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Introduction

Die casting is a very popular manufacturing method. It can create components with the strength required by structural applications and with the surface finish required for aesthetic applications, all at a low price provided you have production volumes high enough to justify the tooling cost. Consequently, it has been chosen as the manufacturing process of choice in thousands of applications.

Die cast tooling must withstand some very demanding environments. It is subjected to very high heat and pressure during the injection of molten aluminum and then it is cooled to a temperature well below the melt temperature of the metal. Over its lifetime, the tool undergoes thousands, if not hundreds of thousands of these thermal cycles. Creating a tool that can survive that kind of operating conditions not only requires special steels, it requires careful heat treatment. Operating conditions are much more severe than for injection mold tooling. It is not surprising that die cast tooling is among the most expensive and has some of the longest lead times of any manufacturing process. In addition, because of the heat treat condition and the hardness of the material used, making changes to the tool are more expensive than for other manufacturing processes.

As a result, the cost of engineering changes to a product after the tooling is built is higher and the time required to make changes is longer than for nearly all other types of tooling. It is important, therefore, to minimize the possibility of design errors before the tooling is built.

Design analysis can go a long way in identifying design weaknesses before the product is available but it requires a good understanding of the loads and operating conditions that the product is likely to see. Often those aren’t well understood. Testing a prototype part, however, will typically expose design weaknesses, even if load conditions aren’t well understood. If those design weaknesses are identified before the tooling is built, the issues can be corrected and tooling changes will be avoided.

The intent of this document is to guide the user through the process of creating prototypes of die cast components.
Why should I prototype?

Designers often question the need for prototyping. After all, it is going to cost money and it may delay getting the product to market (especially if he is behind schedule already). They reason that they can make up a little lost time and reduce their expenses by skipping the prototyping step.

The savings, however, may be a false economy. If, after releasing the product, a design issue is discovered that must be corrected, the cost of correcting the error, and the time lost while correcting it can be many times the cost and time of prototyping. That doesn’t count the lost sales during that period that went to a competitor and you can never get back.

Let’s look at some of the costs of correcting a design error after tooling has been built:

1. **Tooling Modifications** – Even minor changes can be very expensive on a die. Often the tool must be annealed to allow machining, machined, re-heat treated, then machined again (because the tool can move during heat treat). Obviously this can be much more expensive than making modifications on an injection mold. It can take much longer as well.

2. **Lost Sales** – During the time changes are being made, you can’t build product to sell. Customers are unlikely, however, to delay purchases until you are back into production. If possible, they will buy from a competitor. Those are sales lost forever and cannot be regained.

3. **Lost Market Share** – If competitors have a viable product, the sales and reputation they build up during the time you are out of production can build momentum for them that can be very difficult to overcome.

4. **Damaged Brand Reputation** – if the design problem is not identified before the product is released to market, the product problems can have a long lasting effect on customers’ perception of the quality of your brand. This could impact the profitability of all products, not just the one in question.

As you can see, the cost of a design error can be orders of magnitude higher than the cost of prototyping. In prototyping, you are spending a smaller amount now to avoid a much larger loss later. That is why some people refer to prototyping as “product development insurance”.

Done properly, the cost of prototyping die cast components can be quite reasonable and have minimal impact on project schedules. Our intent with this guide is to show you how.
What are the options for Prototyping?

There are a number of ways designers have used to create prototypes of die cast components. They include:

1. **Die Casting** – It is possible to create a prototype die. Typically they are made using a lower strength material and are not heat treated. As a result, they cost is lower and the time required to make the tool is shorter. The tradeoff is that the tool will have a much shorter life than a production tool and may be good only for a few hundred parts. The advantage of this method is that you have true die cast components and they will very accurately mimic the performance of the production parts. The disadvantage is that there is a high upfront cost. If you need a large number of prototypes, however, it can be cost effective.

2. **Machining** – It is relatively straight forward to machine the component from a block of aluminum or zinc. For many designs, it will also be the fastest way to obtain prototypes. There are some things to be aware of, however.
   a. **Geometry differences** – If a prototype is machined, features that are important to a die cast design, such as draft, rounds and some fillets, are likely to be ignored. While the changes are likely very minor, in some cases they could affect the performance of the part.
   b. **Material differences** – The machined part will be in a wrought material, not a casting alloy. As a result, the machined part is likely to be stronger, perhaps significantly stronger, than the die casting. If the prototype survives testing, it doesn’t necessarily mean that the production part will.

