



Standard Classification System for Polyamide-Imide (PAI) Molding and Extrusion Materials¹

This standard is issued under the fixed designation D 5204; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This classification system covers polyamide-imide materials suitable for injection molding and extrusion.

1.2 The properties included in this classification system are those required to identify the compositions covered. There may be other requirements necessary to identify particular characteristics important to specialized applications. These may be specified by using suffixes as given in Section 5.

1.3 This standard allows for the use of recycled materials provided that specification requirements based upon this classification system are met.

1.4 This classification system and subsequent line callout (specification) is intended to be a means of calling out plastics materials used in the fabrication of end items or parts. It is not intended for the selection of materials. Material selection should be made by those having expertise in the plastics field after careful consideration of the design and the performance required of the part, the environment to which it will be exposed, the fabrication process to be employed, the inherent properties of the material other than those covered by this classification, and the economics.

1.5 The values stated in SI units are to be regarded as the standard. (Reporting in inch-pound units is acceptable.)

NOTE 1—There is no equivalent or similar ISO standard.

1.6 The following precautionary caveat pertains only to the test methods portion, Section 11, of this classification system: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies²

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials²

D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials³

D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials²

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing³

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials³

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement³

D 883 Terminology Relating to Plastics³

D 1525 Test Method for Vicat Softening Temperature of Plastics³

D 1600 Terminology for Abbreviated Terms Relating to Plastics³

D 1708 Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens³

D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)⁴

D 3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials⁴

D 3892 Practice for Packaging/Packing of Plastics⁴

D 4000 Classification System for Specifying Plastic Materials⁴

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications⁵

IEEE/ASTM SI-10 Standard for Use of the International System of Units (SI): The Modern Metric System⁵

2.2 *Military and Federal Specifications and Standards*:⁶

MIL-P-46179A Plastic Molding and Extrusion Materials, Polyamide-Imide (PAI)

NOTE 2—MIL-P-46179A property requirements are the basis of Classification System D 5204. The Department of Defense adopted Classification System D 5204 on July 27, 1994, and canceled MIL-P-46179A.

¹ This classification system is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials.

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² *Annual Book of ASTM Standards*, Vol 10.01.

³ *Annual Book of ASTM Standards*, Vol 08.01.

⁴ *Annual Book of ASTM Standards*, Vol 08.02.

⁵ *Annual Book of ASTM Standards*, Vol 14.02.

⁶ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, attn: NPODS.

2.3 SAE Specifications:⁷

AMS 3670B Polyamide-Imide Bar, Rod, and Shapes Molded or Extruded

AMS 3670/1B Unfilled Polyamide-Imide Bar, Rod and Shapes

AMS 3670/2B Polyamide-Imide Bar, Rod and Shapes 20-Graphite-3-Polytetrafluoroethylene Filled

AMS 3670/3B Polyamide-Imide Bar, Rod and Shapes 12-Graphite-3-Polytetrafluoroethylene Filled

AMS 3670/4C Polyamide-Imide Bar, Rod and Shapes 30 Glass Fiber

AMS 3670/5C Polyamide-Imide Bar, Rod and Shapes 30 Carbon Graphite Fiber

3. Terminology

3.1 The terminology used in this classification system is in accordance with Terminology D 883 and D 1600.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *polyamide-imide (PAI)*, *n*—a polymer that may be composed of linkages of all random, or all block, or all alternating, or any combination thereof, amide and imide units in the structural backbone.

4. Classification

4.1 The polyamide-imide materials shall be designated PAI, as specified in Terminology D 1600.

4.2 Polyamide-imide materials are classified into groups that are subdivided into classes and grades as shown in Table PAI.

4.2.1 An example of this classification system is as follows:

The designation PAI012L23 would indicate from Table PAI:
 PAI = Polyamide-imide as found in Terminology D 1600,
 01 (Group) = Injection molding material,
 2 (Class) = Wear resistance PAI, and
 L23 (Grade) = Nominal 20 % graphite and 3 % PTFE with the requirements given in Table PAI.

4.2.2 To facilitate the incorporation of special materials not covered in Table PAI, the “other” category (0) for group, class, and grade is shown on the table with the basic properties to be obtained from Table A.

