Designation: D 5476 – 99

Standard Classification System for Thermoplastic Polyurethane Materials (TPU)[1]

This standard is issued under the fixed designation D 5476; 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.

INTRODUCTION

This classification system and subsequent line callout is intended to be a means of calling out thermoplastic polyurethane 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 performance required of the part, environment to which it will be exposed, fabrication processes to be used, and inherent properties of the material other than those covered by this classification.

1. Scope

1.1 This classification system covers thermoplastic polyurethane materials suitable for injection molding, extrusion, compression molding, melt processing, or other applicable methods. Recycled thermoplastic polyurethanes meeting the classification requirements may be used interchangeably with virgin resin.

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, which may be designated by using the suffixes as given in Section 5.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *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.*

NOTE 1—There are no ISO standards covering the primary subject matter of this ASTM classification.

2. Referenced Documents

2.1 *ASTM Standards:*

D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials[2]

D 412 Test Methods for Rubber Properties in Tension[3]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 638 Test Method for Tensile Properties of Plastics[2]

D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load[2]

D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics[2]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[2]

D 792 Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement[2]

D 883 Terminology Relating to Plastics[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1897 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials[4]

D 2240 Test Method for Rubber Property—Durometer Hardness[4]

D 3892 Practice for Packaging/Packing of Plastics[5]

D 4000 Classification System for Specifying Plastic Materials[5]

D 5033 Guide for the Development of Standards Relating to the Proper Use of Recycled Plastics[5]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]

3. Terminology

3.1 *Definitions*—For definitions of technical terms pertaining to plastics used in this classification, see Terminologies D 883 and D 1600 and Guide D 5033.

[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.

Current edition approved March 10, 1999. Published June 1999. Originally published as D 5476–93. Last previous edition D 5476–93.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 09.01.

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

[5] *Annual Book of ASTM Standards*, Vol 08.03.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

4. Classification

4.1 Unreinforced thermoplastic polyurethane materials are classified into groups according to their chemical composition. These groups are subdivided into classes and grades as shown in the basic property table (Table TPU).

TABLE TPU Requirements for Thermoplastic Polyurethanes

Group	Description	Class	Description[A]	Grade	Description	Tensile Stress, 100 % Elongation, MPa, min, Test Methods D 412	Elongation, Ultimate, %, min, Test Methods D 412	Specific Gravity, ±0.04, Test Method D 792
01	aromatic polyester	1	nominal hardness	1		1.4	600	1.10
			60 Shore A	2		2.0	700	1.10
				0	other			
		2	nominal hardness	1		2.0	700	1.10
			70 Shore A	2		3.0	500	1.10
				0	other			
		3	nominal hardness	1		3.0	300	1.15
			80 Shore A	2		4.0	300	1.17
				3		5.0	300	1.17
				4		6.0	300	1.17
				0	other			
		4	nominal hardness	1		4.0	300	1.22
			90 Shore A	2		6.0	300	1.22
				3		8.0	300	1.22
				4		10.0	300	1.22
				5		12.0	300	1.22
				0	other			
		5	nominal hardness	1		8.0	400	1.22
			50 Shore D	2		10.0	400	1.22
				3		12.0	400	1.22
				4		14.0	300	1.22
				5		16.0	300	1.22
				6		18.0	300	1.22
				0	other			
		6	nominal hardness	1		12.0	250	1.22
			60 Shore D	2		16.0	250	1.22
				3		20.0	250	1.22
				4		24.0	250	1.22
				5		28.0	250	1.22
				0	other			
		7	nominal hardness	1		18.0	200	1.23
			70 Shore D	2		22.0	200	1.23
				3		26.0	200	1.23
				4		30.0	200	1.23
				5		34.0	200	1.23
				0	other			
		8	nominal hardness	1		30.0	100	1.24
			80 Shore D	2		34.0	100	1.24
				3		38.0	100	1.24
				0	other			
		0	other					
02	aromatic polyether	1	nominal hardness	1		2.0	700	1.03
			60 Shore A	0	other			
		2	nominal hardness	1		2.0	700	1.03
			70 Shore A	2		2.5	700	1.06
				3		3.0	500	1.06
				4		3.5	500	1.06
				0	other			
		3	nominal hardness	1		3.5	500	1.06
			80 Shore A	2		4.5	400	1.10
				3		5.5	350	1.11
				4		6.5	300	1.12
				0	other			
		4	nominal hardness	1		4.5	400	1.12
			90 Shore A	2		6.5	400	1.12
				3		8.5	400	1.13
				4		10.5	400	1.13
				0	other			
		5	nominal hardness	1		10.0	400	1.13
			50 Shore D	2		14.0	300	1.14
				3		18.0	300	1.15
				0	other			