3. **Sand Casting** - It is possible to sand cast the design to get an aluminum or zinc part. This can be a very cost effective way to get higher numbers of prototypes but there are some important considerations:
   a. **Geometry differences** – Sand castings require more draft than die castings. In addition, small holes may not be able to be reliably cast. Some changes to the design may be required before prototypes can be made.
   b. **Material differences** – Alloys used for sand casting are different than those used for die casting and will have different material properties. In addition, the die casting process results in a somewhat unique metallurgy. The molten aluminum is quickly solidified against the relatively cold walls of the die and creates a hard, dense “skin” on the component. The interior of the casting cools much more slowly and is softer and less dense. In general, the strength of sand castings will be lower than the strength of the die casting.
   c. **Surface Roughness** – Sand casting cannot provide the surface finish typical on die cast parts. If the surface finish is critical to the performance of the component, sand casting may not be a viable prototyping method.
4. **Investment Casting** – Investment casting is a viable option for prototyping now with direct patterns (investment casting patterns made via a 3D printing process so there is no tooling involved). There are no restrictions on geometry so the die cast geometry can be used for prototyping. As with sand casting, there are differences in both the alloys used to create the casting and in the metallurgy.

5. **Plaster Mold Casting** – Plaster mold casting is similar to sand casting but the mold material is plaster rather than sand. As a result, much smoother surfaces are possible and can be nearly as good as die casting. Plaster mold casting requires less draft than die casting so no modifications need be made to the design, with the exception of closing small holes. As with both sand casting and investment casting, there are differences in both the alloys used and the metallurgy of the casting. Because plaster is a good insulator, solidification is slower than in sand casting or investment casting and as a result, the strength of the casting is lower.

**Which should I choose?**
In general, you should choose the *least expensive method* that will provide prototypes in the *time frame needed* and that will *meet prototyping objectives*. While that statement is simple, there are a number of factors that can influence the best method for your application including your prototyping objective, how quickly prototypes are needed and the number of prototypes required.

**Prototyping Objectives**
There are a number reasons one might want a prototype. They include:

1. **Appearance** – Sometimes the objective is only to get a part that is as close in appearance to the production part as possible. No real testing of the part is required. In this case it is important to use a method that will simulate the appearance and surface finish of a die casting. Plaster mold casting, die casting and investment casting would be good candidates.

2. **Limited Functional Testing** – Most often the prototype is intended to allow testing of the product in normal use, not to failure. Neither appearance nor matching the material properties of the die cast component is critical. In this situation, any of the methods would be acceptable.

3. **Design Load Testing** – Sometimes the objective is to confirm that the component will withstand design loads. Ideally, it would be best to mimic the material properties of the production component so that you can be sure that the production component will survive design loads. If you can’t mimic the material properties, the next best solution is to choose a method that provides a prototype with less strength than the production part. That way if the prototype passes testing, you can be sure that the production part will. It means that the die cast part will
have a factor of safety above design loads. For this objective, any of the methods are acceptable.

4. **Failure testing** – In failure testing, loads are increased until the component fails in order to determine the failure load. Failure testing is not typically required. To obtain accurate results, the material properties and metallurgy of the prototype must closely approximate those of the production part. Typically, this limits prototypes to die castings.

**Lead Time**
The above prototyping methods vary in the amount of time required to create parts. In addition, the complexity of the prototype geometry significantly affects the time required for any method. The table below provides a rough guideline for lead times.

The first column is the time required to create tooling, or in the case of machining, to program toolpaths to machine the geometry and to create fixtures needed. The tooling lead time estimates assume that the project is started immediately and is not delayed by backlog of the vendor.

The second column is a rough estimate of the number of prototypes that can be created in an 8 hour shift once tooling is created. Be aware that the size and complexity of the prototype will affect the estimates shown here.

