Richard Austin (1936-1990) was a metalsmith and author, with several hundred articles to his credit.

After his death I was given custody of an extensive collection of manuscript material-mostly on the technical issues of metalworking.

This text represents the first effort to organize the material—an attempt merely to group the files by topic. None of this is finished, and the text makes reference to illustrations that were never done—illustrations which were stored separately in any case, making it extremely difficult to bring the parts together.

It is unlikely that I will ever be able to spend the time to sort this all out. But it seemed a shame to let these articles languish unread by those who might benefit from them in some small way. So I have decided to release them in their roughly sorted form in the hopes that someone may find them useful.

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The vacuum casting process can take one of two basic variations depending on whether the metal is *melted* in the sprue area of the mold or in a separate crucible. If the metal is to be *melted* in the mold the procedure is very similar to the *steam casting* process.
SHRINKAGE

Tests previously made at the Bureau of Standards on gold rods 0.12" in diameter and 3 1/4" long cast under dental laboratory conditions showed a net linear shrinkage of 1.25 per cent, while more recent tests made on much shorter and bulkier rods cast abnormally weakened vessel molds showed shrinkages ranging up to about 1.6%. Compensation can be made by preparing the wax model at room temperature and investing it at an elevated temperature since the waxes have a high rate of thermal expansion. Generally, the investment expands during the investing process and it may range as high as 0.5%.
CASTING VENTS

The question as to whether or not surface vents are required in the casting process is an area of considerable confusion in the literature. Before adding to that confusion it might be wise to consider the nature of the problem. There are at least three potential sources of gas in the mold cavity:

1) The air which is present in the mold cavity must be displaced. In essence the molten metal must push the air somewhere.

2) Gases may in some cases be generated by the contact of the molten metal with the mold material. This would tend to be a far greater problem in sand casting (where organic binders are present) than in investment casting.

3) Dissolved gasses are also released from the molten metal mass during the cooling process preceding solidification of the metal.

The degree of difficulty associated with gas removal is largely a function of the porosity of the mold material. Both casting sand and commercial casting investments have a significant degree of porosity. In most cases a properly sprued and invested jewelry model which is to be centrifugally cast does not require surface venting. The authors have cast literally thousands of items without such venting. Although venting does no harm it leaves another area on the casting which requires clean up during the finishing process. It should be noted that improper burn-out will deposit carbon in the pores of the casting investment which will materially decrease or restrict air flow.
PEWTER INVESTMENT CASTING

Because of it's relatively low cost and excellent working properties, pewter has been a popular material in the arts and crafts for hundreds of years. With the recent introduction of the high tin low lead materials, pewter tends to retain a brighter finish. With it's excellent foregoing characteristics, pewter has been widely used in raising. However, in the arts and crafts field, pewter casting is not widely used. In commercial practice many small pewter objects are centrifugally cast in rubber molds and excellent directions are available for this technique. Investment casting of pewter is much less well known.

The principle reason seems to be that modern jewelry investments are not well suited to use with pewter. The problem relates to the pewter casting temperature and the thermal expansion properties of the investment.

Most contemporary investments contain varying amounts of cristobolite. This is added to adjust the thermal expansion properties of the investment. Figure 1 shows typical thermal expansion for investments with and without cristobolite. Note the large expansion which occurs at about 400° F. This expansion is built into the investment to compensate for the contraction which occurs in the casting as it cools from the solidification temperature to room temperature. Note that this large dimensional change occurs at a temperature well below the solidification point of most precious metals which
are typically cast at mold temperatures in the range of 600° to 900° F.

Since most modern pewter melts at about 400° F. appreciably lower mold temperatures are required for casting. For most purposes a room temperature mold works well. If a cristobolite based mold is cooled to room temperature it almost invariably cracks. The cracking can range from moderate to severe although blowout seldom occurs. The typical result is a fin or web type casting defect. The obvious answer is to use a material without cristobolite. There at least four options:

. Plaster of Paris
. Plaster plus Silica(home blended)
. Non-Cristobolite Commercial Investments
  - Calcium Sulphate Based
  - Phosphate Based

I must admit that I approached this project with a certain bias. It is certainly worth a warning note. If you contaminate your calcium sulphate based investment with traces of phosphate investment it will dramatically extend the working time. If you are going to use both materials in your shop, excellent housekeeping is required. For this reason I would vastly prefer to find a calcium sulphate based system which would work.

