



Designation: D5204 – 22

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

This standard is issued under the fixed designation D5204; 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 U.S. 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. It is possible that other requirements are necessary to identify particular characteristics important to specialized applications. The use of suffixes as shown in Section 5 is one way of specifying these requirements.

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 needs to 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.)

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—There is no known ISO equivalent to this standard.

1.7 *This international standard was developed in accordance with internationally recognized principles on standard-*

ization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 ASTM Standards:²

- D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
- D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
- D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
- D257 Test Methods for DC Resistance or Conductance of Insulating Materials
- D618 Practice for Conditioning Plastics for Testing
- D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
- D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D883 Terminology Relating to Plastics
- D1525 Test Method for Vicat Softening Temperature of Plastics
- D1600 Terminology for Abbreviated Terms Relating to Plastics
- D1708 Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens
- D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
- D3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials
- D3892 Practice for Packaging/Packing of Plastics
- D4000 Classification System for Specifying Plastic Materials

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

E29 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

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 D5204. The Department of Defense adopted Classification System D5204 on July 27, 1994, and canceled MIL-P-46179A.

2.3 SAE Specifications:⁴

AMS 3670C Bar, Rod, and Shapes Molded or Extruded from Polyamide-Imide Plastics Materials

AMS 3670/1C Bar, Rod, and Shapes Produced from Unfilled Polyamide-Imide

AMS 3670/2C Bar, Rod, and Shapes Produced from 20 % Graphite-3 % Polytetrafluoroethylene Filled Polyamide-Imide Material

AMS 3670/3C Bar, Rod, and Shapes Produced from 12 % Graphite-3 % Polytetrafluoroethylene Filled Polyamide-Imide Material

AMS 3670/4D Bar, Rod, and Shapes Produced from 30 % Glass Fiber Filled Polyamide-Imide Material

AMS 3670/5D Bar, Rod and Shapes Produced from 30 % Carbon Fiber Filled Polyamide-Imide Material

3. Terminology

3.1 The terminology used in this classification system is in accordance with Terminology **D883** and **D1600**.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *polyamide-imide (PAI), n*—a polymer that is 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 are designated PAI, as specified in Terminology **D1600**.

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 **D1600**,
 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 Use Table A to specify physical property requirements for other PAI materials. These properties are shown by a six-character designation. The designation consists 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, not every possible combination of the properties exists or can be obtained.

4.3.2 A single letter is used to identify the grade and indicate the major reinforcement or combinations, or both, along with two digits that indicate the percentage of additive(s) by total mass. The reinforcement and additive letter designations and associated tolerance levels are shown in **Table 1**.

TABLE 1 Reinforcement-Filler Symbols and Tolerances

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 is frequently shown on the supplier’s technical data sheet. If necessary, additional requirements are indicated by use of the suffix part of the system, as given in Section 5.

4.3.4 Reinforced, filled, and lubricated versions of PAI materials that are not in Table PAI are classified in accordance with Tables PAI and A. Table PAI is used to specify the Group or group and class of PAI and Table A is used to specify the property requirements. An example of this classification system for a polyamide-imide material containing 40 % glass 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 are indicated through the use of suffixes.

5.2 Use the suffixes found in Classification System **D4000** (Table 3) for additional requirements as appropriate. Additional suffixes will be added to Classification System **D4000** as test methods and requirements are developed and requested.

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

³ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.

⁴ Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

The designation PAI013G30CBXXX
 PAI013G30 = polyamide-imide material as described in Table PAI,
 C = melting point / softening point from Classification System
 D4000
 B = Test Method **D1525**, Rate A (Vicat), and
 XXX = three digit number indicating minimum value, °C.

5.3 Suffixes for electrical properties, if required, are found in Table SE in the Supplementary Requirements section of this standard.

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 absolute limits, as defined in Practice **E29**.

7.2.1 With the absolute method, an observed value or a calculated value is not rounded, but is to be compared directly with the 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 is defined as material produced in a single compound blend.

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, prepare injection and extrusion resins test specimens by injection molding in accordance with Practice **D3641**.

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°C and 50 % relative humidity in accordance with 3.1.2 of Practice **D618** 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, it is acceptable to retest the material to establish conformity.