4.3 Table A shall be used to specify the physical property requirements that shall be shown by a six-character designation. The designation shall consist of the letter A and the five digits comprising the cell numbers for the property requirements in the order as they appear in Table A.

4.3.1 Although the values listed are necessary to include the range of properties available in existing materials, users should not infer that every possible combination of the properties exists or can be obtained.

4.3.2 A single letter shall be used to indicate the major reinforcement or combinations, or both, along with two digits that indicate the percentage of additive(s) by total mass, with tolerances tabulated as follows:

Category	Material	Tolerance
C	Carbon or graphite fiber reinforced	±3 percentage points

G	Glass fiber reinforced	±3 percentage points
L	Lubricants	±3 percentage points
M	Minerals	±3 percentage points
R	Combinations of reinforcements or fillers, or both	±5 percentage points

4.3.3 This part of the classification system uses the type and percentage of additive to designate the modification of the basic material. To facilitate this designation, the type and percentage of additive can be shown on the supplier’s technical data sheet unless it is proprietary in nature. If necessary, additional requirements shall be indicated by use of the suffix part of the system, as given in Section 5.

4.3.4 An example of this classification system for a polyamide-imide material is as follows:

The designation PAI0130G40A61550
 PAI0130 = polyamide-imide from Table PAI,
 G40 = glass reinforced at 40 % nominal level,
 A = Table A physical-property requirements,
 6 = tensile strength, 172 MPa, min,
 1 = elongation, 4 %, min,
 5 = flexural strength, 269 MPa, min,
 5 = flexural modulus, 11700 MPa, min, and
 0 = unspecified property.

If no properties are specified, the designation would be PAI0130G40A00000.

5. Suffixes

5.1 When additional requirements are needed, based on application, that are not covered by the basic requirements (Table PAI) or cell-table requirements (Table A), they shall be indicated through the use of suffixes.

5.2 A list of suffixes can be found in Classification System D 4000 (Table 3) and may be used for additional requirements as appropriate. Additional suffixes will be added to Classification System D 4000 as test methods and requirements are developed and requested.

5.2.1 An example of this classification system using a suffix is as follows:

The designation PAI041G30CAXXX
 PAI041G30 = polyamide-imide material as described in Table PAI,
 C = melting point / softening point from Classification System D 4000,
 A = Test Method D 1525., Rate A (Vicat), and
 XXX = three digit number indicating minimum value, °C.

5.3 Suffixes for electrical properties, if required, can be found in Table XE in Appendix X1.

6. General Requirements

6.1 Basic requirements from Table A, as they apply, are always in effect unless these requirements are superseded by specific suffix requirements, which always take precedence.

6.1.1 The material composition shall be uniform and shall conform to the requirements specified herein.

7. Detail Requirements

7.1 Test specimens for the various materials shall conform to the requirements prescribed in Table A and the suffix requirements as they apply.

7.2 For the purpose of determining conformance, all specified limits in this specification (line callout) based on this classification system, are lot average by round-off, as defined in Practice E 29.

7.2.1 With the round-off method, an observed value or a

⁷ Available from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

calculated value should be rounded off to the nearest unit in the designated place of figures. The rounded off value should then be compared directly to the specified limiting value. Conformance or nonconformance with a specification based on this classification system is based on this comparison.

8. Sampling

8.1 Sampling shall be statistically adequate to satisfy requirements of 12.2. A batch or lot of material shall be defined as material produced in a single compounding run.

9. Test Specimen

9.1 Dry pellets before molding test specimens. Pellets dried on trays at 149°C (300°F) in a desiccant air drier for a minimum of 24 h have been found to be satisfactory for injection molding.

9.2 Unless otherwise specified, injection and extrusion resins test specimens shall be prepared by injection molding in accordance with Practice D 3641.

NOTE 3—Typical conditions for molding are melt temperature of 315 to 370°C (600 to 700°F) and mold temperature of 195 to 215°C (380 to 420°F), depending on the product. Because of the equipment requirements and difficulty associated with molding PAI, the manufacturer normally does all molding of parts.

10. Conditioning

10.1 Postcure all test specimens in accordance with the manufacturer's instructions.

10.2 Condition all test specimens for a minimum of 40 h at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ relative humidity after postcuring and before testing.