A number of specific investments were tested. Each was used in at least three castings. To keep things uniform I cast a large cross with waxes from a mold. This would be a typically large piece and it's shape would encourage webbing. All materials used the same burnout cycle. At the end of the
burnout the flask was removed from the oven and placed, sprue opening down on a fire brick at room temperature. This resulted in a relatively fast rate of cooling. This should represent the most stressful situation.

Pre-Vest 334 - The manufacturer advertises this material as suitable for room temperature investment casting. The investment powder contained coarse filler which was quite large in particle size. The material had a gloss off time of 10.5 minutes. Recommended water content was 35 parts by weight to 100 parts investment. The material was mixed for three minutes and vacuumed. The investment was allowed to stand for three minutes, poured and re-vacuumed. Furing the initial vacuuming the material exhibited a very large rise or expansion of about 400%. Be sure to mix in a large bowl.

The actual casting was satisfactory but the surface quality was not quite as good as some of the other materials tested. The mold exhibited low structural strength but since blow-out didn't occur I must assume that the structural strength was adequate.

Thermovest - All of the phosphate based investments that I've used have relatively short cycle times. Thermovest was no exception with a gloss off time of 4.5 to 5 minutes. Thermovest has a liquid solution which is added to the water. For this test I used equal parts of solution and water.
CENTRIFUGAL FORCE 992

The force on a particle, compelled to move in a circular path, is determined by the "acceleration" toward the center, or rate of change of velocity direction away from the linear path any rotating particle tends to follow. The centrifugal force may be expressed as:

\[ F = \frac{W}{g} rw^2 \]

Where \( F \) is centrifugal force, \( g \); \( W \) is weight of particle, \( g \); \( r \) is radius of curvature of path, cm.; \( w \) is angular velocity, rad./sec.; \( g \) is acceleration of gravity, usually taken as 981 cm./sec. \(^2\)

Also \( F = \frac{Wv^2}{gr} \)

where \( V \) is peripheral velocity, cm/sec., or

\[ F = \frac{TT^2W r \ (r.p.m.)^2}{900 g} \]

\[ F = 1.118 Wr \ (R.P.M.) 10^{-5} \]

Where the angular velocity is expressed in revolutions per minute.

INVESTMENT

Salt shortens the time for plaster of Paris to set while glue tends to slow the reaction. Lost wax is also called "cire perdue"
Hi,

I guess it has been a long time since I visited Newton's laws. Even the centrifugal force equations don't seem trivial now. I'm not sure how much explanation you are looking for, but this will probably be more than you want even without the rigorous derivations of the equations.

The fundamental concept involved in this problem is Newton's second law of motion which states that the force transmitted to the skull by a falling apple will equal the mass of the apple times its acceleration. In equation form;

\[ F = ma \]

Acceleration is defined as the change in velocity in a given period of time. The key thing to recognize here is that the change in velocity may be in direction only and it is still acceleration.

Now if we look at the specific application of casting we see that the mass in question is that of the molten solder. The force is that which is "driving" the molten metal into the mold. All that is left is to calculate the acceleration. Since the mold is on the end of an arm moving in a circle then the acceleration is a function of a velocity directional change that results in steady circular movement.

A few more equations to be accepted on faith;

\[ v = \left( \frac{2 \pi R}{T} \right) \]

Where \( R \) is the radius and \( T \) is the time of one revolution.

\[ a = \frac{v^2}{R} \]

\[ T = \frac{1}{\text{rpm}} \]

where rpm is the revolutions per min of the casting machine.
Using the above equations in Newton's Second law equation $F=ma$ and simplifying we find;

$F=m(39.6R)((rpm)(rpm))$

The net is if you want to increase the force "driving" the metal into the mold you can increase the length of radius arm or increase the rpms. Increasing the radius increases the force in direct proportion. Increasing the rpm's by the square of the change.

