Designation: F3087 – 15

Standard Specification for Acrylic Molding Resins for Medical Implant Applications[1]

This standard is issued under the fixed designation F3087; 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 specification covers acrylic resins supplied in virgin form (typically pellets, powder, or granules) for medical implant applications. The co-polymers are limited to random co-polymers. This specification provides requirements and associated test methods for this thermoplastic when it is intended for use in manufacturing implantable medical devices or components of medical devices.

1.1.1 While a variety of co-monomers may be used, the composition of the resin shall contain poly(methyl methacrylate) (PMMA) as its primary ingredient. Classification D788 defines an acrylic molding compound as "having at least 70% of the polymer polymerized from methyl methacrylate." The terms PMMA and acrylic as used herein refer generically to both the homopolymer and to co-polymers as defined above.

1.2 As with any material, some characteristics may be altered by the processing techniques (such as molding, extrusion, machining, sterilization, and so forth) required for the production of a specific part or device. Therefore, properties of fabricated forms of this resin should be evaluated using test methods that are appropriate to ensure safety and efficacy as agreed upon between the supplier, purchaser, and regulating bodies.

1.3 This specification allows for designation of acrylic resins for all medical implant applications. The actual extent of performance and suitability for a specific application shall be evaluated by the medical device manufacturer and regulating bodies.

1.4 The properties included in this specification are those applicable for both unfilled acrylic polymers and for formulated resins containing barium sulfate. Indicated properties (Table 1 and Table X3.1) are for unfilled injection molded forms. Forms containing fillers other than barium sulfate, colorants, polymer blends that contain PMMA, or reclaimed materials are not covered by this specification.

1.5 Compliance with this specification does not obviate the need for functional testing of any device fabricated from the resin to demonstrate effectiveness in its intended application.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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:*[2]

D638 Test Method for Tensile Properties of Plastics

D695 Test Method for Compressive Properties of Rigid Plastics

D788 Classification System for Poly(Methyl Methacrylate) (PMMA) Molding and Extrusion Compounds

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer

D1898 Practice for Sampling of Plastics (Withdrawn 1998)[3]

F451 Specification for Acrylic Bone Cement

F748 Practice for Selecting Generic Biological Test Methods for Materials and Devices

2.2 *ISO Standards*[4]

ISO 10993-1 Biological evaluation of medical devices – Part 1: Evaluation and testing within a risk management process

ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories

[1] This test method is under the jurisdiction of ASTM Committee F04 on Medical and Surgical Materials and Devices and is the direct responsibility of Subcommittee F04.11 on Polymeric 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.

[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.

2.3 *Other Reference:*

Klaus-Dieter Kuhn, "Up-to-Date Comparison of Physical and Chemical Properties of Commercial Materials," *Bone Cements*, Springer, 2000.

3. Terminology

3.1 *Definitions:*

3.1.1 *formulated resin, n*—materials, parts, or devices fabricated from virgin polymer resin in such a way as to contain intentional or unintentional adjuvant substances.

3.1.2 *poly(methyl methacrylate) (PMMA), n*—homopolymer of methyl methacrylate (MMA), or random copolymer of MMA with other vinyl monomers in which MMA constitutes the majority of the final content.

3.1.3 *virgin polymer, n*—the initially delivered form of the polymer as synthesized from its monomers prior to any processing or fabrication into a medical device. The resin is typically provided in the form of pellets, granules, or powder and is the material from which fibers, tubes, rods, slabs, sheets, films, or specific parts and devices are fabricated.

4. Significance and Use

4.1 This specification identifies the composition and recommends test methods to establish a reasonable level of confidence concerning the performance of acrylic resins for use in medical implant devices. The required properties are intended to provide a means of ensuring consistent performance. Additional testing should be considered in selecting a material in accordance with specific end-use requirements.

4.2 Acrylic resins may be considered for use in implantable medical devices as well as in non-implant medical applications, but this standard specifically covers resins used for implants. Resins meeting the requirements of this specification may be suitable for non-implant applications, but other acrylic resins that do not conform to this standard may also be suitable for use in non-implant medical applications.