TABLE *Continued*

Group	Description	Class	Description[A]	Grade	Description	Tensile Stress, 100 % Elongation, MPa, min, Test Methods D 412	Elongation, Ultimate, %, min, Test Methods D 412	Specific Gravity, ±0.04, Test Method D 792
		6	nominal hardness	1		16.0	300	1.17
			60 Shore D	2		18.0	300	1.17
				3		20.0	300	1.17
				4		24.0	300	1.18
				5		28.0	300	1.18
				0	other			
		7	nominal hardness	1		...	50	1.19
			70 Shore D	0	other			
		0	other					
03	aliphatic polyether	1	nominal hardness	1		3.0	400	1.10
			70 Shore A	2		4.0	400	1.10
				3		5.0	400	1.10
				0	other			
		2	nominal hardness	1		5.0	400	1.10
			80 Shore A	2		6.0	400	1.10
				3		7.0	400	1.10
				0	other			
		3	nominal hardness	1		10.0	400	1.10
			90 Shore A	2		12.0	400	1.10
				0	other			
		4	nominal hardness	1		18.0	400	1.10
			50 Shore D	2		22.0	400	1.10
				3		26.0	400	1.10
				0	other			
		0	other					
04	aliphatic polyester	1	nominal hardness	1		5.0	400	1.15
			70 Shore A	2		6.0	400	1.15
				0	other			
		2	nominal hardness	1		6.0	300	1.15
			80 Shore A	2		7.0	300	1.15
				3		8.0	300	1.15
				0	other			
		3	nominal hardness	1		6.0	300	1.15
			90 Shore A	2		8.0	300	1.15
				3		10.0	300	1.15
				0	other			
		0	other					
00	other	0	other	0	other			

[A] *Hardness*—Test Method D 2240: Shore A, 5 s delay; Shore D, instantaneous.

NOTE 2—An example of this classification system is as follows. The designation of TPU0133 would indicate:

TPU = thermoplastic polyurethane
01 (group) = aromatic polyester
3 (class) = nominal hardness Shore A 80
3 (grade) = minimal 5.0 MPa tensile stress at 100 % elongation
300 % minimum ultimate elongation
1.17 ± 0.04 specific gravity

4.1.1 To facilitate the incorporation of future or special materials, the "other/unspecified" category (0) for group, class, and grade is shown in Table TPU. The basic properties can be obtained from Table B.

4.2 Reinforced and filled versions of the thermoplastic polyurethane materials are selected by specifying from a matrix of five independent characteristics (Table A).

4.2.1 *Table A Detail Requirements: Reinforced and Filled Thermoplastic Polyurethanes*—An identifying number is formed by the letter A and five digits comprising the cell numbers for the requirements in the designated order as they appear in Table A.

4.2.1.1 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.

NOTE 3—An example of a reinforced thermoplastic polyurethane of this classification system follows. The designation TPU0000-RXXA12315 would indicate the following material requirements from Table A (the RXX designation reflects commercial practice not to specify reinforcement level):

TPU0000 = thermoplastic polyurethane material
RXX = reinforced at unspecified level
A = Table A physical property requirements
1 = flexural modulus, 150 MPa, minimum
2 = Izod impact, 100 J/m, minimum
3 = tensile strength, minimum 30 MPa
1 = coefficient of linear thermal expansion, 2.5 cm/cm/°C, maximum
5 = 115°C heat-deflection temperature, minimum