Good luck, the spring equation will follow.
CRUCIBLE CARE

There are two distinct approaches to the care of crucibles with regard to lining and metal contamination. The first school of thought holds that the proper way is to align the crucible with moist asbestos paper before each melt. For a number of years I followed this practice. As a matter of fact, both the bottom of the crucible and the top of the centrifugal spout opening were lined with paper. The attached sketch indicates how this was accomplished. As long as this paper was changed with every casting there was little tendency for the flux to burn through and fuse the whole thing together. However, if two or more castings were made without changing the liner, generally the flux tended to absorb through and stick to the crucible creating a pretty bad mess. As long as the crucible liner is changed religiously, there is no problem of cross contamination between the various kinds of metal. However, because of the very serious deterioration which led causes in most precious metal within with a crucible liner any lead alloys were always cast in a separate crucible. The second school of thought holds that liners are unnecessary. Beginning with a new crucible, it is treated heavily with a solution of borax and water. When this dries on it can be flamed into place to glaze the crucible. The problem in this case being that the excessive use of flux tends to build up a very thick coating in the crucible. In my experience this coating tends to trap small particles of metal. For this reason, a separate crucible should probably be reserved for each metal type when this method is employed. If you use the second method, eventually your crucibles will become very crusty and build up with layers of flux. At this point, an extended boiling will bring them at least part way back to their original condition.
I have used both methods in my shop and achieved very satisfactory results.

With the current health problems which are becoming to be recognized with asbestos, my present inclination is to move more and more in the direction of not using crucible liners unless they are dictated by very particular circumstances.
FLUXING

As you heat a mass of metal the various constituents of the alloy will react with the oxygen in the air. Pure gold and silver oxidize very slowly but the copper in the karat golds and sterling oxidizes rather quickly. The oxides formed are impurities which affect the quality of the metal in various ways. Other impurities also tend to find their way into the system. These would include traces of investment (from sprue buttons) or bits of the crucible itself. The purpose of flux is really threefold. First, it forms a protective film on the metal that slows down the oxidation process. Second, it serves to dissolve or entrap the various impurities present. Finally, it may act as a reducing agent. Reducing agents reverse the process of oxidation and return the metal to its elemental form. The pure metal can redissolve into the melt and maintain the composition of the alloy.

Traditionally, Borax has been the recommended flux for jewelry casting. I have personally made several thousand successful castings with Borax or Borax combined with boric acid as the flux. However, Borax only serves two of the required functions. It forms a film to inhibit oxidation and it dissolves various impurities. It is not a reducing agent. The result is that the alloy content of your casting is slightly lowered. Copper is oxidized and then the oxides
are dissolved into the flux leaving less copper in the melt. Although this is not a serious problem, I would recommend that you use a commercial reducing type casting flux. They may also contain other compounds which help form a smooth, continuous film of the flux.

When you apply the flux don't fall into the trap of believing that if a little is good a lot is better. Too much flux can make a mess out of your crucibles and if it gets into the mold cavity it will produce very bad surface texture problems. This possibility will also be treated in the chapter on spruing.
FLUX CONTAMINATION

For many years, traditional practice in small scale investment casting employed an asbestos liner in the crucible. However, identification of the health hazards of asbestos have led to the removal of this material from most shop environments. This change has created some defects which were seldom observed with asbestos-lined crucibles. The most common of these defects are caused by flux contamination. When you use a crucible liner, much of the excess flux is absorbed into the liner and discarded after each casting. Without a liner, flux continues to build up in the crucible until it comes to kind of a physical equilibrium and the excess begins to flow out with the metal charge. Under certain circumstances, this flux may be carried into the mold cavity. This manifests itself in a particular kind of pitting and/or porosity. These will be observed as small, bright depressions. If you examine them carefully, they are lined with metal dendrites. This is caused by the crystallization of the metal into the mass of flux. Most often, these defects are observed in the area of the mold toward the center. The flux is lighter than the metal and under the artificial gravity of the centrifuge, it ends up on the top or toward the center of the centrifuge. Most commonly, the flux contamination will be observed close
to the connection between the sprue and the main mold cavity. Several things can be done to minimize this problem. First, you should use the minimum amount of flux necessary to make your castings. Excess flux build-up in the crucible should be minimized.

