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Standard Classification System for Poly(Methyl Methacrylate) (PMMA) Molding and Extrusion Compounds[1]

This standard is issued under the fixed designation D 788; 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.

1. Scope

1.1 The purpose of this classification system is to provide a method of adequately identifying PMMA materials using a system consistent with that of Classification System D 4000. It further provides a means for specifying these materials by the use of a simple line callout designation.

1.2 This classification system covers poly(methyl methacrylate) molding and extrusion compounds. These compounds are polymers based on methyl methacrylate, and at least 70 % of the polymer shall be polymerized from methyl methacrylate.

1.3 The properties in this classification system are those required to identify the compositions covered. There may be other requirements necessary to identify particular characteristics important to specific applications. These shall be described by using the suffixes as given in Section 5.

1.4 Acrylic molding and extrusion compounds are used frequently in applications where extreme clarity and the ability to retain that clarity and color under severe weathering and other environmental exposures are of primary significance. While the test specimen properties of this document may be used to evaluate nonvirgin materials, the user should take precautions to ensure that parts made from these materials meet the desired end-use requirements. Accordingly, this specification allows for the use of those acrylic plastic materials that can be recycled, reconstituted, and regrounded provided the following:

1.4.1 The requirements as stated in this specification are met,

1.4.2 The material has not been modified in any way to alter its conformance to food contact regulations or similar requirements, and

1.4.3 The requirements of the particular end-use application are met.

1.5 This classification system and subsequent line callout (specification) are 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 in which the environment, inherent properties of the materials, performance of the parts, part design, manufacturing process, and economics are considered.

NOTE 1—This classification system is similar to ISO 8257-1:1987 in title only. The technical content is significantly different.

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

1.7 *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:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[2]

D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials[3]

D 257 Test Methods for DC Resistance or Conductance of Insulating Materials[2]

D 542 Test Methods for Index of Refraction of Transparent Organic Plastics[3]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[3]

D 883 Terminology Relating to Plastics[3]

D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics[3]

D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer[3]

D 1525 Test Method for Vicat Softening Temperature of Plastics[3]

[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 (Section D20.15.02).

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This standard was extensively revised in 1993. The current revision includes the addition of 1.4, which addresses the use of recycled materials.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

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

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]
D 1897 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials[4]
D 3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials[4]
D 3892 Practice for Packaging/Packing of Plastics[4]
D 4000 Classification System for Specifying Plastic Materials[4]
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]

2.2 *ISO Standards and Recommendations:*[7]

ISO 178-1975 Plastics—Determination of Flexural Properties of Rigid Plastics
ISO 180-1982 Plastics—Determination of Izod Impact Strength of Rigid Materials
ISO 294
ISO 306-1987 Plastics—Thermoplastic Materials—Determination of Vicat Softening Temperature
ISO 489-1983 Plastics—Determination of the Refractive Index of Transparent Plastics
ISO R 527 November 1966 Plastics—Determination of Tensile Properties
ISO 1133-1981 Plastics—Determination of the Melt Flow Rate of Thermoplastics
ISO 3167-1983 Plastics—Preparation and Use of Multipurpose Test Specimens
ISO 8257-1:1987 Plastics—Poly(Methyl Methacrylate) (PMMA) Moulding and Extrusion Materials—Part 1

2.3 *SAE Standards:*[8]

SAE J576 SEP86—SAE Recommended Practice forPlastic Materials for Use in Optical Parts such as Lenses and Reflectors for Motor Vehicle Lighting Devices
SAE J1885 AUG87—SAE Recommended Practice for Accelerated Exposure of Automotive Interior Trim Components Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus
SAE J1960 JUN89—SAE Standard for Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus

3. Terminology

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

4. Basis of Classification

4.1 Poly(methyl methacrylate) molding and extrusion compounds are classified into groups according to their composition. These groups are subdivided into classes and grades as shown in Table 1. A complete classification must include reference to melt-flow rate, as discussed in 4.2 and 5.1.3.

