



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 approval. 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 call-out (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:*²

- D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
- D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
- D 256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
- D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials
- D 618 Practice for Conditioning Plastics for Testing
- D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
- D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D 883 Terminology Relating to Plastics
- D 1525 Test Method for Vicat Softening Temperature of Plastics
- D 1600 Terminology for Abbreviated Terms Relating to Plastics
- D 1708 Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens
- D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
- D 3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials
- D 3892 Practice for Packaging/Packing of Plastics
- D 4000 Classification System for Specifying Plastic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- IEEE/ASTM SI-10 Standard for Use of the International System of Units (SI): The Modern Metric System

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

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard.

2.2 Military and Federal Specifications and Standards:³ 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.

2.3 SAE Specifications:⁴

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 PAI013G30CAXXX
PAI013G30 = 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 SE in Supplementary Requirements.

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.

³ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, attn: NPODS.

⁴ Available from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

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 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, MPa [psi], min	Tensile Elongation, Test Method D 1708, %, min	Specific Gravity, Test Method D 792	
01	Injection Molding	1	general purpose	M03	3 % mineral	158 [23 000]	9	1.39 to 1.43	
			wear resistance	0	other				
		2	wear resistance	L15	12 % graphite, 3 % PTFE	124 [18 000]	5	1.44 to 1.48	
				L23	20 % graphite, 3 % PTFE	114 [16 500]	5	1.48 to 1.52	
				L20	12 % graphite, 8 % PTFE	97 [14 000]	4	1.48 to 1.52	
				0	other				
3	high strength	G30	30 % glass fiber	172 [25 000]	4	1.59 to 1.63			
		C30	30 % carbon fiber	163 [23 600]	4	1.46 to 1.50			
		0	other						
02	Extrusion	1	general purpose	M03	3 % mineral	158 [23 000]	9	1.39 to 1.43	
			wear resistance	0	other				
		2	wear resistance	L15	12 % graphite, 3 % PTFE	124 [18 000]	5	1.44 to 1.48	
				0	other				
			3	high strength	G30	30 % glass fiber	172 [25 000]	4	1.59 to 1.63
					C30	30 % carbon fiber	163 [23 600]	4	1.46 to 1.50
	0	other							
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	g ^B
1	Tensile strength, ^C MPa ^D [psi], min	unspecified	97	114	124	138	159	172	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	165	193	228	269	290	specify value
4	Flexural modulus, ^E MPa ^D [psi], min	unspecified	3860	5030	5520	9660	11 700	15 900	specify value
5	Izod Impact ^F , J/m ^G , min	unspecified	37	53	64	80	101	117	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, using 3.175 ± 0.05 mm [0.125 in.] thick specimens.

^DMPa X 145 = psi.

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

^FSee Test Method D 256, Method A, using the center portion of a D 638, Type I specimen.

^GJ/m × 0.01873 = ft · lb/in.

SUPPLEMENTARY REQUIREMENTS FOR SPECIAL END USES

The following supplementary requirements shall apply only when specified by the inquiry, contract or order for agencies of the U.S. Government.

S1. Special End Uses

S1.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of acceptance testing per 12.2 of this standard. Except as otherwise specified, the supplier may utilize its own facilities or any commercial laboratory acceptable to the Government. The Government may reserve the right to perform any of the testing or inspections set forth in the specification requirements.

S2. Physical Requirements

S2.1 Material properties, in addition to those in Tables PAI and A, which may be required for initial material qualifications (such as those described in MIL-P-46179A) are given in Table S2.1.

S2.2 Electrical requirements for initial material qualifications are given in Table SE.

TABLE S2.1 Property Values for Initial Qualification Testing

Physical and Thermal Properties	ASTM Methods	Type I	Type II Class 1	Type II Class 2	Type II Class 3	Type III Class 1	Type III Class 2	Type IV
Flexural Strength, min. MPa [psi] ^A	D790	193	165	158	152	290	269	297
Flexural Modulus, min. MPa [psi]	D790	3860	5860	5520	5030	9660	11,700	15,900
Compressive Strength, min. MPa [psi]	D695	165	145	124	103	199	248	203
Shear Strength, min. MPa [psi]	D732	103	89	62	63	110	124	97
Deflection Temp. at 1820 kPa [264 psi], °C [°F], min.	D648	260	260	260	260	260	260	260
Coefficient of Linear Thermal Expansion, 10 ⁻⁶ cm/cm/°C [10 ⁻⁶ in./in./°F]	D696	27–36	22–29	22–29	23–31	12–22	9–17	9–27
Thermal Conductivity W/m-K ^B	C177	0.21–0.28	0.50–0.58	...	...	0.32–0.40	...	0.43–0.57
UL Rating	D3801 (UL94)	V0	V0	V0	V0	V0	V0	V0
Smoke Density Smoldering (D _{max}) ^C	F814	9	...	...	...	4	...	5
Flaming (D _{max})		220	...	...	...	50	...	90
Oxygen Index, min. ^D	D2863	41	42	42	40	46	45	47
Water Absorption wt. %, max. ^E	D570	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Glass Transition Temp., T _g °C [°F], min. ^F	D3418	272 ± 2	272 ± 2	272 ± 2	272 ± 2	272 ± 2	272 ± 2	272 ± 2

^AMPa × 145 = psi

^B1 W/m = 6.933 Btu-in./h - ft² - °F

^CD_{max} = Maximum specific optical density; specimens are 3 in. × 3 in. by thickness supplied.