A relatively small opening in the crucible will tend to create a bottom pour situation. Basically, that means that the metal is forced up into the cup at the end of the crucible and pours out through the bottom of the pool rather than the top where the flux layer is present. This same kind of effect is even more important in the sprue opening. If the sprues are small enough to force the sprue opening to fill, the metal will pour off the bottom of the pool and into the mold cavity. The flux will end up on the flat face of the sprue button.

This defect is most often observed in thick or massive castings with a correspondingly heavy sprue system. It can be minimized by the use of the smallest practical diameter in the sprue wires leading to the model. Also, an elongated sprue system such as that indicated in Figure 70 will provide more time for segregation between the metal and the flux. Note that this elongated sprue system will also provide more hydrostatic pressure and may be beneficial in extremely fine or detailed castings.
**Gross Defects** - There is another type of gross defect which may develop. If the vacuuming process is continued until the investment begins to set, an extensive pattern of large, spherical bubbles will begin to develop. These do not collapse since the investment can no longer flow. The result of this particular defect is illustrated in Figure 9.
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CASTING DYNAMICS

In recent years, a more scientific study of the dynamics of investment casting have been undertaken by a number of people. Although the results reported vary somewhat, certain generalizations can be made. First of all, the cavity fill takes place much more rapidly in centrifugal casting than it does in vacuum casting. However, the differences between these two are not as great as the differences between the investment casting (with some form of pressure) and conventional poured casting.

Generally speaking, you can assume that the investment cavity in a centrifugally poured casting will fill in something in the order of 1/10th of a second. Given that 400 rpm is a typical centrifuge speed, this would indicate that the cavity is full within about one rotation of the casting machine. Obviously, this time will vary depending on the centrifugal force applied, the size and complexity of the cavity and the characteristics of the molten metal, the main point being that this occurs very rapidly. The second principal difference between investment casting and more conventional casting is the rate of chill. Most centrifugal castings in the jewelry trade probably begin to solidify in about one second, and the metal mass has dropped below the solidus about five to fifteen
seconds after the metal is poured. Note that in the case of large poured castings in room temperature molds, the solidification time would normally be measured in minutes and not seconds.
CASTING METHODS

Historically, there have been a wide range of devices used to provide the pressure needed to introduce the molten metal into the cavity. At the present time, there are fundamentally two different methods used. One is centrifugal casting and the second is vacuum-assist/chamber casting. Although both methods can be used to cast almost any type of part, the systems each have inherent advantages and disadvantages.

Vacuum-Chamber/Assist Casting - The principle disadvantage to the vacuum-chamber casting method is the fact that it is somewhat less flexible. Basically, only one degree of pressure can be applied to the metal; that is, one atmosphere or about 14.7 pounds per square inch. This suggests that the vacuum method is somewhat more appropriate for slightly larger parts with thicker sections. Since there are no moving parts, this method is generally considered to be somewhat safer. It is much less likely that molten metal will spill and certainly when it does, it doesn't fly out of the machine. There is no doubt that the vacuum method is very satisfactory for a wide range of investment casting applications.

Centrifugal Casting - Although it has its own inherent disadvantages, centrifugal casting could be characterized as
being more versatile or flexible. Since the speed of the arm can be adjusted by the amount that is wound, it's possible to apply varying degrees of pressure to the metal. Generally speaking, it's possible to apply much higher pressures than those available through vacuum casting. This means that the method is very suitable for small fine parts.