4.1.1 To facilitate the incorporation of future or special materials, the "other/unspecified" category (0) for group, class, and grade is given in Table 1.

4.1.2 When the grade of the basic material is not shown, or is not important, the use of "0" grade classification shall be used in this classification system.

4.2 The melt-flow rate can vary within a given group, class, and grade and can overlap classes or grades. For this reason, the melt-flow rate shall be specified using Suffix V.

4.2.1 Although the values listed in Suffix V are necessary to include the range of properties available in existing materials, users should not infer that every melt-flow rate exists for each class or grade.

NOTE 2—An example of this classification system is as follows:

The designation PMMA0112 indicates:

PMMA	=	poly(methyl methacrylate) as found in Terminology D 1600,
01	=	unmodified (group),
1	=	minimum 77°C Vicat, etc. (class) and
2	=	ultraviolet transmitting (grade).

(See Note 4 for a more complete example.)

NOTE 3—Major industries using these materials now require internationally accepted test methods for product specifications. For this reason, ISO test methods have been used in Table 1 and elsewhere in this classification system where appropriate. Similar ASTM standards have been listed in Section 2. Many of these ASTM standards are now or soon will be equivalent. In future editions, a note in the ASTM standard will indicate the degree of equivalency with a particular international standard. The corresponding ASTM test method may be substituted as long as the specimen size and all other conditions of the test method noted in this classification system as applying to the ISO test method are also applied to the ASTM standard.

4.3 Grade 1 materials are used where special ultraviolet transmission, filtering, or stabilization characteristics are not required.

4.4 Grade 2 materials are used for those specialized applications in which the greatest amount of transmission of UV light is required. The transmission properties are given in Table 2.

4.5 Grade 3 materials (transparent UV stabilized or transparent UV absorbing) are used when either special resistance to slight color change over long exposure times or high-intensity UV radiation is required, or when the material is required to filter out ultraviolet light. These applications are varied and require specific light transmission or color-stability properties to be specified by the user.

5. Suffixes

5.1 When additional requirements are needed, based on the application, that are not covered by the basic 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.

5.1.1 Suffix E = Electrical requirements, as designated by the following digits:

[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.
[7] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
[8] Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001.

TABLE 1 PMMA Poly(Methyl Methacrylate) Materials Detail Requirements

Note—The values listed were developed for natural colors. Colorants or other additives, or both, may alter these properties.