4.3 Acrylic resins intended for use in implant applications are manufactured with more rigorous use of manufacturing or testing controls, or both, to ensure consistency of properties, cleanliness, and biocompatibility. This is further elaborated in 5.1.

5. Classification

5.1 Acrylic resins meeting the requirements of this specification may be considered for use for either prolonged or permanent medical implant applications. Resins classified for permanent implant applications may require additional testing beyond that required for prolonged use as agreed upon between the device manufacturer and regulating bodies. Use of resins for implant applications also implies a higher degree of manufacturing control. Implant grade resins shall be in compliance with the relevant aspects of Good Manufacturing Practices (GMPs), use of process validation, enhanced controls, and testing in a laboratory meeting the requirements of ISO 17025. Acrylic resins classified for implantable devices shall be evaluated for biological response in accordance with ISO 10993-1 or Practice F748, Section 10, or both.

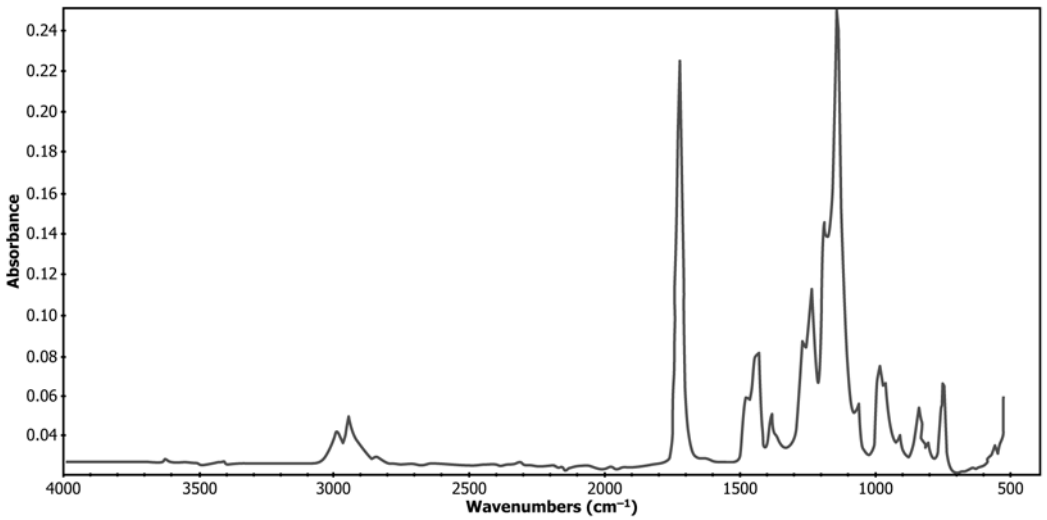
NOTE 1—Implant uses are medical applications implanted in the human body and devices that are in contact with bodily fluids or tissues for greater than 24 h; that is, prolonged (24 h to 30 days) or permanent (> 30 days) exposure. Non-implant uses are medical applications in which the device is in contact with bodily fluids or tissues for 24 h or less (that is, limited exposure).

5.2 The class and grade of unfilled acrylic plastic shall be designated in accordance with Classification D788.

6. Chemical Composition

6.1 The acrylic resin shall be a homopolymer of MMA or a random co-polymer of MMA and other vinyl monomers where MMA constitutes the majority of the composition. No additives other than radiopaque fillers or stabilizers shall be used.

6.2 The acrylic resin shall yield an infrared transmittance spectrum that exhibits major transmittance bands at the same



NOTE 1—Spectrum courtesy of Wright Medical Technology, Memphis, TN. Nicolet Magna IR spectrometer, Attenuated Total Reflectance mode.