5. Suffixes

5.1 When requirements are necessary that supersede or supplement the property table or cell table requirements, they

TABLE A Requirements for Thermoplastic Polyurethanes, Reinforced or Filled

Designation Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Flexural modulus, MPa, min, Test Methods D 790, Method I 1.3 mm/min 50 mm span, tangent calculation	unspecified value	150	500	750	1300	1800	2400	3000	3500	specify value
2	Izod impact, J/m, min, Test Methods D 256, Method A	unspecified value	50	100	150	220	300	450	600	750	specify value
3	Tensile strength, MPa, min, Test Method D 638, Type I bar, 50 mm/min	unspecified value	20	25	30	37	42	48	54	60	specify value
4	Coefficient of linear thermal expansion, $10^{-5}°C^{-1}$, max, Test Method D 696	unspecified value	2.5	3.3	4.2	5.0	5.9	6.8	7.6	8.5	specify value
5	Deflection temperature under load, °C, min, Test Method D 648, 455 kPa	unspecified value	70	80	93	104	115	127	138	150	specify value

TABLE B Requirements for Thermoplastic Polyurethanes

Designation Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Nominal hardness, Test Method D 2240, A/D durometer[A]	unspecified	60A	70A	80A	90A	50D	60D	70D	80D	specify value
2	Tensile stress, 100 % elongation, Test Methods D 412, MPa, min	unspecified	1.5	3	5	7	10	16			
	Test Method D 638 (Type M-II specimen, test speed 50 mm/min), MPa, min								23	35	specify value
3	Elongation, Test Methods D 412, %, min	unspecified	50	100	200	250	300	400			
	Test Method D 638 (Type M-II specimen, test speed 50 mm/min), MPa, min								500	700	specify value
4	Specific gravity, Test Method D 792, ± 0.04	unspecified	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.24	specify value
5	To be determined	unspecified									

[A] Hardness: Shore A, 5 s delay; Shore D, instantaneous.

shall be specified through the use of suffixes. In general, the first suffix letter indicates the special requirement necessary, and the second letter indicates the condition or test method, or both, with a three-digit number indicating the specific requirement. The suffixes that may be used are listed in Table 3 of Classification D 4000.

5.1.1 Additional suffixes will be added to this classification system as test methods and requirements are developed or requested, or both.

6. General Requirements

6.1 The basic requirements from property or cell tables are always in effect, unless superseded by specific suffix requirements, which always take precedence.

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

7. Detail Requirements

7.1 Test specimens and their preparation shall conform to the requirements prescribed in Tables TPU, A, and B and applicable suffix requirements.

7.2 Observed or calculated values obtained from analysis, measurement, or testing shall be rounded off to the nearest unit in the last right-hand place of figures used in expressing the specified limiting value in accordance with the rounding-off method of Practice E 29.

7.2.1 The value obtained is compared directly with the specified limiting value. This comparison determines conformance or nonconformance with a specification based on this classification system.

8. Sampling

8.1 Sampling shall be statistically adequate to satisfy the requirements of 12.4.

8.2 A resin lot shall be considered as a unit of manufacture as prepared for shipment and may consist of a blend of two or more production runs or batches of material.

9. Specimen Preparation

9.1 Table TPU test specimens shall be prepared by die cutting in the direction of flow from a 50 to 130-mil thick plaque injection molded as specified in Practice D 1897 for the specific products tested.

9.2 Table A references injection-molded test specimens.

10. Conditioning

10.1 Test specimens shall be conditioned for a minimum of three days in the standard laboratory atmosphere in accordance with Procedure A of Practice D 618 before performing the required tests.

10.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity in accordance with Practice D 618.

10.3 If specimens are heat treated before testing, this should be reported.

11. Test Methods

11.1 Determine the properties enumerated in this classification system by means of the test methods referenced.

11.1.1 The number of tests shall be conducted consistently with Section 8 and 12.4.

12. Inspection and Certification

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. The lot acceptance inspection shall consist of tests applicable to the specific product.

12.2.1 For unreinforced TPUs, this shall include tensile stress at 100 % elongation, ultimate elongation, and specific gravity.

12.2.2 For glass-reinforced TPUs, tests shall include flexural modulus, Izod impact, and tensile strength.

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.

12.4 Certification shall be 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 for the lot meet the requirements of the specification (line callout).

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

13. Packing, Packaging, and Marketing

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

14. Keywords

14.1 classification; elastomers; line callout; specification; thermoplastic polyurethane