Group	Description	Class	Description[A]	Grade	Description[A]	Izod Impact, Test Method ISO 180,[B] kJ/m², min	Tensile Strength, Test Method ISO 527,[C] MPa, min	Luminous Transmittance, Test Method D 1003,[D] %, min	Haze, Test Method D 1003,[D] %, max	Index of Refraction, Test Method ISO 489[D]	Flexural Modulus, Test Method ISO 178,[E] MPa, min	Vicat Softening Temperature, Test Method ISO 306,[F] °C, min
01	Unmodified[G]	1	Formerly Grade 5 (D 788 – 84)	1	General purpose	1.1	58	90	2.5	1.48–1.50	2700	77
				2	UV transmitting[H]	1.1	58	90	2.5	1.48–1.50	2700	77
				3	UV stabilized[I]	1.1	58	90	2.5	1.48–1.50	2700	77
				0	Other/unspecified	...	...	...	...	...	...	...
		2	Formerly Grade 6 (D 788 – 84)	1	General purpose	1.1	62	90	2.5	1.48–1.50	2700	86
				2	UV transmitting[H]	1.1	62	90	2.5	1.48–1.50	2700	86
				3	UV stabilized[I]	1.1	62	90	2.5	1.48–1.50	2700	86
				0	Other/unspecified	...	...	...	...	...	...	...
		3	Formerly Grade 8 (D 788 – 84)	1	General purpose	1.1	65	90	2.5	1.48–1.50	2700	95
				2	UV transmitting[H]	1.1	65	90	2.5	1.48–1.50	2700	95
				3	UV stabilized[I]	1.1	65	90	2.5	1.48–1.50	2700	95
				0	Other/unspecified	...	...	...	...	...	...	...
		4		1	General purpose	1.1	65	90	2.5	1.48–1.50	2700	104
				2	UV transmitting[H]	1.1	65	90	2.5	1.48–1.50	2700	104
				3	UV stabilized[I]	1.1	65	90	2.5	1.48–1.50	2700	104
		0		0	Other/unspecified	...	...	...	...	...	...	...
				0	Other/unspecified	...	...	...	...	...	...	...
02	Impact modified[J]	1		1		2.0	51	88	4.0	1.48–1.50	2500	95
				0	Other/unspecified	...	...	...	...	...	...	...
		2		1		2.6	38	88	4.0	1.48–1.50	2000	90
				0	Other/unspecified	...	...	...	...	...	...	...
		3		1		4.7	31	88	4.0	1.48–1.50	1400	85
				0	Other/unspecified	...	...	...	...	...	...	...
		0		0	Other/unspecified	...	...	...	...	...	...	...
03	Heat-Resistance modified[K]	1		1	General purpose	1.1	65	90	2.5	1.48–1.50	2700	113
				2	UV transmitting[H]	1.1	65	90	2.5	1.48–1.50	2700	113
				3	UV stabilized[I]	1.1	65	90	2.5	1.48–1.50	2700	113
				4	Impact modified also	1.5	56	88	4.0	1.48–1.50	2400	113
				0	Other/unspecified	...	...	...	...	...	...	...
		2		1	General purpose	1.1	65	90	2.5	1.48–1.50	2700	122
				2	UV transmitting[H]	1.1	65	90	2.5	1.48–1.50	2700	122
				3	UV stabilized[I]	1.1	65	90	2.5	1.48–1.50	2700	122
				0	Other/unspecified	...	...	...	...	...	...	...
		0		0	Other/unspecified	...	...	...	...	...	...	...
00	Other	0		0	Other/unspecified	...	...	...	...	...	...	...

[A] No descriptions are listed unless needed to describe a special grade or class. All other categories are listed by requirements.

[B] Preferred test specimens are 4 by 10 by 80 mm with a notch radius of 0.25 mm with 8-mm depth below notch (Type 1) and are tested by Method A. When necessary, to fit existing equipment, these specimens may be cut to 63.5-mm length. An alternative specimen, 3.2 by 12.7 by 63.5 mm with a notch radius of 0.25 mm and with 10.2-mm depth below notch (Type 4), is permitted. Annealing is neither required nor prohibited.

[C] Test specimens are tensile bars with dimensions corresponding to the ISO 3167 multipurpose test specimen, tested at a crosshead speed of 5 mm/min. Annealing is neither required nor prohibited.

[D] Test specimens are 3.2-mm thick of colorless material.

[E] Test specimens are 80 by 10 by 4 mm. Test with a 64-mm span and a speed of 2 mm/min. Annealing is neither required nor prohibited.

[F] Test specimens are 4-mm thick, tested at a rate of 50°C/h and a load of 50 N. They are placed in a desiccator immediately after molding to prevent water pickup and kept dry until ready for test. Alternatively, they can be dried for 16 h at 80± 3°C and then cooled in a desiccator until ready for test.

[G] Unmodified group materials are polymerized from 70 to 100 % methacrylate monomer and 0 to 30 % acrylic comonomers.

[H] See 4.3 for description.

[I] See 4.4 for description.

[J] Impact-modified materials contain 50 to 95 % unmodified polymer and 5 to 50 % of impact modifier(s), maintaining the requirement that the overall composition of these materials is polymers made from monomers, at least 70 % of which are methyl methacrylate.

[K] Heat-resistance modified materials are polymerized from 70 to 95 % methyl methacrylate monomer and 5 to 30 % comonomers.