<table>
<thead>
<tr>
<th>Method</th>
<th>Tooling Lead Time</th>
<th>Prototypes per Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die Casting</td>
<td>1-4 weeks</td>
<td>100</td>
</tr>
<tr>
<td>Machining</td>
<td>1-5 days</td>
<td>1-10</td>
</tr>
<tr>
<td>Sand Casting</td>
<td>2-5 days</td>
<td>10-30</td>
</tr>
<tr>
<td>Investment Casting</td>
<td>3-8 days</td>
<td>1-15</td>
</tr>
<tr>
<td>Plaster Mold Casting</td>
<td>7-10 days</td>
<td>10-50</td>
</tr>
</tbody>
</table>

These are rough guidelines and assume single cavity tools in the case of die casting, sand casting and plaster mold casting. Investment cast prototypes are assumed to be made from direct patterns (made from an additive manufacturing process) and the prototypes per shift is limited by the rate at which direct patterns can be created.

**Prototype Cost**
There are three factors that are the primary determinants of the cost of prototypes; the cost of tooling, the incremental cost of prototypes, and the number of prototypes required.

The cost of tooling is primarily the cost of creating the tool, but may include CAD work if necessary to adjust the CAD model to fit the prototyping process, and may include the cost of a master pattern in the case of plaster mold casting. For machining, it will include the cost of CNC programming and any machining fixtures that may be required.
The incremental prototype cost is the cost of creating one prototype once the tooling has been created. In the case of investment casting, it will include the cost of the direct pattern required to create the part. For any of the methods, the incremental prototype cost may also include secondary machining, heat treat costs, impregnation costs, etc. While the incremental cost may decline slightly with volume, for the range of volumes typically encountered in prototyping, it will be relatively constant.

The total cost of prototyping is then shown in the plot below.

![Total Prototyping Cost vs. Number of Prototypes](image)

The tooling is required before prototypes can be created so the cost line starts at the cost of the tool. The slope of the line is the incremental cost. The cost of each prototyping method can be plotted in this manner, but the tooling cost and incremental cost for each method is different. The table below gives typical relative tooling and incremental costs of each of the methods. For any of the methods, both the tooling cost and incremental cost will vary with the size and complexity of the part.

<table>
<thead>
<tr>
<th>Method</th>
<th>Tooling Cost</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die Cast</td>
<td>High</td>
<td>Very Low</td>
</tr>
<tr>
<td>Machining</td>
<td>Low-Medium</td>
<td>Medium – High</td>
</tr>
<tr>
<td>Sand Casting</td>
<td>Low – Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Investment Casting</td>
<td>None</td>
<td>Medium</td>
</tr>
<tr>
<td>Plaster Mold Casting</td>
<td>Low-Medium</td>
<td>Low-Medium</td>
</tr>
</tbody>
</table>

If we plotted the total prototype cost versus number of prototypes for all of the prototyping methods, it might look something like the plot below. The plots for all methods will vary depending on the size and complexity of the part, but in general, the following plot is representative. To determine the least expensive method, locate the number of prototypes desired on the horizontal axis and then move vertically. The first line encountered will be the least expensive for that number of parts.
One thing is obvious from the plot: the lowest cost method for one number of prototypes may not be the lowest cost method at another number of prototypes. For example, in the example above, investment casting is the lowest cost method at very low volumes, but at medium volumes, it is the highest cost method.

It is not necessary to go to this level of detail to choose the best method. After considering your prototype objective, you most likely will have ruled out one or more prototyping methods. Only in rare circumstances will die casting be the method of choice for prototyping die cast parts. The cost and lead time of tooling can’t be justified. In most cases, the surface roughness, greater draft requirements, and loss of feature resolution of sand casting rule it out as a prototyping method. For parts of medium or higher complexity, the cost of machining rules out machining.

Consequently, in the majority of cases, the decision is between investment casting and plaster mold casting. In general, for very low quantities, perhaps 5 or less, investment casting will be less expensive. For higher quantities, plaster mold casting will be cheaper. Of course the breakeven quantity will vary depending on the size and complexity of the component, but five is certainly in the ball part. It is probably worthwhile to get quotes for both methods to make sure.

