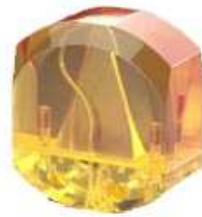




Liquid Resin Casting™ Design Guide



Learn about:

- **Liquid Resin Casting (LRC™) process**
- **Designing or modifying a part using LRC™**

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The Liquid Resin Casting (LRC™) Process

Overview

The LRC™ process is accomplished by pouring liquid plastic resins into molds. The molds are of various styles and materials depending on the application. Once poured, heat is added to the mix to speed the process of curing the resin to solid form. This reaction is irreversible, as cast materials are thermoset.

Molds

Molds are generally made using one of the following methods:

Cast: pouring silicone, epoxy, or polyurethane over a pattern.

Machined: typically aluminum, but may be steel or plastic.

Combinations of the above may also be used such as a silicone outer mold with a metal core. Tolerance requirements, production quantities, and other factors will determine which configuration is best suited for the job. The sizing of any tooling element may need to be adjusted by a shrink factor.

Patterns

Cast molds are made from a pattern (also referred to as a master) that represents the actual part being produced. A pattern may be one of the types listed below, and may be either provided by Polymer Corporation or customer supplied to Polymer Corporation's specifications:

Metal Pattern: usually machined from aluminum; better quality parts can be made with metal "half patterns".

Rapid Prototype: provides a pattern that is of lesser quality, usually suitable only for prototype use. Some available types are:

SLA	Stereo Lithography
SLS	Selective Laser Sintering
SPI	3D Wax Printer and Casting Masters
FDM	Fused Deposition Modeling
LOM	Laminated Object Manufacturing

Plastic Pattern: machined or 2nd generation (cast and machined, typically using a rapid prototype pattern); suitable for small quantities of parts with low tolerances.

Production Capacity

One-part silicone mold (or two-part made from half patterns):

Epoxy	6 parts per day per pattern
Hard Polyurethane	12 parts per day per pattern
Soft Polyurethane	18 parts per day per pattern

Quantities per day are approximate, depending on specific resin, tolerances, cosmetic requirements, and complexity of the part (undercuts, etc.). The number of metal core sets will further limit daily production.

Multi-part silicone mold (made from one-piece pattern): divide the above quantities by the number of mold parts.

Metal mold: 1 part per day for each mold.

As-cast Tolerances

Features made with silicone mold elements and those dependent on relationships between metal and silicone elements can typically be held within $\pm .004$ units per unit (inches per inch or millimeters per millimeter).

Features made entirely with metal tooling elements can usually be held within $\pm .002$ units per unit.

For silicone molds, tolerances across parting lines are typically within $\pm .01$ units per unit. These tolerances are general and vary with material selection. Tighter tolerances can be achieved by secondary operations.

Machined Secondary Operation Tolerances

Hole diameters will normally be held to $\pm.002$ inch. Other machined dimensions can normally be held to a standard $\pm.005$ inch tolerance. Non-critical overall dimensions created by removing the chimney (or gate) where the mold is filled, are often created by grinding or sanding to blend with cast radii and are thus subject to as-cast tolerances. For tight tolerances on large dimensions, the temperature at which the parts are machined and measured must be the same. The coefficient of thermal expansion must be considered when mating plastic parts with metal parts.

As-Cast Material Properties

Hardness Ranges: Shore A-10 through A-90 (Elastomers)
Shore D-50 through D-90 (Plastics)

Typical Heat Distortion Temperatures: 130 to 225 degrees F

Epoxies are available with an HDT of 300 to 450 degrees F, allowing autoclaving. A number of our customers have successfully qualified some of these materials for medical applications.

Data sheets are available for most resins giving detailed properties.

Colors

We have a large number of pigments on hand providing a wide variety of colors. Black, white, and several shades of gray are cast in large quantities daily, providing economy of scale. Most colors can be matched in most resins. A number of resins, particularly elastomers and high temperature epoxies, have various levels of amber tint, making it difficult or impossible to match light colors.

There is a nominal charge to match a custom color to a sample or a standard such as a Pantone color. Please note that pigment is color matched for a particular resin and will rarely provide the same color when used in another resin.