Although centrifugal casting is perfectly safe when conducted properly, it is inherently somewhat more dangerous than vacuum casting. There is the possibility that a certain amount of molten metal will be thrown from the crucible and in extreme cases (when improperly used), the flask or crucible may fly out of the casting arm.
CASTING

CASTING IN PLACE

Sooner or later, almost everyone who owns a casting machine will become interested in the possibility of casting gemstones in place. There seem to be two reasons for this interest. Beginning goldsmiths who have difficulty preparing a well-fitting model or casting sound prongs may view this as an easy way out of technical problems which have other solutions. This is a very poor reason to consider casting in place. However, more experienced casters tend to view this technique as a way to construct jewelry which would be difficult or perhaps impossible to fabricate by any other technique. This second motive is a satisfactory one, and excellent results have been achieved. However, the process is somewhat uncertain and demands an extra degree of care.

If you use this process, you need to understand that the probability of failure and/or damage to the stone is not insignificant. In commercial applications, failure may consistently run as high as ten percent, and in one-of-a-kind pieces, the failure rate will probably approach twenty percent. I would never use this process on someone else's stone or an item with any sentimental value or uniqueness. Since this is a gamble, you should never bet more than you can
afford to risk. Your chances of success are dependent on a number of factors. The specific type of stone used, the stone's history of treatment, the casting cycle and the finishing technique may all be important.

Let's begin by considering the stones which you can use. We can begin by rejecting whole classes of heat-sensitive material such as turquoise, opal, pearls and jade. At the other extreme, many types of natural quartz, spinel, corundum and diamond will survive the process. The synthetic corundums and spinels are also satisfactory in most cases. However, it is important to understand that the history of the specific stone may also influence your success rate. If stones have been improperly treated, they may be subject to serious internal strains. This may occur during the heat treatment of natural stones or the cooling and stress relieving of synthetics. Because it's impossible to determine the precise history of stones available in the trade, this problem of prior treatment is probably one of the key elements relating to failure. It should also be noted that certain kinds of heat or radiation treatments are reversible, and color changes may occur during the process. Conversely, stones which have not been previously treated may also change color just as they would in any commercial heat treating.
Before you design a piece, it's important to remember certain basic facts. First of all, when the wax is burned out, the stone must remain locked securely in the investment. For example, a conventional tiffany-type mounting would leave the stone in contact with the investment at a number of points. In this case, the stone would be well locked in place.

However, if you prepared a solid-backed cabochon mounting as indicated in Figure 96, the stone would be very likely to fall loose in the cavity after burnout. In designing your piece, remember that you will still be faced with the problem of polishing the work after it's cast. It's very easy to prepare a wax model that is difficult or impossible to deal with in a finished work. This is particularly important since the polishing process also presents the hazard of damaging the stone. You should polish the wax and prepare the model as carefully as possible. The better the casting, the easier the final finishing process. With these cautions, you can construct almost any kind of model you wish. All of the conventional model-making materials are satisfactory for this application.

After the model is prepared, it is sprued and invested in the conventional way.

The key to success in this process is to minimize the thermal
shock received by the stone. Many stones are resistant to relatively high sustained temperatures, but rapid heating or cooling can damage them. It seems unlikely that the slow temperature rise during burnout presents much threat. Most of the thermal shock will occur during the casting and cooling process. After burnout and casting, the treatment should be somewhat different than a conventional casting. First, it's vital not to quench the work. The best procedure seems to be to return the flask to the furnace (the sprue down to slow cooling) and bring it to room temperature over a period of time. There are a number of viewpoints about how long this should take. However, a long, slow cooling of eight to twenty-four hours is probably your best bet. If you have a large, massive furnace (with a brick lining), you can simply replace the flask and just turn it off. I often cast during the early afternoon, bring the furnace down slowly until quitting time, and then simply turn it off and let it cool overnight. If you use a fiber-lined furnace which tends to cool more rapidly, you will have to bring the temperature down slowly using the controls.

After the model is cooled to room temperature, it is removed from the investment. There are several schools of thought about how this can be accomplished. Generally speaking, a few sharp raps to the outside of the flask will begin to crack the
material. If you soak it in water for a few minutes, it should be relatively easy to remove. Obviously, this is never quite as simple as the quenching operation would be.