Quickparts does not sell investment castings but we can refer you to some quality foundries. Please contact us for information.

Quickparts does provide plaster mold castings and we would be happy to quote your project. Please see the “How to Get a Quote” section later in this guide.
How does the Plaster Mold Process Work?

Plaster mold casting is similar to sand casting except that the mold is made of plaster instead of sand. Like in sand casting, the mold can only be used once and is destroyed in the process of extracting the casting. Consequently, a plaster mold must be created for each casting created.

Like sand casting, a plaster mold has two main components, a cope and a drag, the top and bottom pieces of the mold. Also like sand casting, the mold is made by packing the mold material against a pattern. In plaster mold casting, however, the mold material is plaster rather than sand. Two patterns are required, one for the cope and one for the drag.

Process Overview
To make the cope and drag patterns, we start with a master pattern. The steps in the process are illustrated in the series of diagrams below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppose we want to create an aluminum or zinc part that looks like this. (Forgive the cartoon figure, but it is easy to create).</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td>The first step is to create a CAD model. It must be a 3D model, either a solid model or a completely surfaced model. This is the model to be supplied to the foundry.</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>The next step is the foundry’s responsibility. It is important to scale the model up to compensate for shrinkage of the metal as it solidifies. For aluminum, the model is scaled up approximately by 1%.</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>The scaled model is used to create an SLA master pattern. The SLA pattern will be finished to provide a smooth surface.</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>Description</td>
<td>Diagram</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>The next step is to create the follow board, or often called a parting line block. Its purpose is to define where the mold is going to part. It will cover all of the pattern on one side of the parting line and expose all parts of the pattern on the other side of the parting line.</td>
<td><img src="Follow_Board.png" alt="Follow Board" /></td>
</tr>
<tr>
<td>Now the A side of the negative is poured. A frame is placed around the assembled master pattern/follow board and RTV silicon rubber, here colored light blue, is poured against the pattern on the follow board. The silicon is allowed to harden.</td>
<td><img src="Follow_Board.png" alt="Follow Board" /></td>
</tr>
<tr>
<td>Once the rubber has solidified, the entire block in inverted and the follow board is removed. A frame is placed around the A negative and pattern and a mold release is applied to the top surface.</td>
<td><img src="Follow_Board.png" alt="Follow Board" /></td>
</tr>
<tr>
<td>At this point, additional RTV silicone rubber is poured against the pattern and the A side of the negative. We are creating the B side negative.</td>
<td><img src="Follow_Board.png" alt="Follow Board" /></td>
</tr>
<tr>
<td>Once the B side Negative has solidified, the two negatives can be separated and the master pattern removed. This is the A side negative.</td>
<td><img src="Follow_Board.png" alt="Follow Board" /></td>
</tr>
<tr>
<td>This is the B side negative inverted.</td>
<td><img src="Follow_Board.png" alt="Follow Board" /></td>
</tr>
<tr>
<td>Description</td>
<td>Diagram</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Now it is time to make the positives. A frame is placed around the negative and mold release is applied to the surface. RTV rubber is then poured into the frame to form the positive. Here is the A side positive as poured, shown in green.</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td>This is the B side positive as poured.</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>Once the positives have cured, they can be removed and inverted. The positives are the tooling for the plaster mold casting process. Here is the A side positive.</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>This is the B side positive.</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>At this point we can begin making plaster molds. A frame is placed around the positive, and wet plaster is poured against the positive. Here is plaster (the plaster is actually white but colored pink here for clarity) poured against the A side positive.</td>
<td><img src="image5" alt="Diagram" /></td>
</tr>
<tr>
<td>Here is plaster poured against the B side positive.</td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td>After about 20 minutes, the plaster will be set up enough that it can be removed from the positive. It will then be moved to an oven and baked overnight to evaporate all the remaining moisture from the the mold. Here is the A side plaster.</td>
<td><img src="image7" alt="Diagram" /></td>
</tr>
</tbody>
</table>
Here is the B side plaster. It also will be baked overnight to dry.

Once they are dried, the two side can be assembled to create the plaster mold. Here is the assembled mold.