FIG. 1 Poly(Methyl Methacrylate) Homopolymer Infrared Spectrum

wavelengths as shown in Fig. 1. The purpose of the infrared (IR) spectrum, as used in this specification, is to identify the PMMA present and does not necessarily indicate an acceptable degree of material purity. The presence of additional bands in the IR spectrum of a sample may indicate a co-polymer fraction, or impurities, or both.

6.3 The acrylic resin (prior to formulation or molding) shall meet the requirements of Table 1 as determined using a validated method.

6.4 The acrylic resin shall contain no more than 0.5 % residual monomer as determined using a validated method (typically gas chromatography or high performance liquid chromatography (HPLC)).

6.5 The molar mass of the acrylic resin shall be appropriate to the intended molding method (that is, injection molding, extrusion, etc.). The molar mass may be measured directly through use of size exclusion chromatography (SEC), intrinsic viscosity, etc., or indirectly through evaluation of the melt flow index in accordance with Test Method D1238. The melt flow index for injection molding of acrylic resins can usually be determined at 230°C with a piston mass of 3.8 kg, but other conditions may be required as agreed upon between the user and the supplier.

7. Properties and Sampling

7.1 Table X3.1 lists typical mechanical properties of non-sterilized fabricated forms molded from unfilled PMMA homopolymer. Acrylic co-polymers typically have lower strength and modulus values and higher elongations at break compared to homopolymers. Specific requirements shall be as agreed upon between the resin supplier and the customer.

7.1.1 The properties listed in Table X3.1 are determined from specimens injection molded in accordance with the resin supplier's process recommendations. Additional or different treatments and processing steps (such as extrusion, molding, machining, sterilization, and so forth) may alter the material properties.

7.2 The material shall be sampled in accordance with standard sampling procedures such as those described in Practice D1898, unless otherwise agreed upon between the customer and the supplier.

7.3 Testing shall be conducted on specimens fabricated under the same relevant conditions used on the finished product.

7.3.1 Testing for lot acceptance purposes may be conducted on as-molded parts. Testing for device evaluation shall be performed on materials that have been through all processing intended for the final product, including cleaning and sterilization.

8. Appearance

8.1 The resin shall be inspected for particulate foreign matter contamination using the following or an equivalent procedure:

8.1.1 Spread a 100-g sample of the resin onto a flat, white surface and visually inspect (20/20 corrected vision if necessary) at a distance of 18 to 20 in. No more than 4 visible particles smaller than 0.5 mm shall be allowed. No particles greater than 0.5 mm shall be allowed. It may not be possible to evaluate foreign matter contamination for opaque materials using this method.

8.2 More sophisticated methods or stricter criteria, or both, for evaluating contamination may be agreed upon between the supplier and the customer, including the use of lower limits than given in 8.1.

9. Certification

9.1 Material suitable for medical implant applications shall be certified as meeting the requirements of this specification. Additionally, certification shall be as indicated in the material Specification D788 unless otherwise agreed upon between the supplier and the customer. Testing and certification may be performed by either the resin manufacturer or the medical device manufacturer.

9.2 Melt flow rate and residual monomer concentration shall be used to determine lot acceptance properties. These test results shall be included on the certificate of analysis. However, a periodic check of other designated properties may also be agreed upon between the purchaser and the supplier, depending on the application. Agreement between the purchaser and the supplier may also include testing of other designated properties for validation and certification, depending on the application.

9.3 The certification shall state that the material was manufactured by a process in statistical control and sampled, tested, and inspected in accordance with this specification, and that the average values for the lot meet the requirements of this specification.

NOTE 2—The ASTM Manual on Presentation of Data and Control Chart Analysis provides detailed information about statistical process control.

10. Assessment of Selected Tissue Effects

10.1 The assessment of selected tissue effects of implant devices made using acrylic polymers meeting this specification shall be determined in accordance with Practice F748 or the ISO 10993 series, unless otherwise agreed upon between the implant manufacturer and regulating bodies. Biological testing should be conducted on the finished product after it has gone through all processing steps, including sterilization.