Finishing should proceed carefully. Many of the abrasive bonded rubber wheels use grit which is harder than most stones. This means that a slip of the wheel will damage the surface. Obviously, in the case of diamonds this is much less of a problem. In any event, polishing should proceed with considerable care. In my experience, I've found that a crocus compound such as ZAM can be used for the final polish. If used only briefly, it seldom does any noticeable damage to the stones.
CASTING

FOUNDRY PRACTICE

A good way to understand the investment casting process is to begin by examining sand-casting which is one of the simpler forms of metal casting. It is used in industry to produce a wide range of parts from a few ounces, to tens of tons. However, some general comments about the techniques used will give you some insights which may be useful in setting up your investment casting.

A key difference between sand casting and investment casting is the fact that the sand mold is massive, and sufficiently impervious, to prevent air in the mold cavity from being forced through the mold material. Most sand-castings have one or more openings from the cavity back to surface of the mold, which allow the air to escape. A quick review of the layout and nomenclature of a sand-casting will illustrate how this is accomplished.

The sand casting is constructed in a framework of metal or wood. This is called a flask which is also the nomenclature used in investment casting. The flask serves the same basic purpose. It reinforces and contains the mold making material. The surface of the mold has a funnel shaped opening, which leads to a sprue, which connects to the mold cavity. In essence, the spure performs exactly the same function which
it does in investment casting. The real difference is that most sand-castings also have what's known as a riser. This is a major opening, which leads back to the surface of the mold. When molten metal is introduced into the funnel, it flows through the sprue system, and into the mold cavity. When the mold cavity is filled, it fills the riser until it seeks a level the same height of the metal in the funnel and sprue system. During actual molding, this provides a visual way to tell when the mold is full.

You will note from the drawing, that the riser connects from one of the high points of the mold cavity (where air would be trapped) to the surface of the mold. If there is more than one such point, a number of risers may be provided for. In addition, a series of vents may be placed through the mold. These are simply small openings which project close to, but not into the mold cavity. These allow the air to diffuse through the sand and find its way out through the vent holes ahead of the metal.

To round out your understanding of the sand-casting process, the final nomenclature will be useful. The connection between the bottom of the sprue and the mold cavity is known as a runner. This is basically a horizontal channel through the mold. Since the mold for sand-casting is prepared in two parts, they also have a name. The bottom half of the mold
is known as the drag, and the top half of the mold is known as the cope. The locating pins which align the top and bottom halves of the flask are known as dowels. The basic board used to build up the mold is called a mold board. The nomenclature is indicated in Figure 6.
MODERN INVESTMENT CASTING

Although, the technique of lost wax casting has very ancient origins there have been tremendous strides in quality and productivity. These relate to two primary factors. The introduction of some form of pressure to fill the mold cavity and the modern investments with their gas permability.
CASTING

PROBLEM DEFINITION

Before delving into the project it would be worthwhile to consider the overall nature of the casting problem. Reduced to its simplest extreme, casting is a matter of pouring molten metal into a cavity in some heat resistant material. In actual practice the problem turns out to be somewhat more complicated. If there is a single opening leading to the cavity it may be blocked by the metal during pouring. Thus the first problem: where does the air in the mold cavity go? In some sand castings and in conventional investment casting, the air escapes directly through the pores in the mold material. If the mold material is not sufficiently porous, then vents must be provided for the air to escape. Conventional foundry practice makes extensive use of Venting system.

A second problem is caused by the cooling of the molten metal. If the metal cools to its "freezing" point before the mold is filled, the work will fail. Thus, there is the need to completely fill the mold as quickly as possible. Most forms of investment casting solve these problems by applying some kind of force to the metal. This force can come from air pressure, steam pressure, centrifugal force, or atmospheric pressure (in the case of vacuum casting). The force insures rapid filling of the mold and drives the air out through the pores in the investment. The application
of some extra force also drives the metal into very fine details of the mold which would normally not be filled due to the surface tension of the molten metal.
CASTING

CENTRIFUGAL

Spring loaded centrifugal casters have proved extremely effective. This effectiveness is inherent in the characteristics of spring loaded systems. As a spring is bent or wound more and more, it requires a constantly increasing force to deflect the spring further. If you don't believe this, wind your centrifugal caster one turn. Observe carefully how much energy or pressure it takes toward the end of that turn. Go another turn and compare that to how much force you have to apply at the end of the second turn. The energy is delivered from the spring in exactly the same way. The highest force is delivered first. This is particularly desirable in the case of centrifugal casting where the unit is released from a stationary position.