At this point the mold is ready to be poured. In this simple example we have not shown gates, risers and other features necessary to get the metal into the mold. Once poured, the cavity will be filled with molten metal.

Once the metal has solidified and cooled, the plaster mold is broken apart and the casting extracted. The plaster mold can only be used once. A new mold is created for each casting required.

This is a quick and simplified overview of how the process works.

**Complications**

Some features in the component can complicate the plaster mold casting process and require additional steps. Some common features include:

1. **Undercuts** – Undercuts are features that would prevent the pattern from being removed from the mold. They are the same kinds of features that would prevent a die casting from being ejected from the die. In die casting, these features are formed with a moveable part of the die, often a slide. In plaster mold casting they are formed with a core. The core is a loose plaster piece that is molded separately and is assembled into one side of the mold before the cope and drag are assembled. It is held in place by extensions on the core (called core prints) that fit into pockets in the mold and keep the core from moving when molten metal is poured into the mold.
2. **Small holes** – Small holes are difficult to cast because it would require a thin plaster column to form them. The plaster is likely to break off during pouring and end up somewhere in the casting resulting in scrap. Instead, small holes in the master pattern are usually filled and the holes are drilled out as a secondary operation.

3. **Machined areas** – Machining is often required on prototypes to ensure flat surfaces are truly flat, to ensure that critical areas are within tolerance or to form threads. In such cases, machine stock is typically added to the area to be machined.

All these complications may result in additional charges for the prototypes.
Secondary Operations

Plaster mold castings may require secondary operations to meet the needs of the applications. Common secondary operations include:

1. **Machining** – If there are tight tolerances that can’t be met by the casting process alone, surfaces that must be milled flat, holes to be drilled or tapped of external threads cut, machining will be required. It may be necessary to add machine stock to the master pattern to ensure that there will be adequate material to machine.

2. **Heat Treatment** – Because they cool so slowly, plaster mold castings are relatively soft and have lower strength than die castings. Material properties can be improved through heat treatment. Two heat treatments are typically offered for plaster mold castings
   a. **T5** – The T5 heat treatment artificially ages the casting by holding it at a relatively low temperature (300-400°F) for several hours. The T5 heat treatment stabilizes the casting, provides some improvement in material properties and improves machinability.
   b. **T6** – In the T6 process, the casting is heated to close to the melting point and held for a period of time to allow alloying elements to go into solid solution. The casting is then quenched, typically in water, to freeze the structure. The casting is then artificially aged with a T5 treatment. This heat treatment provides significant improvements in tensile and yield strength while maintaining elongation.

3. **Impregnation** – Plaster mold castings may contain minor amounts of porosity that prevent the castings from being pressure tight. To make them tight, it is possible to impregnate them with a solution that will fill the pores and harden in place. Impregnation is recommended for any components expected to hold pressure or that serve as a fluid container.

4. **Pressure Testing** – If the casting needs to hold pressure, it may be important to check to make sure that the casting is pressure tight. Checking pressure may require a special fixture to allow the part to be pressurized.

5. **Finishing** – The casting can be finished as necessary to achieve the desired appearance. Castings can be painted, plated or anodized.

6. **Inspection** – The castings can be inspected to ensure that they are within design tolerances.
Are There Differences Between the Plaster Mold Casting and the Die Casting?

Yes, there are differences and it is important to understand them if accurate conclusions about the production parts are to be drawn from testing prototype parts.

Material differences
For aluminum castings, the alloys used for die casting are different than the ones used for gravity casting applications like sand casting, investment casting or plaster mold casting. While the material properties are similar, there are some significant differences.

Most die casting is done with the 380 series of aluminum alloys, particularly 380 and 384. Die casting alloys tend to have more impurities such as iron which aid in the die casting process by reducing the tendency of the alloys to “solder” or stick to the walls of the die during solidification. Die casting alloys are very difficult to pour in gravity casting processes and tend to yield unacceptable castings.

Most gravity casting is done with 350 series alloys, particularly A356

Metallurgy Differences
In the die casting process, molten metal is injected under pressure into a relatively cold steel mold. The molten metal solidifies quickly against the cold surface and creates a “skin” of dense aluminum with a fine grain structure that gives it high strength and hardness. The interior of the casting, however, solidifies more slowly and consequently has a larger grain structure and lower strength. In addition, since the metal shrinks as it solidifies, microscopic voids are created in the interior of the casting making it somewhat porous.