11. Test Methods

11.1 Determine the properties enumerated in this classification system in accordance with the relevant methods as they apply.

11.2 Specify methods for reinforcement and additive concentration.

12. Certification and Inspection

12.1 Inspection and certification of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

12.2 Lot acceptance inspection shall be the basis on which acceptance or rejection of the lot is made and shall consist of the tests listed, as they apply, as follows: tensile strength at break, tensile elongation at break, and specific gravity.

12.3 Periodic check inspection shall consist of the tests specified for all requirements of the material under this classification system. Inspection frequency shall be adequate to ensure that the material is certifiable in accordance with 12.4

NOTE 4—If any failure occurs, the material may be retested to establish conformity.

12.4 Certification shall state that the material meets the requirements of the acceptance tests of this classification system in accordance with 12.2. Lot average values shall be reported for the lot acceptance properties as designated by the classification in accordance with Table PAI.

12.5 A report of the test results shall be furnished when requested. The report shall consist of the lot-acceptance inspection for the shipment. The results of the most recent periodic-check inspection shall also be furnished when requested by the purchaser.

13. Packaging and Package Marking

13.1 For packing, packaging, and package marking, the provisions of Practice D 3892 shall apply.

14. Keywords

14.1 extrusion material; line call-out; molding material; polyamide-imide

TABLE PAI Requirements for Polyamide-Imide Plastics

Group	Description	Class	Description	Grade	Description	Tensile Strength, Test Method D 1708, Pa (psi), min	Tensile Elongation, Test Method D 1708, %, min	Specific Gravity, Test Method D 792	
01	Injection Molding	1	general purpose	M03 0	3 % mineral other	158 (23 000)	9	1.39 to 1.43	
		2	wear resistance	L15 L23 L20 0	12 % graphite, 3 % PTFE 20 % graphite, 3 % PTFE 12 % graphite, 8 % PTFE other	124 (18 000) 114 (16 500) 97 (14 000)	5 5 4	1.44 to 1.48 1.48 to 1.52 1.48 to 1.52	
	3	high strength	G30 C30 0	30 % glass fiber 30 % carbon fiber other	172 (25 000) 163 (23 600)	4 4	1.59 to 1.63 1.46 to 1.50		
			02	Extrusion	1	general purpose	M03 0	3 % mineral other	158 (23 000)
	2	wear resistance	L15 0		12 % graphite, 3 % PTFE other	124 (18 000)	5	1.44 to 1.48	
	3	high strength	G30 0		30 % glass fiber other	172 (25 000)	4	1.59 to 1.63	
00	Other	0	other	0	other				

TABLE A Detailed Requirements for Special Polyamide-Imides

Designation Order	Property ^A	0	1	2	3	4	5	6	9 ^B
1	Tensile strength, ^C MPa ^D (psi), min	unspecified	97 (14 000)	114 (16 500)	124 (18 000)	138 (20 000)	159 (23 000)	172 (25 000)	specify value
2	Elongation, ^C % , min	unspecified	4	5	6	7	8	9	specify value
3	Flexural strength, ^E MPa ^D (psi), min	unspecified	152 (22 000)	165 (24 000)	193 (28 000)	228 (33 000)	269 (39 000)	290 (42 000)	specify value
4	Flexural modulus, ^E MPa ^D (psi), min	unspecified	3860 (560 000)	5030 (730 000)	5520 (800 000)	9660 (1 400 000)	11 700 (1 700 000)	15 900 (2 300 000)	specify value
5	To be determined	unspecified	specify value

^APhysical property data were determined using injection molded and postcured specimens.

^BIf a specific value is required it must be shown in the call-out.

^CSee Test Method D 1708.

^DMPa X 145 = psi.

^ESee Test Method D 790, Method 1, Procedure A.

APPENDIXES

(Nonmandatory Information)

X1. CROSS REFERENCE FROM MIL-P-46179A AND CLASSIFICATION SYSTEM D 5204

X1.1 This classification system contains pertinent specification items from MIL-P-46179A, for plastic molding and extrusion materials, polyamide-imide (PAI).

X1.2 The cross-reference designations are listed in Table X1.1.

