



Designation: D5138 – 23

Standard Classification System and Basis for Specification for Liquid Crystal Polymers Molding and Extrusion Materials (LCP)¹

This standard is issued under the fixed designation D5138; 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 This classification system covers liquid crystal polymeric (LCP) materials suitable for injection molding and extrusion. This classification system allows the use of liquid crystal polymers that are recycled, reconstituted, recycled-regrind, recovered, or reprocessed, or a combination thereof, provided that the requirements as stated in this classification system are met. It is the responsibility of the supplier and the buyer of liquid crystal polymers that are recycled, reconstituted, recycled-regrind, recovered, or reprocessed, or a combination thereof, to ensure compliance.

1.2 The properties included in this classification system are those required to identify the compositions covered. Other requirements necessary to identify particular characteristics important to specialized applications are allowed. These shall be agreed upon between the user and the supplier, by using suffixes as given in Section 5.

1.3 This classification system and subsequent line callout (specification) are intended to be a means of calling out plastic materials used in the fabrication of end-use items or parts. It is not intended for the selection of materials. Material selection can 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 costs involved, and the inherent properties of the material other than those covered by this classification system.

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

1.5 The following precautionary caveat pertains only to the test method 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.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization 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

- 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
- D883 Terminology Relating to Plastics - d5138-23
- D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
- D1600 Terminology for Abbreviated Terms Relating to Plastics
- D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
- D3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials
- D3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer
- D3892 Practice for Packaging/Packing of Plastics
- D4000 Classification System for Specifying Plastic Materials
- D5630 Test Method for Ash Content in Plastics

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

- 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 IEC and ISO Standards:⁴
 - IEC 112 Recommended Method for Determining the Comparative Tracking Index of Solid Insulation Materials
 - IEC 243 Recommended Methods of Test for Electrical Strength of Solid Insulating Materials at Power Frequencies
 - ISO 62 Plastics—Determination of Water Absorption
 - ISO 75-1 Determination of Temperature of Deflection Under Load—General Test Method
 - ISO 75-2 Determination of Temperature of Deflection Under Load—Plastics and Ebonite
 - ISO 178 Plastics—Determination of Flexural Properties of Rigid Materials
 - ISO 180 Plastics—Determination of Izod Impact Strength of Rigid Materials
 - ISO 294-1 Plastics—Injection Moulding of Test Specimens of Thermoplastic Materials—General Principles for Injection Moulding
 - ISO 527-1 Plastics—Determination of Tensile Properties—General Principles
 - ISO 527-2 Plastics—Determination of Tensile Properties—Test Conditions for Moulding and Extrusion of Plastics
 - ISO 604 Plastics—Determination of Compressive Properties

- ISO 3451-1 Plastics—Determination of Ash Content—Part 1: General Methods
- ISO 11357-1 Plastics—Differential Scanning Calorimetry (DSC)—Part 1: General Principles
- ISO 11357-3 Plastics—Differential Scanning Calorimetry (DSC)—Part 3: Determination of Temperature and Enthalpy of Melting and Crystallization
- ISO 11443 Plastics—Determination of the Fluidity of Plastics Using Capillary and Slit-Die Rheometers
- ISO 20753 Plastics—Test Specimens
- 2.3 Military Standard:⁵
 - MIL-M-24519 Molding Plastics—Electrical Thermoplastics
- 2.4 Underwriters Laboratories (UL):⁶
 - UL 94 Test for Flammability of Plastic Materials for Parts in Devices and Appliances
- 2.5 National Technical Information Service (NTIS):⁷
 - AD297457 Procedure and Analytical Method for Determining Toxic Gases Produced by Synthetic Compounds

3. Terminology

3.1 *Definitions*—Except for the terms defined below, the terminology used in this classification system is in accordance with Terminologies D883 and D1600.

3.2 *Definitions of Terms Specific to This Standard:*

⁵ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.

⁶ Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, <http://www.ul.com>.

⁷ Available from National Technical Information Service (NTIS), 5301 Shawnee Rd., Alexandria, VA 22312, <http://www.ntis.gov>.

