10^{14}	5×10^{14}	5×10^{14}	7.6×10^{15}	2.5×10^{15}	-
(ohm-in)	(4×10^{15})	(2×10^{14})	(2×10^{14})	(2×10^{14})	(3×10^{15})	(1×10^{15})	-
Surface resistivity,							
ohms, min	1×10^{16}	1×10^{15}	8×10^{14}	2×10^{15}	2×10^{15}	2×10^{15}	-
Dielectric strength,							
kV/mm	19.3	-	-	-	28.0	16.1	-
(volts/mil), min	(490)	-	-	-	(710)	(410)	-

TABLE V. Examination of the material for defects in appearance and workmanship.

Examine	Defect
Appearance and workmanship	When required, form size not as specified Not uniform in form from container to container Not uniform in color from container to container Not clean, presence of foreign material

TABLE VI. Examination of packaging.

Examine	Defects
Packing	Not level specified; not in accordance with contract requirements. Any nonconforming component, component missing, damaged or otherwise defective affecting serviceability. Inadequate application of components such as: incomplete closures of case liners; container flaps, loose or inadequate strappings, bulged or distorted container
Quantity of material	Less than specified or indicated quantity.
Weight	Gross weight exceeds specified requirements.
Markings	Interior or exterior markings omitted, illegible, incorrect, incomplete, of improper size, location, sequence, method of application, or not in accordance with contract requirements.

TABLE VII. Test methods.

Property	Method
Physical:	
Specific gravity	ASTM D 792 (Method A-1)
Water absorption	ASTM D 570 (24 h immersion)
Glass transition temperature	ASTM D 3418
Mechanical:	
Tensile strength at break	ASTM D 1708
Tensile elongation at break	ASTM D 1708
Flexural strength	ASTM D 790 (Method I)
Izod impact strength	ASTM D 256 (Method A)
Compressive strength	ASTM D 695
Shear strength	ASTM D 732
Thermal:	
Deflection temperature	ASTM D 648
Coefficient of linear thermal expansion	ASTM D 696
Thermal conductivity	ASTM C 177
Flammability:	
UL rating	UL 94
Smoke density	ASTM F 814
Limiting oxygen index	ASTM D 2863
Average extent of burning	ASTM D 635
Electrical:	
Dielectric constant	ASTM D 150
Dissipation factor	ASTM D 150
Volume resistivity	ASTM D 257
Surface resistivity	ASTM D 257
Dielectric strength	ASTM D 149

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-P-46179A	PLASTIC MOLDING AND EXTRUSION MATERIALS, POLYAMIDE-IMIDE(PAI

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR
b. ADDRESS *(Street, City, State, ZIP Code)*	☐ USER
	☐ MANUFACTURER
	☐ OTHER *(Specify)*: _____

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

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