First Digit

0 = to be specified by the user.
1 = specimen thickness, 3.2 mm, nominal.

Second Digit

0 = to be specified by the user.
1 = volume resistivity, dielectric strength, dielectric constant, and dissipation factor meet property limits as given in Table 3.

5.1.2 Suffix H = Heat-stability requirements, as designated by the following digits:

TABLE 2 Transmission of Grade 2 Materials at Various Wavelengths[A,B]

Wavelength, nm	Transmission, min, %
400	86
340	85
310	70
290	50
280	26
270	12

[A] Measured with UV spectrophotometer using an integrating sphere and a sample thickness of 3.2 mm.

[B] These requirements are in addition to the luminous transmittance requirements given in Table 1.

TABLE 3 Electrical Properties of Unmodified PMMA

Property	Test Method	Requirement
Insulation resistance, min, Mohm	D 257	1×10^7
Dielectric strength min, kV/mm[A]	D 149	13.8
Dielectric constant at 1 MHz, max	D 150	4.5
Dissipation factor at 1 MHz, max	D 150	0.05

[A] kV/mm × 25.4 = V/mil.

First Digit

0 = to be specified by the user.
1 = 1000 h at 70 ± 2°C.
2 = 1000 h at 80 ± 2°C.
3 = 1000 h at 90 ± 2°C.

Second Digit

0 = to be specified by the user.
1 = change in tensile strength and impact strength not to exceed limits as given in Table 4A after aging in an air-circulating oven at the conditions indicated by the first digit and subsequent conditioning according to Section 12.
2 = change in tensile strength, tensile elongation, and impact strength not to exceed limits as given in Table 4B after aging in an air-circulating oven at the conditions indicated by the first digit and subsequent conditioning according to Section 12.

5.1.3 Suffix V = Melt-flow property requirements as designated by the following digits, determined according to ISO 1133-1981, Condition 13 (equivalent to Test Method D 1238 at Conditions 230/3.8):

First Digit

0 = unspecified.
1 = greater than 0 g/10 min.
2 = greater than 2 g/10 min.
3 = greater than 3 g/10 min.
4 = greater than 6 g/10 min.
5 = greater than 11 g/10 min.
6 = greater than 17 g/10 min.
7 = greater than 23 g/10 min.

NOTE 4—An example of this classification system for a PMMA resin with specified melt-flow rate properties is as follows:

The designation PMMA0112V5 indicates:

PMMA0112 = Unmodified, minimum 77°C Vicat, etc., ultraviolet transmitting material from Table 1,
V = Melt-flow property requirements, from V suffix requirements above,
5 = Greater than 11 g/10 min. Melt-flow rate from V suffix requirements above.

5.1.4 Suffix W = Resistance to weathering as designated by the following digits:

TABLE 4 A Heat-Stability Properties of PMMA

Property	Test Method	Requirement
Change in tensile strength	ISO 527	±15 % max
Change in impact strength	ISO 180	±15 % max

TABLE 4B Heat-Stability Properties of PMMA

Property	Test Method	Requirement
Change in tensile strength	ISO 527	±15 % max
Change in tensile elongation	ISO 527	±20 % max
Change in impact strength	ISO 180	±15 % max

First Digit

0 = to be specified by the user.
1 = exposure as defined in SAE J576.
2 = exposure as defined in SAE J1885.
3 = exposure as defined in SAE J1960.

Second Digit

0 = to be specified by the user.
1 = meets the requirements of SAE J576.

5.2 An additional list of suffixes can be found in Classification System D 4000 and may be used for additional requirements, as appropriate.

6. Basic Requirements

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

7. General Requirements

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

8. Detail Requirements

8.1 Test specimens for the various materials shall conform to the requirements prescribed in Table 1, Suffix V requirements, and optional other suffix requirements, as they apply.

8.2 For purposes of determining conformance, all specified limits for a specification (line callout) based on this classification system are absolute limits, as defined in Practice E 29.

8.2.1 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 is based on this comparison.