As the LRC™ process involves making small quantities of a part each day, colors may vary slightly day to day. Also, the purchased resins may vary from lot to lot, sometimes making long-term consistency difficult.

If various processes are used to make the components of an assembly, it is advisable to specify different colors for each process.

Transparent water-clear materials are available in a wide range of flexible and rigid materials. These materials can be tinted to any desired color, subject to a color-match charge.

Color stability due to ultraviolet exposure and other factors varies for different resin systems. UV stabilizers can be added to some resins. If this is a concern for your design, please contact Polymer Corporation for consultation.

Surface Finish

Silicone molds provide excellent detailed reproduction of all textures and surface finish qualities. With metal molds, the application of mold release limits the level of texture detail.

Silicone molds provide excellent detailed reproduction of all textures and surface finish qualities.

When a customer-supplied pattern is used, the texture and all other surface finish qualities will be accurately reproduced on each part, unless arrangements are made for applying a new texture and finish. Typical textures created by our tooling department included sanded (satin), polished, matte (various levels of bead blasting), and painted. Mold-Tech finishes can be applied to metal tooling elements to create any desired texture (<http://www.mold-tech.com/>).

Additional Capabilities

Assemblies: We will provide complete assemblies that are bonded, screwed, or otherwise fastened together consisting of multiple cast parts and purchased or customer-furnished parts.

Contrast Filling: Lettering, logos, and/or other graphics can be engraved into the pattern, creating depressed characters in the cast part that can be filled with material of a different color. This marking cannot be wiped off or wear away when done with resin that chemically bonds to the base material.

Encapsulations: We commonly encapsulate PC boards, wiring, connectors, and/or other components as required for your application. Threaded inserts can be molded in place or self-tapping inserts installed afterwards.

Pad Printing: We now have in-house capabilities for pad printing graphics on parts, allowing lower cost marking, particularly on surfaces with textures that interfere with contrast filling.

Painting: If your parts need to have color or uniform finish that cannot be cast in place, we can paint them to your specifications.

RFI/EMI Shielding: We can apply a copper coating to the inside of your parts to provide shielding if required.

Injection Molding: We specialize in high-quality, low- to medium-volume production. Temperature- and humidity- controlled clean environments. Real-time process control monitoring is available.

Part Design Guidelines

Draft Angles: Draft angles may be applied but are not necessary on patterns used to make silicone molds, even on heavily textured parts. Eliminating draft angles results in tooling that is more easily produced and thus, less expensive. Draft may be preferable on large internal surfaces to be created by metal cores.

Radii: Avoid sharp corners, both internal and external. They cause parts to be more difficult to de-mold and decrease the life of silicone molds, thus increasing the unit cost. Radius all edges and corners as much as and wherever possible.

Wall Thickness: Although we do cast parts with walls down to .025 inches thick (and as little as .010 inches on extremely tiny parts), this makes the parts more fragile and increases the likelihood of entrapping air (voids) in these thin features. Try to keep walls a minimum of .100 inches thick wherever possible. The uniform wall thickness requirement of injection molded parts is not necessary in most cases. Thick features do not usually cause sinks in cast parts.

Bosses: Bosses that are near a wall should be made integral with that wall whenever possible. When designing bosses, the diameter of a round boss should be at least two times the outside diameter of the insert (which is approximately 3 times the thread OD or 4 times the tap drill size).

Cast-In Threads: Avoid cast-in threads smaller than 1/4-20. For these sizes, either use an insert or have threads machined in as a secondary operation. For threaded holes 1/4-20 and larger, casting in place is acceptable. (Smaller thread sizes are machined in as a secondary operation.)

Encapsulations: With relatively low cure temperatures (typically 200 degrees F or less, except for high temperature epoxies), most parts can be encapsulated without damage. Most polyurethane formulations can be cured at or close to room temperature if necessary when components cannot withstand any heat. Thin wall plastic tubing, electrical wire, connectors and fragile components such as printed circuit boards are easily encapsulated using LRC™.

