



Classification System and Basis for Specification for Polyphenylene Ether (PPE) Materials¹

This standard is issued under the fixed designation D4349; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope*

1.1 This classification system covers the basic polymers and copolymers known as polyphenylene ethers and polyphenylene oxides, as well as filled, modified, and reinforced versions. Recycled materials are included in this standard as Class 5 of Table PPE.

NOTE 1—Addition to the natural polymer or copolymer of pigments, colorants, or other additives can cause the final composition to no longer meet the requirements specified for the natural polymer or copolymer.

NOTE 2—The preferred abbreviation for polyphenylene ether is PPE, as noted in Terminology **D1600**.

1.2 This classification system and subsequent line callout (specification) are intended to provide a means of calling out plastic 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 plastic 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 costs involved, and the inherent properties of the material other than those covered by this standard.

1.3 There may be other requirements necessary to identify particular characteristics important to specific applications. These are to be specified by using the suffixes described in Section 5.

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

NOTE 3—There is no known ISO equivalent to this standard.

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. Referenced Documents

2.1 *ASTM Standards*:²

- D256** Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
 - D618** Practice for Conditioning Plastics for Testing
 - D638** Test Method for Tensile Properties of Plastics
 - D648** Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
 - 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
 - D1600** Terminology for Abbreviated Terms Relating to Plastics
 - D3892** Practice for Packaging/Packing of Plastics
 - D4000** Classification System for Specifying Plastic Materials
 - D7209** Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products (Withdrawn 2015)³
 - E29** Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- ### 2.2 *Underwriters Laboratories*:
- UL 94** Standards for Tests for Flammability for Parts in Devices and Appliances⁴

3. Terminology

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

3.2 The polyphenylene ether materials will be designated PPE as specified in Terminology **D1600**.

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.

³ The last approved version of this historical standard is referenced on www.astm.org.

⁴ Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, <http://www.ul.com>.

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

4. Classification

4.1 Polyphenylene ether-based materials are classified into groups according to their compositions. These groups are subdivided into classes and grades, as shown in Basic Property Table PPE.

NOTE 4—An example of this classification system is as follows:
The specification ASTM D4349 PPE 0223 would indicate:

- PPE = polyphenylene ether,
- 02 = polystyrene-modified material (Group),
- 2 = flame retarded (Class Description), and
- 3 = requirements given in Table PPE.

4.1.1 Reinforced, filled, and lubricated versions of PPE materials are classified according to the reinforcement used and the nominal level, by weight percent, of the reinforcement. The grade is identified by a single letter that indicates the filler or reinforcement used and two digits that indicate the nominal quantity in percent by weight. Thus, a grade containing 15 % glass reinforcement would be indicated by PPE0110 G15. This callout indicates:

- PPE = polyphenylene ether ___ as found in Terminology D1600,
- 01 = unmodified (group),
- 1 = general purpose (class),
- 0 = other (grade), and
- G15 = 15 % glass reinforcement

The reinforcement letter designations and associated tolerance levels are shown in Table 1.

TABLE 1 Reinforcement-Filler,^A Symbols,^B and Tolerances

Symbol	Material	Tolerance
C	Carbon and graphite	±2 %
D	Alumina trihydrate	±2 %
E	Clay	±2 %
F	Cellulose	±2 %
G	Glass	±2 %
H	Aramid	±2 %
J	Boron	±2 %
K	Calcium carbonate	±2 %
L	Lubricants (for example: PTFE, graphite)	Depends upon material and process—to be specified.
M	Mineral	±2 %
N	Natural organic (for example: cotton, sisal, hemp, flax)	±2 %
P	Mica	±2 %
Q	Silica	±2 %
R	Combinations of reinforcements and/or fillers	±3 %

^AAsh content of filled and/or reinforced materials is to be determined using either Test Method D5630 or ISO 3451-1 where applicable.

^BAdditional symbols will be added to this table as required.

NOTE 5—This part of the system uses the type and percentage of additives, fillers, and reinforcements to designate the modification of the basic material. The types and percentages are sometimes shown on the suppliers technical data sheet. If necessary, additional control of these compositional variables can be accomplished using the suffix part of the system, Section 5.

NOTE 6—Materials containing reinforcements or fillers, or both, at nominal levels not in multiples of five are included in the nearest grade designation. For example, a material with a nominal glass fiber level of 33 % is included with Grade G35 as shown in 4.1.1.

4.1.1.1 Although the values listed are necessary to include the range of properties available in existing materials, not every possible combination of the properties exist or can be obtained.