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

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

TABLE LCP Liquid Crystal Polymers—Classification

| Group | Description | Class | Description | Grade ^A | Description |
|-------|---|-------|--|--------------------|-------------|
| 01 | unsubstituted or methyl substituted, wholly aromatic copolyester, polyether, or polyester amide | 1 | high temperature DTUL ^B >260°C | 0 | |
| | | 2 | medium temperature DTUL = 220–260°C | 0 | |
| | | 3 | general purpose DTUL <220°C | 0 | |
| 02 | mixed aromatic/aliphatic copolyesters, polyethers, or polyester amides | 1 | high temperature DTUL >260°C | 0 | |
| | | 2 | medium temperature DTUL = 220–260°C | 0 | |
| | | 3 | general purpose DTUL <220°C | 0 | |
| 03 | aromatic copolyesters, polyethers, or polyestaramides with aliphatic sidechain | 1 | high temperature DTUL >260°C | 0 | |
| | | 2 | medium temperature DTUL = 220–260°C | 0 | |
| | | 3 | general purpose DTUL <220°C | 0 | |
| 04 | blends | 1 | high temperature DTUL >260°C | 0 | |
| | | 2 | medium temperature DTUL = 220–260°C | 0 | |
| | | 3 | general purpose DTUL <220°C | 0 | |
| 00 | other | 0 | other | 0 | |

^A Description unspecified.

^B DTUL is deflection temperature under load measured at 1.8 MPa and is determined in accordance with Table A or Table B.

3.2.1 *liquid crystal polymer (LCP)*—A family of thermo-plastic polymers which upon heating to the processing temperature, exhibit ordered structure and under shear, highly aligned chains that are retained in the solid state. Liquid crystal polymers are polymers that in the molten state exhibit birefringence in polarized light.

4. Classification

4.1 The LCP materials are classified into groups according to their chemical composition. These groups are subdivided, whether reinforced or not, into classes based on thermal performance as shown in Table LCP.

NOTE 2—An example of this classification system is as follows: The specification LCP0120 indicates the following LCP = liquid crystal polymer as found in Terminology D1600:

- 01 = Unsubstituted, or methyl substituted, wholly aromatic copolyester, polyether, or polyester amide (group)
- 2 = Medium temperature, DTUL = 220-260°C (class)
- 0 = Other (grade)

4.1.1 To facilitate the incorporation of future or special materials, the “other” category for Group (00), Class (0), and Grade (0) is shown in Table LCP.

4.2 Reinforced, filled, and lubricated versions of LCP materials are classified in accordance with Tables LCP and Table A. Table LCP is used to specify the group or the group and class of LCP and Table A is used to specify the property requirements.

NOTE 3—Test specimens shall be prepared in accordance with ISO 20753, Specimen Type A1 or Practice D3641 accordingly.

NOTE 4—A similar callout can be developed using Table B.

4.2.1 Reinforced, filled, and lubricated variations of the basic materials are identified by a single letter that indicates the filler, or reinforcement used, or both, and two digits that indicate the nominal quantity in percent by weight. The reinforcement letter designations and associated tolerance levels are shown in Table 4.

NOTE 5—This part of the system uses the percent of reinforcements or additives, or both, in the callout of the modified basic material. The types and percentages of reinforcements and additives are shown on the suppliers’ technical data sheet unless they are proprietary in nature. If necessary, additional callout of these reinforcements and additives can be accomplished by the use of the suffix part of the system (see Section 5).

4.2.2 Specific requirements shall be shown by a six-character specification. The specification will consist 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.

4.2.2.1 Although the values listed are necessary to include the range of properties available in existing materials, this does not imply that every possible combination of properties exists or can be obtained.

4.2.3 When the grade or class of the basic material is not known or is not important, the “0” classification shall be used.

NOTE 6—An example of this classification for specifying a reinforced LCP material is given as follows: The specification LCP0120G30A22450 would indicate the following material requirements:

- LCP = Liquid Crystal Polymer as found in Terminology D1600
 - 01— = Unsubstituted or methyl substituted, wholly aromatic copolyester, polyether, or polyester amide (group),
 - 2 = medium temperature (class)
 - 0 = unspecified (grade)
 - G30 = Glass reinforced at 30 % nominal level
 - A = Table A property requirements
 - 2 = Tensile strength, min, 100 MPa
 - 2 = Flexural modulus, min, 8 GPa
 - 4 = Notched izod impact, min, 15 kJ/m
 - 5 = Deflection temperature under load, min, 260°C at 1.8 MPa,
 - 0 = Unspecified
- If no properties are specified, the specification would be LCP0120G30A00000.

5. Suffixes Requirements

5.1 When additional requirements are needed that 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 is found in Classification System D4000 (Table 3) and are used for additional requirements as appropriate.