12.4 Certification shall state that the material was manufactured by a process in statistical control, sampled, tested, and inspected in accordance with this classification system, and that the average values meet the requirements of the specification (line call-out).

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 **D3892** 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,	Tensile Elongation,	Specific Gravity,
						Test Method D1708, MPa (psi), min	Test Method D1708, %, min		Test Method D792
01	Injection Molding	1	general purpose	M00	0 % mineral	158 (23 000)	9	1.36 to 1.39
				M03	3 % mineral	158 (23 000)	9	1.39 to 1.43
				0	other			
		2	wear resistance	L15	12 % graphite, 3 % PTFE	124 (18 000)	5	1.44 to 1.48
				L23	20 % graphite, 3 % PTFE	124 (18 000)	5	1.48 to 1.53
				L20	12 % graphite, 8 % PTFE	97 (14 000)	4	1.48 to 1.52
	R30			30 % filled	69 (10 000)	4	1.52 to 1.59	
	R35			35 % filled	110 (16 000)	3	1.56 to 1.60	
	3	high strength	R45	45 % filled	96 (14 000)	3	1.53 to 1.58	
			0	other				
			G30	30 % glass fiber	200 (29 000)	4	1.59 to 1.63	
			C30	30 % carbon fiber	163 (23 600)	4	1.46 to 1.50	
0			other					
0			other					
02	Extrusion	1	general purpose	M00	0 % mineral	158 (23 000)	9	1.36 to 1.39
				M03	3 % mineral	158 (23 000)	9	1.39 to 1.43
				0	other			
		2	wear resistance	L15	12 % graphite, 3 % PTFE	124 (18 000)	5	1.44 to 1.48
				L23	20 % graphite, 3 % PTFE	124 (18 000)	5	1.48 to 1.53
				R30	30 % filled	69 (10 000)	4	1.52 to 1.59
	R35			35 % filled	110 (16 000)	3	1.56 to 1.60	
	R45			45 % filled	96 (14 000)	3	1.53 to 1.58	
	3	high strength	0	other				
			G30	30 % glass fiber	200 (29 000)	4	1.59 to 1.63	
			C30	30 % carbon fiber	163 (23 600)	4	1.46 to 1.50	
			0	other				
0			other					
0			other					
00	Other	0	other	0	other			

iTech Standards
(<https://standards.it-ebooks.net>)
TABLE A Detailed Requirements for Special Polyamide-Imides

Designation	Property ^A	0	1	2	3	4	5	6	g ^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	Izod Impact ^F , J/m ^G (ft · lb/in.), min	unspecified	37 (0.7)	53 (1.0)	64 (1.2)	80 (1.5)	101 (1.9)	117 (2.2)	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 D1708, Speed B, using 3.175 ± 0.05 mm (0.125 in.) thick specimens.

^DMPa X 145 = psi.

^ESee Test Method D790, Method 1, Procedure A.

^FSee Test Method D256, Method A, using the center portion of a D638, Type I specimen.

^GJ/m × 0.01873 = ft · lb/in.

SUPPLEMENTARY REQUIREMENTS
FOR SPECIAL END USES

The following supplementary requirements 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 is permitted to utilize its own facilities or any commercial laboratory acceptable to the Government. The Government reserves 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, are sometimes 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.	D790 (Procedure A)	193 (28 000)	165 (24 000)	158 (23 000)	152 (22 000)	290 (42 000)	269 (39 000)	297 (43 000)
MPa (psi) ^A								
Flexural Modulus, min.	D790 (Procedure A)	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)
MPa (psi)								
Compressive Strength, min.	D695	165 (24 000)	145 (21 000)	124 (18 000)	103 (15 000)	199 (28 900)	248 (36 000)	203 (29 500)
MPa (psi)								
Shear Strength, min.	D732	103 (15 000)	89 (12 900)	62 (9000)	63 (9200)	110 (16 000)	124 (18 000)	97 (14 000)
MPa (psi)								
Deflection Temp. at 1820 kPa (264 psi), °C (°F), min.	D648	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)	D696	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) ^B	C177	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)
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 (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)

^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. × 1/2 in. × 1/8 in. Test specimens sometimes glow after flaming combustion.

^E24 h immersion

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