TABLE PPE Requirements for Polyphenylene Ether (PPE) Materials

NOTE 1—Values given are for natural materials only. Other colors can be different.^A

Group Description	Class Description	Grade Description	Heat Deflection, min		Specific Gravity, ASTM D792, min	Tensile Strength, D638, ^{B, C} MPa, min	Flexural Modulus, D790, ^{B, C} MPa, min	Izod Impact, D256, ^{B, D} J/m, min	
			at 1.82 MPa, D648, ^{B, C}	at 0.45 MPa, D648, ^{B, C}					
01 Unmodified	1 general purpose	0 other	E		1.03	32	1750	265	
	2 flame retarded ^F	0 other	E						
	0 other	0 other	E						
02 PS modified materials	1 general purpose	1	90	N/A ^G	1.03	38	1900	240	
		2	100	N/A ^G	1.03	44	2150	185	
		3	100	N/A ^G	1.04	55	2300	160	
		4	110	N/A ^G	1.05	57	2300	160	
		5	130	N/A ^G	1.05	57	2300	160	
	2 flame retarded ^F	0 other
		1	67	N/A ^G	1.06	36	2200	190	
		2	80	N/A ^G	1.07	40	2250	130	
		3	85	N/A ^G	1.07	48	2350	100	
		4	105	N/A ^G	1.07	55	2350	160	
	03 PA modified materials	1 general purpose	5	125	N/A ^G	1.08	60	2500	160
			0 other
			0 other
			1	N/A ^G	145	1.05	50	2000	170
			2	N/A ^G	155	1.05	50	2000	160
2 flame retarded ^F		3	N/A ^G	170	1.05	50	1800	530	
		4	N/A ^G	180	1.05	55	2000	185	
		5	N/A ^G	195	1.05	58	2200	160	
		0 other	...	...	...	...	...	...
		0 other	...	...	...	...	...	...
04 Other	1 general purpose	0 other	...	...	...	...	...	...
		0 other	...	...	...	...	...	...

Group Description	Class Description	Grade Description	Heat Deflection, min		Specific Gravity, ASTM D792, min	Tensile Strength, D638, ^{B, C} MPa, min	Flexural Modulus, D790, ^{B, C} MPa, min	Izod Impact, D256, ^{B, D} J/m, min
			at 1.82 MPa, D648, ^B °C	at 0.45 MPa, D648, ^B °C				
05 Rework modified	2 flame retarded ^F	0 other	...	...	...	...	...	...
	0 other	0 other	...	...	...	...	...	...
	1 general purpose	0 other	...	...	...	...	...	...
	2 flame retarded ^F	0 other	...	...	...	...	...	...
	0 other	0 other	...	...	...	...	...	...

^A Use Tables A and B where necessary for colored materials.
^B See Table 2 for drying and molding conditions. Table 3 for test specimen sizes.
^C MPa × 145 = psi.
^D J/m × 0.01873 = ft-lbf/in.
^E Unfilled materials currently not available. Use Table A.
^F Flammability ratings determined in accordance with UL 94.
^G N/A—Not applicable for grade description.

TABLE A Reinforced Polyphenylene Ether Materials, Details Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Heat deflection temperature, ^A D648, ^B 1.82 MPa, °C, min	unspecified	100	110	120	130	140	150	160	170	specify value
2	Heat deflection temperature, ^A D648, ^B 0.45 MPa, °C, min	unspecified	180	190	200	210	220	230	240	250	specify value
3	Tensile strength, D638, ^B MPa, ^C min	unspecified	45	55	65	80	100	120	140	160	specify value
4	Flexural modulus, D790, ^B MPa, ^C min	unspecified	2000	3000	4000	5000	6000	7500	9000	10 500	specify value
5	Izod impact, D256, ^B J/m, ^D min	unspecified	25	50	75	100	125	150	200	250	specify value

^A For specifying HDT use the “order number” corresponding to the appropriate test conditions for the material being defined. It is intended that one or the other of these requirements be used unless specific agreement between the supplier and the user requires both.
^B See Table 3 for test specimen sizes.
^C MPa × 145 = psi.
^D J/m × 0.01873 = f-lbf/in.

TABLE B Unreinforced Polyphenylene Ether Materials, Details Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Heat deflection temperature, ^A D648, ^B 1.82 MPa, °C, min	unspecified	65	75	85	95	105	115	125	135	specify value
2	Heat deflection temperature, ^A D648, ^B 0.45 MPa, °C, min	unspecified	125	135	145	155	165	175	185	195	specify value
3	Tensile strength, D638, ^B MPa, ^C min	unspecified	30	35	40	45	50	55	60	65	specify value
4	Flexural modulus, D790, ^B MPa, ^C min	unspecified	1500	1800	2100	2400	2700	3000	3300	3600	specify value
5	Izod impact, D256, ^B J/m, ^D min	unspecified	100	150	200	250	300	400	500	600	specify value

^A For specifying HDT use the “order number” corresponding to the appropriate test conditions for the material being defined. It is intended that one or the other of these requirements be used unless specific agreement between the supplier and the user requires both.
^B See Table 3 for test specimen sizes.
^C MPa × 145 = psi.
^D J/m × 0.01873 = ft-lbf/in.