Because the plaster insulates the casting, a plaster mold casting solidifies much more slowly resulting in larger grain structure and the casting does not have the strength or hardness of the die casting. In addition, material properties do not vary across the cross section nearly to the extent that die castings do.

Material Property Differences
It is important to recognize that the material properties in a die casting will vary across the cross section. The highest strength and density are found in the “skin” of the die casting with lower values found in the interior porous regions. It is the material properties in the skin that control the performance of the part and will be the properties we will use for comparison. Some of the major differences in material properties include:

1. **Yield Strength** – Die castings will have a higher yield strength both because of the higher strength of the 380 series of alloys compared to the 350 series. In addition, because of the manufacturing process, grain size in the die casting will be smaller than for the plaster mold
castings. As a result, the plaster mold castings will have a yield strength approximately 20% lower than that for a die casting.

2. **Ultimate strength** – For the same reasons, the ultimate strength of plaster mold castings is about 20% lower than for die castings. This is critical only if testing to failure which is not recommended for plaster mold castings.

3. **Coefficient of heat transfer** – Plaster mold castings tend to conduct heat much better than die castings. Several years ago a small engine manufacturer developed an engine using plaster mold castings. When they went to production, however, engines were overheating and seizing. The difference in conductive heat transfer was the cause. If you are designing a component intended to transfer heat, you want to keep these differences in mind.

It is important to keep these differences in mind when interpreting the results of testing plaster mold cast prototypes. The lower strength is typically not a serious issue. If the prototype does not fail during testing, it is fairly certain that the production die casting will not fail. The lower values provide a factor of safety in the design.

Unfortunately, components whose function is dependent on heat transfer have the opposite problem. If prototypes function acceptably in testing, it does not necessarily mean that the production part will.

The following table lists typical material properties for A356, the most common plaster mold casting alloy and the most common die casting alloys.

<table>
<thead>
<tr>
<th>Property</th>
<th>A356 T5</th>
<th>A356 T6</th>
<th>380</th>
<th>384</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, psi</td>
<td>25,000</td>
<td>30,000</td>
<td>46,000</td>
<td>48,000</td>
</tr>
<tr>
<td>Yield Strength, psi</td>
<td>20,000</td>
<td>20,000</td>
<td>23,000</td>
<td>24,000</td>
</tr>
<tr>
<td>Elongation, %</td>
<td>1.5</td>
<td>2.0</td>
<td>3.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
How are the castings priced?
When you get a quote for plaster mold castings, you will likely see several charges listed on the quote including:

1. Tooling – The tooling charge will include the cost of several steps involved in creating the final patterns.
   a. the cost of making the master pattern including finishing
   b. the cost of creating the parting line block
   c. the cost of making the negatives
   d. the cost of creating the positives or patterns
   e. the cost of making core tooling if cores are necessary

2. Castings – the casting price includes the cost of several steps involved in creating each casting.
   a. The cost of making the plaster mold
   b. The cost of pouring the casting
   c. The cost of the metal
   d. The cost of extracting the casting
   e. The cost of trimming gates
   f. The cost of straightening the casting

3. Machining – if finish machining is required, there will be a machining charge for each casting. Specific machining operations will be detailed on the quote.

4. Machining fixture – if machining requires a fixture, there will be a charge for the fixture. This will be a onetime charge, not a per-casting charge.

5. Heat Treatment – if heat treatment is requested, there will be a charge for heat treatment. It typically is a lot charge rather than a per-casting charge.

6. Impregnation - If the casting is to be impregnated, the charge will be called out separately. It will be a per casting charge

7. Pressure Testing - If pressure testing is required, the charge will be called out separately.

8. Inspection - If inspection of the parts is required, whether it be a quick check of critical dimensions on first article, a full layout of a sample of castings or 100% inspection of a critical dimension, the charge will be listed along with a description of the inspection to be done. The type of inspection will determine whether it is a lot charge or a per casting charge.