5.2.1 Additional suffixes will be added to that standard as test methods and requirements are developed and requested.

6. General Requirements

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

TABLE A Property Requirements for Liquid Crystal Polymer Based on ISO Test Methods

| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|----------|-------------|-----|-----|-----|-----|-----|-----|-----|-----|---------------|
| 1 | Tensile strength, min, MPa | ISO 527 | unspecified | 70 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | specify value |
| 2 | Flexural modulus, min, GPa | ISO 178 | unspecified | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | specify value |
| 3 | Notched izod impact, min, kJ/m ² | ISO 180 | unspecified | 5 | 9 | 12 | 15 | 18 | 25 | 37 | 50 | specify value |
| 4 | DTUL ^A at 1.8 MPa, min, °C | ISO 75/A | unspecified | 140 | 180 | 220 | 240 | 260 | 300 | 340 | 380 | specify value |
| 5 | To be determined | | unspecified | | | | | | | | | specify value |

^A DTUL = Deflection temperature under load tested flatwise on 80 by 10 by 4-mm specimen.

TABLE B (Formerly Table A in D5138 – 90) Property Requirements for LCP Based on ASTM Test Methods

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|-------------|-----|-----|-----|-----|-----|-----|-----|-----|---------------|
| Tensile strength, MPa, min, ^A (D638) | unspecified | 70 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | specify value |
| Flex modulus, GPa, min, ^B (D790) | unspecified | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | specify value |
| Notched Izod impact, min, J/m, (D256) ^C | unspecified | 40 | 75 | 100 | 125 | 150 | 200 | 300 | 400 | specify value |
| Deflection temperature, min, °C at 1.8 MPa, (D648) ^D | unspecified | 140 | 180 | 220 | 240 | 260 | 300 | 340 | 380 | specify value |
| To be determined | unspecified | | | | | | | | | specify value |

^A Type 1 tensile bar, 3.2 mm thick tested at 5 mm/min ± 25 % (minimum length 200 mm).

^B 127 by 12.7 by 3.2-mm bar tested at 1.3 mm/min.

^C Bar thickness 3.2 mm.

^D Test Method D648, Method A.

TABLE 4 Reinforcement-Filler^A Symbols^B and Tolerances

| Symbol | Material | Tolerance (Based on Total Mass ^A) |
|--------|---|---|
| C | carbon and graphite fiber | ±2 % |
| G | glass | ±2 % |
| L | lubricants (for example PTFE, graphite, silicone, and molybdenum disulfide) | depends upon material and process—to be specified |
| M | mineral | ±2 % |
| R | combinations of reinforcements or fillers, or both | ±3 % for the total |

^A Ash content of filled, or reinforced material, or both, is determined using either Test Method D5630 or ISO 3451-1 where applicable.

^B Additional symbols will be added to this table as required.

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

7. Detail Requirements

7.1 The material shall conform to the requirements prescribed in Tables LCP and A (or B), and the suffix requirements as they apply.

7.2 For the purposes of determining conformance with this classification system, all specified limits for a specification (line callout) based on this classification system are absolute limits, as defined in Practice E29.

7.3 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.

8. Sampling

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

8.2 A batch or lot shall be constituted as a unit of manufacture as prepared for shipment. A batch or lot is allowed to consist of a blend of two or more production runs.

9. Specimen Preparation

9.1 The moisture content of the molding material for the preparation of test specimens shall not exceed 0.01 %. Material having a moisture content above these limits shall be dried in accordance with the instructions of the manufacturer.

9.2 The test specimens shall be prepared by an injection molding process as specified in ISO 294-1 for Table A or Practice D3641 for Table B. The processing conditions specified in Table 5 are guidelines only. Since mechanical properties can vary depending on the molding conditions, contact the manufacturer of the grade for molding conditions appropriate for specification purposes.

9.3 Because of the shear sensitivity of LCP materials, occasionally a gate smaller than the gate specified by the molding practice or method is required to fill the part adequately. When reporting data in accordance with a specification (line callout), the gate design shall be reported if different than the applicable molding practice or method requirement.

10. Conditioning

10.1 Test specimens shall be conditioned in the standard laboratory atmosphere for a minimum of 12 h (condition 12/23/50 of Practice D618).

11. Test Methods

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

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.

TABLE 5 Processing Guidelines for Liquid Crystal Polymers for Preparation of Test Specimens^A

| Material | Melt Temperature, °C | Cycle Time, s | Average Injection Velocity, mm/s | Mold Temperature, °C |
|------------------------|----------------------|---------------|----------------------------------|----------------------|
| Liquid crystal polymer | ^B | 30 ± 5 | 150–600 | 90 ± 5 |

^A Contact the manufacturer of the grade for more specific molding conditions when conducting tests for comparison with the requirements of this classification system.

^B Target melt temperature shall be ±20°C around the melt point. Actual melt temperature shall be held at ±3°C of the target. The melt point is defined as the nominal melt transition temperature as measured by differential scanning calorimetry.