X1.3 Appropriate additional suffixes can be used as required.

X1.4 Additional tests may be required for initial acceptance of a material.

TABLE X1.1 Cross Reference Designations for MIL-P-46179A and Classification System D 5204

MIL-P-46179A	Classification System D 5204
Type I	PAI011M03 or PAI021M03
Type II Class 1	PAI012L15 or PAI022L15
Type II Class 2	PAI012L23
Type II Class 3	PAI012L20
Type III Class 1	PAI013G30 or PAI023G30
Type IV	PAI013C30

X1.5 Table XE contains additional information on electrical properties from MIL-P-46179A indicating material capability. These are to be used only for initial qualification testing and are not to be construed as lot acceptance tests.

X1.5.1 An example of this classification system using Table XE is as follows:

The designation PAI013G30E5 indicates the following:

PAI013G30 = polyamide-imide as described in Table PAI,
 E = electrical properties from Table XE,
 5 = all of the electrical properties as specified in Column 5 of Table XE. (Note—Any time that a column from Table XE is specified, all of the electrical properties in that column shall be met. If all of these are not required, then Table 3 of Classification System D 4000 can be used for specific electrical properties.)

X2. REFERENCE SPECIFICATIONS FROM THE SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

X2.1 This classification system contains pertinent specification items from the SAE specifications given in 2.3.

TABLE XE Electrical Property Requirements

Property	1	2	3	4	5	6
Dielectric constant, max: ^A						
1 kHz	4.6	6.6	8.0	7.5	4.8	4.7
1 Mhz	4.3	5.9	7.3	6.6	4.6	5.1
Dissipation factor, max: ^A						
1 kHz	0.033	0.046	0.074	0.046	0.028	0.050
1 MHz	0.039	0.053	0.079	0.089	0.064	0.055
Volume resistivity, min: ^B						
Ω-cm	10×10^{15}	5×10^{14}	5×10^{14}	5×10^{14}	7.6×10^{15}	2.5×10^{15}
(Ω-in.)	(4×10^{15})	(2×10^{14})	(2×10^{14})	(2×10^{14})	(3×10^{15})	(1×10^{15})
Surface resistivity, min, ^B Ω	1×10^{16}	1×10^{15}	8×10^{15}	2×10^{15}	2×10^{15}	2×10^{15}
Dielectric strength, min: ^C						
kV/mm	19.3				28.0	16.1
(V/mil)	(490)				(710)	(410)

^ASee Test Method D 150.

^BSee Test Method D 257.

^CSee Test Method D 149.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this classification system. For the convenience of the user, Committee D-20 has highlighted those changes that may impact the use of this classification system. This section may also include descriptions of the changes, or reasons for the changes, or both.

D 5204 – 99:

- (1) Reference to compression molding was deleted (1.1).
- (2) A section on the use of recycled materials was added (1.3).
- (3) An ISO equivalency statement was added (Note 1).
- (4) Several ASTM reference documents were added to 2.1.
- (5) Note 2 on the adoption of Classification System D 5204 by the DoD was added.
- (6) SAE references were updated (2.3).
- (7) Section 4.2 was added to include group, class, and grade in the classification system.
- (8) The example of the classification system was revised to include group, class, and grade (4.3.4).
- (9) The section on suffixes was simplified (Section 5).
- (10) Basic and general requirements were combined into a single section (Section 6).
- (11) The absolute method was replaced by the round-off method. Both are acceptable in accordance with Practice E 29 (7.2).

- (12) Batch (lot) of material was redefined (Section 8).
- (13) Conditions for drying pellets were added (9.1).
- (14) Typical molding conditions were added (Note 3).
- (15) Specific gravity was added as a lot acceptance test (12.2).
- (16) Note 4 on retesting was added.
- (17) The certification clause was revised (12.4).
- (18) Table X1.1 was revised to simplify the cross reference to MIL-P-46179A.
- (19) Reference to MIL-P-46179A Type III Class 2 materials in Table X1.1 was deleted since this product is no longer available.
- (20) Table PAI, which defines group, class, and grade, was added.
- (21) Table E was moved to the appendix and changed to Table XE. An example of how to use Table XE has been included.

 **D 5204**

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