TABLE 1 Required Properties of Virgin Resins

Property	ASTM Test Method	Property Values
Density, g/cm^3	D792	1.17 to 1.20
Residual monomer, %	Gas chromatography or HPLC	0.5 % max
Melt flow index, g/10 min	D1238 (typically at 230°C and 3.8 kg; use other conditions as required.)	As agreed upon between the user and the supplier.

10.2 Acrylic polymers meeting the requirements of Specification F451, which consist primarily of PMMA but with substantially higher concentrations of residual monomer (MMA), have been used successfully as in-situ curing bone cements for over 35 years. A comprehensive listing of commercially available bone cements has been published that includes information on the co-monomers used, although the percentages of the co-monomers are not given.[5] In-situ cured PMMA is characterized by a transient tissue response that has been shown to be due to a combination of thermal damage from the exothermic curing reaction, and leaching of residual monomer, which can be present in concentrations as high as 5 %. Molded devices of PMMA have residual monomer levels at least an order of magnitude lower than that of bone cements, and are therefore inherently more biocompatible than an in-situ curing acrylic bone cement. Therefore, if it can be demonstrated through quantitative chemical analysis that the types and amounts of co-monomers used in the synthesis of the injection molding resin fall within the composition of an in-situ curing acrylic bone cement with a successful clinical history it may not be necessary to conduct full biocompatibility testing on the molding resin. This information should be taken into account in the biological evaluation within a risk management process in accordance with ISO 10993-1.

[5] Klaus-Dieter Kuhn, Bone Cements.

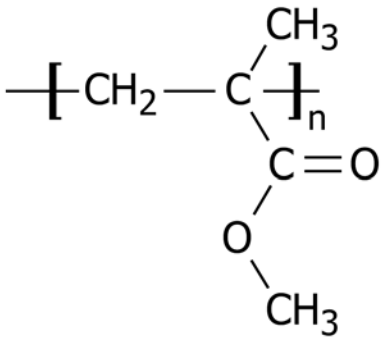
11. Keywords

11.1 acrylic resins; co-polymers; molding; PMMA; polymers; surgical applications

APPENDIXES

(Nonmandatory Information)

X1. CHEMICAL STRUCTURE OF POLY(METHYL METHACRYLATE)



X2. RATIONALE

X2.1 Devices molded from poly(methyl methacrylate) (PMMA) have a long history of clinical use as permanent implants. For example, distal centralizers, also known as cement restrictors, molded from PMMA resins are used to position cemented total hip femoral stems, ensuring an even thickness cement mantle. They are also one of the most commonly used materials for cranioplasty. The extensive and long-term use of this class of materials justifies the need for standardization of the polymer properties that are important for device function and for an acceptable and reproducible tissue response.

X2.2 This specification was established to provide guidance in the specification and testing of acrylic resin intended for use in medical device applications. It recommends test methods for the measurement of chemical, physical, and mechanical properties. Additional tests should be selected in accordance with end-use applications. It is intended that biocompatibility be established on the finished product by the appropriate procedures, after it has gone through all processing steps and after all adjuvant substances have been incorporated.

X2.3 Acrylic resin may be processed by most techniques available for thermoplastic polymers. Sterilization methods used successfully in past applications include ethylene oxide and irradiation. Actual suitability shall be determined by testing suitable for the application. It should be noted that radiation sterilization is known to cause chain scission resulting in a reduction of average molar mass.

X3. TYPICAL MECHANICAL PROPERTIES

TABLE X3.1 Typical Mechanical Properties of Fabricated Forms for PMMA Homopolymers

Property	ASTM Test Method	Typical Property Values[A]
Tensile elongation at break, %	D638	2.5 to 5
Tensile modulus of elasticity, GPa	D638	2.2 to 3.1
Tensile strength, MPa	D638	47 to 70
Ultimate compressive strength, MPa	D695	70 to 120

[A]Typical property values are tabulated here for reference. Specification limits may be indicated by reference. Acrylic copolymers typically exhibit reduced strength and modulus and increased elongation (ductility) compared to homopolymers.