Small diameter and/or curved holes: Holes as small as .020 inches in diameter can be cast in place to most any length, and do not have to follow a straight path, allowing internal channels that cannot be created by conventional fabrication techniques.

Undercuts and O-Ring Grooves: Internal undercut shapes including some O-ring grooves can be cast in place without expensive tooling. External undercut shapes can often be cast in a silicone mold with no additional parting line. However, the ability to cast these features to specified tolerance is dependent on actual part geometry. Please consult Polymer Corporation if you are designing undercut features.

Countersinks: Countersunk holes have an inherent problem with not allowing for any positional tolerance, making it necessary to drill and countersink as secondary operations. With other screw head styles, counterbored holes can be cast in place, saving on part cost.

Cosmetic Inspection Criteria

Knowing the cosmetic requirements of a part will help in quoting a job. Below is an abbreviated version of Polymer Corporation's Cosmetic Standards. The full document (QAFM-21) should be obtained upon placement of an order.

Cosmetic Inspection Criteria continued

Purpose: To provide a common basis for defining and reviewing cosmetic characteristics of Liquid Resin Cast parts between Polymer Corporation and our customers. It is intended that this standard be the exclusive reference used throughout the design, manufacture and assembly process by all parties. An exception: to use a customer standard it must be approved and documented on all appropriate procedures prior to manufacture. This document will assist in the understanding of the viewing standard, flaw standard, and process of defining cosmetic requirements to meet the needs of our customers.

Scope: This standard applies to all plastic parts produced by Liquid Resin Casting (LRC™) Techniques, as well as, customer and vendor supplied component parts and sub-assemblies. This includes those characteristics defined in the primary casting process, and those created during secondary operations. Secondary operations may include: filing, machining, painting, contrast filling, or silk screening. M&E (Duplicates of customer supplied parts) will not fall under the scope of this standard. Criteria for M&E projects will be pre-defined by the original supplied part. All noticeable flaws or imperfections will be documented upon receipt of the master, and this will be used to make accept/reject decisions. First article approvals and customer approved color samples will be kept on file in Polymer's Engineering Department. Additional copies will be on file in Quality Control.

Do the impossible: While the above guidelines are intended to encourage your designs to be friendly to the LRC™ process, we pride ourselves on our ability to "do the impossible." We process parts with exceptions to the above guidelines on a regular basis. If you would like your part to have features that do not appear to be manufacturable, give us a call.

Responsibilities: Ultimately it is the responsibility of Polymer Corporation's Quality Assurance Manager to implement and regulate all aspects of this standard. Due to the scope of this document, it is essential that all parties involved communicate a complete, and accurate understanding of the customer's needs at the highest possible level. Any breakdown in this communication will add unnecessary cost to the product. It is a company policy at Polymer that cosmetic inspection is the responsibility of all employees. If an employee notices a flaw that exceeds the customer's criteria of acceptance, it is imperative that he/she notify the appropriate individuals (internal or external) for corrective action.

Definitions:

Cosmetic: The appearance or visual attributes of a part.

Discoloration: Any visually perceived change under standard lighting conditions, from approved or standard color.

Flaw: A visible defect or imperfection that could render the part unacceptable for appearance, fit, form or function.

Flow Marks: Wavy or streaked appearance of a surface.

Gate Marks/Parting Line: A visible or raised line on a surface.

Haze: Cloudiness or a transparent part or a glossy opaque surface.

Pits: Small craters on a surface.

Protrusions: A raised area on a surface.

Scratches: Shallow grooves on a surface.

Shrink/Sink Marks: Depressions in a surface.

Specks: Small contrasting colored particles on it in the material.

Swirls: A marbled appearance in the color of a part that does not affect the material properties. It is usually caused by the inability of a material to completely accept a dye or pigment.

Voids: Air bubbles that were trapped or created during the curing process. They may either be on or within the material.

Standards Defined:

1A or 2A: Usually reserved for the most demanding surfaces

Typical Applications: Viewed areas of clear windows. Requires several extensive in-process cosmetic inspections prior to final inspection. Some in-process rejection is inevitable. Repair of substandard parts may not be a viable option.