4.2 When the grade of the basic material is not known, or is not important, the use of “0” grade classification shall be used for reinforced materials in this system.

NOTE 7—An example of this classification system for a reinforced polyphenylene ether is as follows: The designation ASTM D4349 PPE 210G30A22245 indicates the following material requirements from Table A:

- PPE 210 = polystyrene-modified polyphenylene ether from Table PPE,
- G30 = glass-reinforced at nominal 30 % (see 4.2),
- A = Table A Property requirements,
- 2 = 110°C deflection temperature at 1.82 MPa, min,
- 2 = 190°C deflection temperature at 0.45 MPa, min,
- 2 = 55-MPa tensile strength, min,
- 4 = 5000-MPa flexural modulus, min, and
- 5 = 125-J/m Izod impact, min.

If no properties are specified, the designation would be ASTM D4349 PPE 210G30A00000.

4.3 Table B has been incorporated into this classification system to facilitate the classification of special materials where Table PPE or Table A do not reflect the required properties. Table B shall be used in the same manner as Table A.

NOTE 8—Mechanical properties of pigmented or colored polyphenylene ether materials can differ from the mechanical properties of natural polyphenylene ether material, depending on the choice and concentration of colorants. The main property affected is ductility, as illustrated by a reduction in Izod impact strength and tensile elongation values. If specific properties of pigmented polyphenylene ether materials are required, a classification using Table B should be used to designate those properties.

NOTE 9—An example of a special material using this classification system is as follows: The designation ASTM D4349 PPE0310B54220 indicates the following, with the material requirements from Table B:

- PPE 0310 = polyamide-modified polyphenylene ether from Table PPE,
- B = Table B Property Requirements,
- 5 = 105°C deflection temperature at 1.82 MPa, min,
- 4 = 155°C deflection temperature at 0.45 MPa, min,
- 2 = 35-MPa tensile strength, min,
- 2 = 1800-MPa flexural modulus, min, and
- 0 = unspecified Izod Impact.

4.4 Group 5 has been included in Table PPE to allow line call-out designation for “recycle” resins. Class and grades given should be used with the property ranges from Table A or B, as appropriate.

4.5 Requirements for materials tested using ISO specimen dimensions are not covered by this classification system. Classification System D4000 can be used to list property requirements involving ISO criteria as long as detailed notes describing specimen dimensions, test speeds, and so forth, are included.

5. Suffixes

5.1 When additional requirements are needed and are not covered by the basic requirements or cell-table requirements, they shall be indicated through the use of suffixes.

5.2 A list of suffixes, which can be used for additional requirements as appropriate, is found in Classification System D4000 (Table 3). Additional suffixes will be added to that standard as test methods and requirements are developed and requested.

6. General Requirements

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

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

7. Detail Requirements

7.1 The materials shall conform to the requirements prescribed in Tables PPE, A and B, and suffix requirements, as they apply.

7.2 For the purpose of determining conformance with this classification systems, all specified limits in this standard 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 to the specified limiting value. Conformance or nonconformance with this classification system is based on this comparison.

8. Sampling

8.1 Sampling shall be statistically adequate to satisfy 12.4.

8.2 A batch or lot is a unit of manufacture as prepared for shipment and can consist of a blend of two or more “production runs.”

9. Specimen Preparation

9.1 The test specimens shall be injection molded.

9.2 Mechanical properties can vary with injection molding conditions. Drying and molding conditions to be used are listed in Table 2.

10. Conditioning

10.1 Where test specimens are stored in controlled temperature/humidity chambers, the chamber atmosphere should be 23 ± 5°C and 50 +0/–40 % RH. Dry, air-conditioned air is acceptable. Otherwise, test specimens shall be conditioned in the standard laboratory atmosphere in accordance with Procedure A of Practice D618 before performing the required tests.

10.2 Testing conditions should be stable for a minimum of 2 h to ensure stable performance of electronics. Conduct those tests influenced by ambient conditions in the standard laboratory atmosphere of 23°C and 50 % relative humidity.

11. Test Methods

11.1 Determine the properties enumerated in this classification system by means of the test methods referenced in Section 2.

TABLE 2 Drying and Molding Parameters

Table PPE	Dry Time, h	Dry Temperature, °C	Melt Temperature, °C	Mold Temperature, °C
Group 1	2.0	120	355	88
Group 2 ^A	0.5–1.5	95–120	220–320	65–88
Group 3 ^B	3.0–6.0	120	300	88

^A Materials with lower heat deflection values are dried and molded at the lower end of the time and temperatures listed.

