



Classification System for Polyphenylene Ether (PPE) Materials¹

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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.

NOTE 1—Addition to the natural polymer or copolymer of pigments, colorants or additives may result in the final composition not meeting the requirements specified for the natural polymer or copolymer. Discussions with the supplier should take place before specifications of altered compositions are established.

NOTE 2—The preferred abbreviation for polyphenylene ether is PPE, as noted in Terminology D 1600.

1.2 This classification system is not intended for the selection of materials, but only as a means to call out plastic materials to be used for the manufacture of parts. The selection of these materials is to be made by personnel with expertise in the plastics field where the environment, inherent properties of the materials, performance of the parts, part design, manufacturing process, and economics are considered.

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

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

NOTE 3—No ISO standard exists that covers these materials.

2. Referenced Documents

2.1 ASTM Standards:

- D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials²
- D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing²
- D 638 Test Method for Tensile Properties of Plastics²
- D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load²
- D 790 Test Methods for Flexural Properties of Unreinforced

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 Annual Book of ASTM Standards, Vol 08.01.

TABLE 1 Testing Parameters

ASTM Test Method	Test Specimen and Testing Parameters
D 638	Type I, 3.2-mm thickness, crosshead speed of 5 mm/min for reinforced materials and 50 mm/min for unreinforced materials.
D 790	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.
D 256	3.2 by 12.7-mm specimen, tested by Test Method A.
D 648	3.2 by 12.7-mm specimen, 102-mm support span, unannealed prior to testing.

- and Plastics and Electrical Insulating Materials²
- D 792 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacements²
- D 883 Terminology Relating to Plastics²
- D 1600 Terminology for Abbreviated Terms Relating to Plastics²
- D 1898 Practice for Sampling of Plastics²
- D 3892 Practice for Packaging/Packing of Plastics³
- D 4000 Classification System for Specifying Plastic Material³
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁴

2.2 Underwriters Laboratories:

- UL 94 Standards for Tests for Flammability for Parts in Devices and Appliances⁵

3. Terminology

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

3.2 The polyphenylene ether materials will be designated PPE as specified in Terminology D 1600.

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 Table PPE.

³ Annual Book of ASTM Standards, Vol 08.02.

⁴ Annual Book of ASTM Standards, Vol 14.02.

⁵ Available from Underwriters Laboratories Inc. Publications Stock, 333 Pfingsten Road, Northbrook, IL 60067.

TABLE PPE Requirements for Polyphenylene Ether (PPE) Materials

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

Group Description	Class Description	Grade Description	Heat Deflection, min		Specific Gravity, ASTM D 792, min	Tensile Strength, D 638, ^{B,C} MPa, min	Flexural Modulus, D 790, ^{B,C} MPa, min	Izod Impact, D 256, ^{B,D} J/m, min	
			at 1.82 MPa, D 648, ^B °C	at 0.45 MPa, D 648, ^B °C					
1 Unmodified	1 general purpose	0 other	E						
	2 flame retardant ^F	0 other	E						
	0 other	0 other	E						
2 PS modified materials	1 general purpose	1	90	N/A ^G	1.03	32	1750	265	
		2	100	N/A ^G	1.03	38	1900	240	
		3	100	N/A ^G	1.03	44	2150	185	
		4	110	N/A ^G	1.04	55	2300	160	
		5	130	N/A ^G	1.05	57	2300	160	
		0 other
	2 flame retardant ^F	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	
		5	125	N/A ^G	1.08	60	2500	160	
		0 other
		0 other
		0 other
		0 other
3 PA modified materials	1 general purpose	1	N/A ^G	145	1.05	50	2000	170	
		2	N/A ^G	155	1.05	50	2000	160	
		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
	2 flame retardant ^F	0 other	E	...	...	...	...	...
	0 other	0 other	...	...	...	...	...	...
	4 Other	1 general purpose	0 other
		2 flame retardant ^F	0 other
0 other		0 other	...	...	...	...	...	...
0 other		0 other	...	...	...	...	...	...
5 Rework modified	1 general purpose	0 other	...	...	...	...	...	...
	2 flame retardant ^F	0 other	...	...	...	...	...	...
	0 other	0 other	...	...	...	...	...	...

^A Use Tables A and B where necessary for colored materials.

^B See Table 1 for test parameters and conditions.

^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 D 648, ^B 1.82 MPa, °C, min	unspecified	100	110	120	130	140	150	160	170	specify value
2	Heat deflection temperature, ^A D 648, ^B 0.45 MPa, °C, min	unspecified	180	190	200	210	220	230	240	250	specify value
3	Tensile strength, D 638, ^B MPa, ^C min	unspecified	45	55	65	80	100	120	140	160	specify value
4	Flexural modulus, D 790, ^B MPa, ^C min	unspecified	2000	3000	4000	5000	6000	7500	9000	10 500	specify value
5	Izod impact, D 256, ^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 1 for test specimen sizes.

^C MPa × 145 = psi.

^D J/m × 0.01873 = ft-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 D 648, ^B 1.82 MPa, °C, min	unspecified	65	75	85	95	105	115	125	135	specify value
2	Heat deflection temperature, ^A D 648, ^B 0.45 MPa, °C, min	unspecified	125	135	145	155	165	175	185	195	specify value
3	Tensile strength, D 638, ^B MPa, ^C min	unspecified	30	35	40	45	50	55	60	65	specify value
4	Flexural modulus, D 790, ^B MPa, ^C min	unspecified	1500	1800	2100	2400	2700	3000	3300	3600	specify value
5	Izod impact, D 256, ^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 1 for test specimen sizes.