2B or 3B: Usually reserved for very important, highly viewed external surfaces of cosmetically sensitive products.

Typical Applications: External surfaces of hand held instrumentation, CRT bezels, front panels. May require some handwork, but usually requires several close cosmetic inspections in-process and at final inspection. Some fairly minor level of in-process rejection will occur.

Cosmetic Inspection Criteria continued

Standards Defined continued

3C: Reserved for external or internal surfaces that are sometimes visible to the end user. Surface importance considered mid level.

Typical Applications: Inside surface of battery compartment, bottom surface of front panel that is normally not viewed. Rework and in-process rejection should not occur.

3D: Same as 3C except slightly high level of flaws are considered permissible.

3E: Reserved for external or internal surfaces that are never visible to the end user of cosmetically sensitive products. May be viewed by end user in cosmetically non-critical applications. Surface finish relatively unimportant. Structural integrity of the part would not be compromised.

Typical Applications: Inside surface of housings or enclosures that will be sealed up. Surfaces that will be covered up with an overlay. Selected areas that may be painted as a finishing operation.

Note: Select an appropriate classification for the zone or area on your part that matches the needs of the application. Do not over specify as this may add unnecessarily to product cost. On drawings referencing this specification, uncoded surfaces shall be considered 3E.

Quotations:

Polymer Corporation's typical customer is very quality conscious. Appearance as well as function are essential. As a result, our basic standards for quality are very high.

When Polymer receives a Request for Quotation (RFQ), a thorough review of all provided documentation is normally followed by a phone conversation with the customer's technical representative. We will discuss cosmetic and dimensional requirements in an attempt to integrate our understanding of the customer's needs into the quote. At Engineering tool-up phase this will be reviewed again to confirm the assumptions or understandings regarding cosmetic/dimensional characteristics that form the basis for our quote. Prior to a full production release the product enters the Pilot Production Phase (PIP) of manufacture. The product cost, criteria, processing and inspection protocol should be approved or modified at this time.

Cost Impact:

Each set of standards has a cost associated with it. The higher the standard, the better the part will appear with an attendant increase in cost. In some instances the cost impact is minor, in others, it can be quite significant. Over specifying adds unnecessary cost to a product. The following are some helpful suggestions to use in the cosmetic decision process:

Our goal is to provide our customers with what they require, at the best possible price.
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Cost Impact continued:

1. A class 1A is considered a "Perfect Part", flawless in every characteristic. This standard should be used for highly visible clear products such as magnification lenses only. The requirements of this standard adversely effects the yield rates adding significant cost to a part.
2. Highlight critical areas with appropriate text. E.g. "sealing surface, piston surface, highly visible to end user, o-ring", etc.
3. Define separate standards for the individual needs of a part. E.g. "3B-contrast fill area, 3D-internal surfaces, 2A-o-ring groove, 2B+ around display recess".
4. If possible, define the operational functions of the part. Polymer Corporation's staff is required to make quality decisions daily regarding this product. This additional information will ensure the most accurate mutually beneficial decision.
5. Color, texture, and finish can affect the choice of a standard. E.g.—A textured surface will not show a flaw as readily as a gloss finish would but it is also not as easily reworked. Pantone colors can have a shade variance due to texture.

Use of the standard:

Viewing angle: Parts shall not be manipulated to reflect a single light source in order to accentuate surface flaws.

Magnification: Magnification shall not be used when inspecting for cosmetic flaws, unless otherwise specified in approved documentation.

Illumination: A uniform, non-directional cool-white fluorescent light source, between 80 and 150 foot candles will be used. The light source should be mounted five to six feet directly over the part/parts being inspected. Note: The average daylight is about 100 foot candles. At greater than 150 foot candles, caution should be used not to over inspect. The acceptable use of this standard is voided when a light source over 150 foot candles is used.

Repetitive Inspection: A flaw that occurs repeatedly at the same location becomes more easily noticed with each inspection. If this flaw was judged acceptable at the first piece inspection of the lot, then it shall be acceptable for the entire lot. Note: This can indicate a tooling or mold flaw that can be easily corrected.