9. Engineering Charges - If design work is required, such as to add draft to a design, or to make customer specified modifications to a design, a onetime charge may be added.
10. **Finishing Charges** – If painting, plating or anodizing is required, the associated charges will be listed separately.
Frequently asked Questions

**How many castings can be made per day?**
The limit on the number of castings is how many molds can be made. It takes about 15-20 minutes for the plaster to set up before the mold can be lifted off the pattern. As a result it limits the number of molds per shift to about 10-15, depending on size, whether there are cores involved, and workload in the foundry. Since a mold is required for each casting, castings are limited to 10-15 per day as well. Molds with cores require more time for molding cores and for assembly and as a result, production rates will be lower.

**Are higher production rates possible?**
If a higher production rate is required, it can be accomplished in one of two ways. First, multiple cavity tools can be made. If the castings are not too large, it is possible to make a two or three cavity tool. Even though we are still limited to about 20 molds per day, a two cavity two will yield 40 castings. With a two cavity tool, the tooling cost increases, but the casting cost will actually be lower.

The second method is to make two patterns. That way, two molds at a time can be created and casting production can be increased to 40 per day. Since making a second pattern involves only repeating the last step of the tooling creation process, the increase in tooling cost will only be in the range of 20%. Casting prices will remain the same.

**What CAD formats can you work with?**
We can work with most native CAD formats and all neutral formats such as IGES. For a specific list, check our website or call.

**Can the castings be finished?**
Yes, we have in house painting capability and can provide a high quality painted finish on the parts. We can also have the castings plated, anodized, or powder coated to your specifications. Contact us for further information.

**What heat treatments can you provide?**
We offer two heat treatments; T5 and T6. They are described in more detail in the Secondary Operations section. We have in-house heat treating capability so the time required for heat treatment is minimized.
How Can I Get a Quote?

There are several pieces of information needed to provide a complete quote. They include:

- **CAD Model** – We can work from most native CAD formats and all neutral formats such as IGES,
- **Material Desired** – The materials we offer include A356 aluminum and Zamac 3.
- **Quantity Desired** – We can quote multiple quantities if you aren’t sure exactly how many casting you need.
- **Machining Requirements** – if there are areas to be machined, please note them so we can accurately quote the project.
- **Heat Treat Requirements** – If you would like the castings heat treated, indicate which you would prefer. We offer T5 and T6.
- **Impregnation Requirements** – If the casting is expected to be pressure tight or will act as a vessel to hold fluid, it is advisable to have the casting impregnated to ensure that it is fully sealed.
- **Pressure Testing Requirements** – If the casting is expected to hold pressure, it may be worthwhile to have the casting pressure tested to make sure there will be no leaks.
- **Finishing Requirements** – If you would like the castings to be painted, anodized, or plated, please indicate that.
- **Inspection Requirements** – If there are specific inspection requirements, please indicate the dimensions and sampling requirements.

If you like, you can use the Quote Request Form on the following page to document your requirements.

To get a quote, send the completed form along with the CAD model to:

Randy Spears  
3D Systems  
Randy.Spears@3dsystems.com  
(931) 766=7247
### Request for Quote Form

**Request for Plaster Mold Casting Quote**

<table>
<thead>
<tr>
<th>Company:</th>
<th>Address</th>
<th>Address</th>
<th>City, State, Zip</th>
<th>Contact:</th>
<th>Phone:</th>
<th>E-mail:</th>
</tr>
</thead>
</table>

**Part Name**

**CAD File Name**

**Quantities to Quote**

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<tr>
<th>Material</th>
<th>Heat Treat</th>
<th>Impregnate</th>
<th>Pressure Test</th>
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</thead>
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</tr>
<tr>
<td></td>
<td>Zamac 3</td>
<td>T5</td>
<td>Yes</td>
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<tr>
<td></td>
<td></td>
<td>T6</td>
<td>No or Yes</td>
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<td>To _____ psi</td>
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</tbody>
</table>

**Machining Requirements**

**Inspection Requirements**

**Finish Requirements**

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Email to Randy Spears at Randy.Spears@3Dsystems.com or fax to (931) 762-2426
Examples of Plaster Mold Castings