^C MPa × 145 = psi.

^D J/m × 0.01873 = ft-lbf/in.

NOTE 4—An example of this classification system is as follows:
The designation PPE 223 would indicate:

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

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 PPE. The basic properties can be obtained from Tables A and B as they apply (see 4.3).

4.2 When using Table A to classify reinforced materials, a single letter shall be used for the major reinforcement or combination, or both, along with two numbers that indicate percent addition by mass, with the tolerances as tabulated as follows:

Category	Material	Tolerance (Based on the Total Mass)
C	Carbon- and Graphite-Fiber-Reinforced	±2 %
G	Glass-Reinforced	
	≤15 % glass content	±2 %
	>15 % glass content	±3 %
L	Lubricants (such as PTFE, graphite, silicone, and molybdenum disulfide)	Depends on material and process to be specified.
M	Mineral-Reinforced	±2 %
R	Reinforced-combination/mixtures of reinforcements or other fillers/reinforcements	±3 % based on the total reinforcement

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 should be shown on the suppliers technical data sheets unless they are proprietary in nature. If necessary, additional control of these compositional variables can be accomplished using the suffix part of the system, Section 4. Special agreements on tolerances may be required below 5 % levels.

4.2.1 Specific requirements of some reinforced, filled, or modified polyphenylene ether materials may be assignable using Table PPE. Requirements for those not so covered shall be shown by a six-character designation consisting of the letter A or B and the five digits comprising the cell numbers for the property requirements in the order that they appear in Tables A or B, whichever applies.

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 materials with every possible combination of the properties exist or can be obtained.

4.2.2 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 6—An example of this classification system for a reinforced polyphenylene ether is as follows: The designation 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 section 3.2.1),
- 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 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 7—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, prior testing between the materials supplier and end user should be initiated. Once these agreements are reached, a classification using Table B should be employed to ensure proper property compliance.

NOTE 8—An example of a special material using this classification system is as follows: The designation PPE 310B54220 indicates the following, with the material requirements from Table B:

- PPE 310 = 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 Classification 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 D 4000 may 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. In general, suffixes consist of a suffix letter, which gives the requirement needed, a first digit, which gives the test condition, and a second digit, which gives the specific requirement.

5.2 Additional suffixes may be added as required. See Table 3 of Classification System D 4000 for other suffix designations. Requirements specified by suffix references always take precedence over values from the property or cell tables for the same properties.

6. General Requirements

6.1 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 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 E 29.

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 Sections 12 and 13. A lot of material 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.

9. Number of Tests

9.1 The number of tests shall be consistent with the requirements of Sections 8 and 13.

10. Specimen Preparation

10.1 The test specimens shall be injection molded.

10.2 Mechanical properties may vary with injection molding conditions. Dialog between the customer and the supplier should include consideration of the affect of molding conditions when issues of discrepant material arise. Drying and molding conditions are listed in Table 2.

11. Conditioning

11.1 Conditioning, when specified, shall be for at least 40 h at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ RH in accordance with Procedure A of Practice 618. Only nylon-modified materials are sensitive to moisture and should be tested dry as molded.

11.2 Unless otherwise specified, testing conditions should be stable for a minimum of 2 h to ensure stable performance of electronics. Where test specimens are stored in controlled temperature/humidity chambers, the laboratory atmosphere should be $23 \pm 5^\circ\text{C}$ and $50 + 0/-40\%$ RH. Dry, air-conditioned air is acceptable. Where specimens are not stored in controlled chambers, see 11.1.

12. Test Methods

12.1 Determine properties by means of the appropriate ASTM test methods, as they apply, unless otherwise stated or agreed upon between the purchaser and the supplier.

12.2 Methods for determination of reinforcements, additives, fillers, and lubricants shall be as agreed upon between the purchasers and the suppliers.

13. Inspection and Certification

13.1 Lot acceptance inspection may include all, some, or other requirements than are listed in this classification system.

13.2 Periodic check inspection shall include all the requirements specified and may include additional tests. These inspections typically are done annually, as a minimum.

13.3 Certification by lot acceptance inspection, periodic check inspection, or some other certification procedure may be used to show compliance to requirements.

13.4 Reports of test results, with or without certification, shall be furnished at a frequency agreed upon between the purchaser and the supplier.

14. Packaging and Package Marking

14.1 Provisions to Practice D 3892 apply.

15. Keywords

15.1 live call-out specification; plastics; polyphenylene ether resin; recycled plastics

TABLE 2 Drying and Molding Parameters

Table PPE	Dry Time, h	Dry Temperature, $^\circ\text{C}$	Melt Temperature, $^\circ\text{C}$	Mold Temperature, $^\circ\text{C}$
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.

APPENDIX
(Nonmandatory Information)
X1. CROSS-REFERENCES

X1.1 The following cross-references between government specifications and Classification System D 4349 are provided for information purposes only.

TABLE X1.1 Cross-Reference Designations for Classification System D 4349 and Government Specifications

Government Specifications	Classification System D 4349	
	Previous	Revised ^A
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.

^A Izod specimens are to be of 6.4-mm thickness.

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