Cosmetic Inspection Criteria continued

Process Control: Manufacturing steps which might affect finished product appearance shall be prepared to ensure compliance with this standard.

Accept/Reject Decision: When flaws are observed within the specified time and distance the accept/reject decision is difficult to make. Refer to table 2 on page 10. Parts are often cosmetically acceptable even though flaws are noticeable.

Use of the standard continued:

Viewing Standard: Prior to using this specification a viewing standard must be set. Viewing standards are labeled 1 through 3. Viewing standard 1 has the closest distance of 10 inches, and the longest viewing time of 10 seconds. Refer to table 1 on page 10 for additional information.

Flaw Standard: Along with the viewing standard mentioned above, a flaw standard must also be set. Flaw standards are labeled A through E. Flaw standard A has no visible flaws (refer to "special note on cost impact of standards [section 6-B-1]"). Standard E would have visible flaws, but they would not impact the function of viewing standard; the flaw standard would provide an objective criteria for acceptance or rejection.

Typical objective criteria are size and quantities of flaws. Refer to table 2 on page 10 for additional information.

Flaw Variance: To avoid making this standard so complex that it may not be used effectively we have limited the flaw standards to five choices (A through E). This may not always provide the customer with the options required to clearly define their cosmetic needs. To further expand the variety of standards we have added a variance option. Should a cosmetic requirement fall between standards or slightly above or below a standard, the variance can be used to indicate this need. Example: 2B/C would translate into a very important surface, but flaws, larger or more numerous than those defined in the "B" column can be allowed (4 voids at .010 instead of 2 per 4"x 4" square). 2B/A reduces the magnitude of flaw size and quantity without entering the next level.

Inspection Protocol: Cosmetic inspection of parts shall use the "time & distance" (TD) inspection procedure and shall rely on the judgment of trained inspectors. In general, a product leaving Polymer Corporation should not contain flaws that would impair functionality or imply inferior workmanship. When difficult decisions arise, the Material Review Board (MRB) will make the final decision. Material that does not meet customer specifications regarding cosmetics will not be shipped without a written waiver from that customer.

Order of Inspection: Inspection of finished parts shall be the last inspection performed by Polymer Corporation and it is expected that it will be the first inspection performed by the customer.

Table 1: Cosmetic Inspection Viewing Time and Distance For Designated Areas

Viewing Standard	1	2	3
Viewing Distance	10 in. (250mm)	18 in. (450 mm)	24 in. (600 mm)
Viewing Time	10 seconds	5 seconds	3 seconds

Table 2: Flaw Standards (1)

	A	B	C	D	E
FLAW TYPE		Max Qty MaxSize	Max Qty MaxSize	Max Qty MaxSize	
Pits & Voids	(2)	.005 6 or .010 2	.015 8 or.030 4	.060 10 or.130 6	(3)
Specks & Protrusions	(2)	.005 6 or.010 2	.015 8 or.030 4	.060 10 or.130 6	(3)
Scratches	(2)	.20x 2.002 or.10x 1.005	.30x 4.005 or.20x 2.01	.60x 6.01 or.30x 3.02	(3)
Sinks	(2)	.005 5% ofdeep surface	.01 10% ofdeep surface	.02 20% ofseep surface	(3)
Parting Line	(2)	.003 above or below the surrounding area	.01 above or below the surrounding area	.02 above or below the surrounding area	(3)
Gate Surface	(2)	.003 above or below the surrounding area	.01 above or below the surrounding area	.02 above or below the surrounding area	(3)
Swirls	(2)	Barely distinguishable	Distinguishable	Distinguishable	(3)
Discoloration Flow Marks & Haze	(2)	Barely distinguishable	Distinguishable	Distinguishable	(3)

Note (1): The allowable quantity of flaws refers to those visible in any 4"x4" square area viewed from a single viewing angle at the specified time and distance.

Note (2): When viewed at the specified time and distance, surfaces indicated as Flaw Standard A shall have no apparent flaws.

Note (3): When viewed at the specified time and distance, surfaces indicated as Flaw Standard E shall be permitted to have flaws in excess of those defined in Flaw Standard D; however, these flaws must not impair functionality or imply workmanship.