9. Sampling

9.1 Sampling shall be statistically adequate to satisfy the requirements of 13.4.

9.2 A batch or lot shall be constituted as a unit of manufacture as prepared for shipment, and may consist of a blend of two or more“ production runs.”

10. Number of Tests

10.1 The number of tests shall be consistent with the requirements of Section 9 and 13.4.

11. Specimen Preparation

11.1 The specimens shall be prepared by the injection molding process under the conditions outlined in Table 5 and Table 6. Specimens shall be prepared using an average injection velocity of 250 ± 100 mm/s through the parallel section of the test specimen. Injection velocity shall be calculated as follows:

$$V_{Iav} = (n \times d^2 \times V_s)/(4 \times n \times A_c) \quad (1)$$

TABLE 5 Melt Temperature Conditions

NOTE 1—The melt temperature was determined by using the hot-probe technique as described in Practice D 3641 and ISO 294.

Viscosity Classification	Melt Temperature,° C
V0	270
V1	265
V2	250
V3	250
V4	240
V5	230
V6	220
V7	210

TABLE 6 Mold Temperature Conditions

Group/Class Designation	Mold Temperature,° C
PMMA011	50
PMMA012	60
PMMA013	70
PMMA014	70
PMMA021	60
PMMA022	50
PMMA023	50

where:

V_{Iav} = average injection velocity, (mm/s),
d^2 = screw diameter, (mm),
V_s = screw injection velocity (mm/s),
n = number of cavities, and
A_c = cross sectional area of parallel section of test specimen (4 mm × 10 mm = 40 mm^2).

11.2 Materials must be dried prior to molding to ensure bubble-free test specimens. A moisture content of 0.08 % or less is usually sufficient.

12. Conditioning

12.1 Condition molded test specimens at 23 ± 2°C and 50 ± 5 % relative humidity for not less than 40 h prior to testing in accordance with Procedure A of Practice D 618. However, the specimens for Vicat softening temperature should not be conditioned in accordance with Procedure A of Practice D 618. These Vicat specimens should either be kept in a desiccator from the time of molding until tested or redried at 80 ± 3°C for 16 h and cooled in a desiccator until ready for test.

12.2 Conduct tests at the standard laboratory temperature of 23 ± 2°C and not more than 55 % relative humidity.

13. Certification and Inspection

13.1 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.

13.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of melt flow rate, Vicat softening point on all grades, and Izod impact on impact-modified materials.

13.3 Periodic check inspection shall consist of the tests specified for all requirements of the material under this classification system. The supplier shall determine and use an inspection frequency that shall be adequate to ensure that the material is certifiable in accordance with 13.4.

13.4 Certification shall be that the material was manufactured, sampled, tested, and inspected in accordance with this specification and that average values meet the requirements at a confidence level of 95 %.

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

14. Packing, Packaging, and Package Marking

14.1 The provisions of Practice D 3892 apply to packaging, packing, and marking of containers for plastic materials.

15. Keywords

15.1 acrylic; acrylic plastic; acrylic resins; clear weatherable plastics; line callout; plastic; plastic materials; PMMA; poly(methyl methacrylate); recycled; transparent plastics

APPENDIX

(Nonmandatory Information)

X1. CROSS-REFERENCES

See Table X1.1 and Table X1.2.

TABLE X1.1 Cross-Reference to Prior Version of This Classification System (ASTM D 788 – 84)

Former Grade Designation	This Specification
Grade 5	PMMA0111V0
Grade 6	PMMA0121V0
Grade 8	PMMA0131V0

TABLE X1.2 Cross-Reference Designations to Federal Specifications

Federal Specification L-P-380C	This Specification
Type I—General-Purpose	
Class 1	PMMA0111V0
Class 2	PMMA0121V0
Class 3	PMMA0131V0
Type II—Electrical-Type Material	
Class 1	PMMA0111E11V0
Class 2	PMMA0121E11V0
Class 3	PMMA0131E11V0

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