^DType A, self-supporting samples, approximately 4.0 in. × ½ in. × ¼ in. Test specimens may glow after flaming combustion.

^E24 h immersion

^FGlass transition temperature shall be determined on dry, fully cured specimens.

S3. Quality Assurance

S3.1 *Acceptance Criteria*— Lot acceptance testing shall be in accordance with 12.2 of this standard.

S3.2 *Sample Size*— The minimum number of test specimens to be tested shall conform with the requirements of the respective test method or, if different, by agreement with the customer.

S3.3 *Test Methods*— Testing shall be in accordance with the methods specified in Table PAI and Table S2.1.

S3.4 *Conditioning*— Test specimens shall be conditioned as described in Section 10.

S3.5 *Lot Certification*— Lot certification shall be in accordance with 12.4 of this standard.

TABLE SE 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.]						
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]						

^ASee Test Method D 150.

^BSee Test Method D 257.

^CSee Test Method D 149.

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 molding and extrusion materials, polyamide-imide (PAI).

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

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

MIL-P-46179A	DOD D5204 Adoption Notice Dated 27 July 1994 (Based on D 5204 – 91)	D 5204 – 99	D 5204 – 01
Type I	PAI000R03A56316E11FB41	PAI011M03 or PAI021M03	PAI000R03A56316E11FB41 or PAI011M03 or PAI021M03
Type II Class 1	PAI000L15A32232E12FB42	PAI012L15 or PAI022L15	PAI000L15A32232E12FB42 or PAI012L15 or PAI022L15
Type II Class 2	PAI000L23A22133E13FB42	PAI012L23	PAI000L23A22133E13FB42 or PAI012L23
Type II Class 3	PAI000L20A11122E14FB40	PAI012L20	PAI000L20A11122E14FB40
Type III Class 1	PAI000G30A61643E15FB46	PAI013G30 or PAI023G30	PAI000G30A61643E15FB46 or PAI013G30 or PAI023G30
Type III Class 2	PAI000G40A61553E16FB45	Not Manufactured	Not Manufactured
Type IV	PAI000C30A51661FB47	PAI013C30	PAI000C30A51661FB47 or PAI013C30

Explanation of Call-Outs for Table X1.1

An example of specifying Type III Class 1 material using property Table A in this standard and Table 3 in D4000 is as follows:

The designation PAI000G30A61643E15FB46 would indicate:

PAI000	= unspecified polyamide-imide material,
G30	= glass reinforced at 30 % nominal level,
A	= Table A physical properties,
6	= tensile strength, min 172 MPa,
1	= elongation, min 4 %,
6	= flexural strength, min 290 MPa,
4	= flexural modulus, min 9660 MPa,
3	= Izod impact of 64 J/m,
E	= Table SE electrical property requirements,
1	= electrical tests as specified in the footnotes of Table SE,
5	= electrical properties as given in column 5 of Table SE,
FB	= Table 3 (suffix symbols and requirements) in D 4000, and
46	= oxygen index, max 46 %

An example of specifying Type III Class 1 material using only Table PAI is as follows:

The designation PAI013G30 would indicate from Table PAI:

PAI	= polyamide-imide as found in Terminology D 1600,
01 (Group)	= injection molding material,
3 (Class)	= high strength PAI, and
G30 (Grade)	= glass reinforced at the 30 % nominal level with the requirements given in Table PAI.

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

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.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this classification system. For the convenience of the user, Committee D20 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 – 03:

(1) Added Group 02, Class 3, Grade C30 material and properties to Table PAI.

D 5204 – 01:

(1) Corrected the call-out in 5.2.1 from PAI041G30CAXXX to PAI013G30CAXXX. (There is no PAI041 in Table PAI.)

(2) Izod impact was added to Table A. (Izod impact was in the 1991 version of this standard, but was removed when revised in 1999. It is needed to recreate the original call-outs.)

(3) Added the Supplementary Requirements section, including Table S2.1, which contains the initial qualification tests from MIL-P-46179A.

(4) Revised Appendix X1 to show the relationships between the call-outs in the 1991, 1999, and the current version of this standard. It also shows that the call-outs in both the 1991 and 1999 versions of this standard can now be used.

(5) Added the thickness of the D1708 tensile bar to note B in Table A.

(6) Added the following to note F in Table A: “using the center portion of the D638 Type I tensile bar.”

(7) Moved Table XE to the Supplementary Requirements section. It was also renamed Table SE.

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.

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