^B Material not in sealed packaging will require dry time at the high end of the range listed.

11.1.1 The number of tests shall be consistent with the requirements of 8.1 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. Lot acceptance inspection includes all those requirements listed in this classification system.

12.3 Periodic check inspection with reference to a specification based upon this classification system shall consist of the

tests for all requirements of the material under the specification. Inspection frequency shall be adequate to ensure 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).

NOTE 10—The ASTM publication *Manual on Presentation of Data and Control Chart Analysis, 8th Edition*⁵ provides detailed information about statistical process control.

12.5 A report of test results shall be furnished when requested. The report shall consist of results of the lot-acceptance inspection for the shipment, the percent by weight of recycled plastic as defined in 3.1.47 of Guide D7209, if requested, and the results of the most recent periodic-check inspection.

TABLE 3 Testing Parameters

ASTM Test Method	Test Specimen and Testing Parameters
D638	Type I, 3.2-mm thickness, crosshead speed of 5 mm/min for reinforced materials and 50 mm/min for unreinforced materials.
D790	3.2 by 12.7-mm specimen, tested by Method I, Procedure A (tangent) with a crosshead speed of 1.3 mm/min and a span to depth ratio of 16 to 1.
D256	3.2 by 12.7-mm specimen, tested by Test Method A.
D648	3.2 by 12.7-mm specimen, 102-mm support span, unannealed prior to testing.

13. Packaging and Package Marking

13.1 Provisions to Practice D3892 apply.

14. Keywords

14.1 line call-out specification; plastics; polyphenylene ether resin; recycled plastics

⁵ Available from ASTM International Headquarters. Order Catalog Number: MNL-8TH-EB.

APPENDIX
(Nonmandatory Information)
X1. CROSS-REFERENCES

X1.1 The following cross-references between government specifications and Classification System D4349 are provided for information purposes only.

TABLE X1.1 Cross-Reference Designations for Classification System D4349 and Government Specifications

Government Specifications	Classification System D4349	
	Previous	Revised ⁴
MIL-P-46129A		
Class 1	PPE 214	obsolete
Class 2	PPE 224	obsolete
Class 3	PPE 221	obsolete
MIL-P-46131B		
Type 1		
Class 1	PPE 210G20A40342	PPE210G20FL024GH123GL119KY097MA016PA085UB052YB132
Class 2	PPE 220G20A30342	PPE210G20FL011GH123GL119KY097MA016PA085UB052YB132
Type 2		
Class 1	PPE 210G30A40452	PPE210G30FL024GH129GL125KY110MA014PA101UB072YB151
Class 2	PPE 220G30A30452	PPE210G30FL011GH129GL125KY110MA014PA101UB072YB146
Type 3		
Class 1	PPE 210G40A40562	PPE210G40FL024GH140GL136KY124MA010PA091UB079YB154
MIS-31875		
Class 1	PPE 214	PPE210FL024GH113GL105KY055LB020MA010PA160YB116
Class 2	PPE 224	PPE220FL011GH113GL105KY055LB020MA010PA160YB116
Class 3	PPE 221	PPE220FL010GH113GL105KY045LB020MA010PA192YB074
MIL-C-52765 (Table III)	PPE 221	PPE210NB054UB023ZPO1ZPO2 ZPO1: ASTM D256 (Test Method A, Izod) ¼-in. bar, 23°C, 267 J/m, min. ZPO2: ASTM D256 (Test Method A, Izod) ¼-in. bar, – 40°C, 80 J/m, min.

⁴Izod specimens are to be of 6.4-mm thickness.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D4349 - 10) that may impact the use of this standard. (September 1, 2016)

- (1) Added D7209 to 2.1.
- (2) Replaced the word retardant with the correct word retarded in Table PPE and examples.
- (3) Renumbered Groups in Table PPE to have two digits (standard D4000 practice).
- (4) Correct footnotes B in Tables PPE, A, and B.
- (5) Changed designation to specification where appropriate.
- (6) Revised 4.1 to conform to wording from D5740, Standard Guide for Writing Material Standards in the Classification D4000 Format.
- (7) Added Table 1 to 4.1.1, renumbered other tables.
- (8) Revised Note 7 to eliminate extraneous agreements.
- (9) Corrected 5.1 definition of suffix format by removing it.
- (10) Added 6.1 to Section 6 (D5740).
- (11) Replaced test specimens with materials in 7.1.
- (12) Replaced “A lot of material shall be considered as” with “A batch or lot is” in 8.2.
- (13) Removed Section 9 (see 11.1.1); renumbered following sections.
- (14) Clarified language in 10.1 and 10.2.
- (15) Made a choice for Lot Acceptance Inspection in 12.2.
- (16) Added reference for Control Charting to 12.4.
- (17) Modified 12.5 to take recycled materials into account.

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