What is required is a high rate of acceleration. The machine should come to speed as quickly as possible. This is necessary since the metal will begin to cool and solidify the moment the heat is removed. Put simply, the more spring force that is applied to the arm, the faster it will accelerate. The faster it accelerates, the more quickly the metal flows into the cavity. This gives it the optimum chance to fill all the detail before solidification begins.
CASTING

FLOWBACK

There is a good deal of discussion and controversy over whether or not the molten metal can be expected to flow out into the mold, and then flow back toward the sprue opening as the mold fills. The answer is actually straightforward. As long as all portions of the cavity remain below the fill level of the sprue button, there is no reason the metal will not flow backward into the mold. If the trapped air can diffuse out quickly enough (a function of distance, porosity, and pressure), then the part will fill satisfactorily. The more pressure applied to the system the greater the degree of flowback you can reasonably expect. This means that pieces of part at the far end of the model system should flow back more readily than those nearer the level of the sprue button.

In order to test this hypothesis, a special experiment was conducted. A heavy central sprue was set up. Attached to this sprue were small wax wires, which pointed back toward the sprue button. Three rows were placed on each of four sides of the central sprue. One row was ten gauge, one row 12 gauge, one row 14 gauge, and one of 16 gauge. This part was cast. The photograph in Figure 15 illustrates the result. At the larger diameters, all of the return wires
fully filled at any distance from the sprue button. However, in the smallest size wires, only those return sections farthest from the sprue button (under the most hydrostatic pressure) filled completely.

Obviously, the degree of flowback is influenced by all the parameters, which affect the casting process. That is, the speed (amount of centrifugal force), depth, metal temperature, cross section and so on. However, to the extent that the process can be standardized this performance can be predicted based on this kind of empirical test.
CASTING

METAL PRESSURE

The pressure exerted on the molten metal during the mold filling process is a major factor in casting success. It is no surprise that a good deal of equipment development has been focused on techniques to add pressure to the metal during casting.

During the poured casting process the pressure on the metal is simply the hydraulic pressure created by the weight of the molten metal. If the casting were poured in the configuration shown in Figure 16 the pressures on the metal would range (for sterling) from 0 psi at A to 0.361 psi at B and 0.722 psi at C.

At sea level the atmospheric pressure is approximately 14.7 psi. If this could be added to the hydraulic pressure the total pressure on the metal at point C could be increased by over 20 times. In essence this is accomplished by vacuum casting. If the pressure is removed from the back of the flask (reduced to 0) then the atmospheric pressure is added directly to the metal. Obviously the improvement is limited to the maximum atmospheric pressure.

The use of pressure casting improves the situation even more since it is easy to create air pressures well above 14.7 psi.
Forty psi is a typical pressure for the pressure casting process. This would yield a pressure of 40.72 psi at point C or an increase of about 55 times in pressure. This situation is illustrated in Figure 18.
CASTING MECHANICS

In addition to the physical configuration of the mold itself, the specific gravity of the material may also have a significant influence on how the system works. For example, 14K yellow gold is roughly 40% higher in specific gravity than sterling silver. This means that any depth the hydraulic pressure exerted by this mold material would be roughly 40% more. It's reasonable to assume that this difference could be significant in marginal situations. As a practical fact, it may be one of the reasons which accounts for the somewhat better results which are generally achieved with gold casting versus silver.
CASTING MECHANICS

When you are winding the centrifugal caster, the flask size (weight) influences the number of turns you need. At any given number of turns (for example, three turns) the spring will exert a certain amount of force when released. This force works against the total mass of the arm and the flask. As the weight of the system increases, the arm will accelerate more slowly. This means that additional force is required and the spring must be more tightly wound.
SURFACE PROFILE

I think everyone understands that the finish on a cast piece may not be as fine as that on the model. For example, by using hard plastic it's possible to create a highly polished master and yet, the casting still has a very fine matte surface detail. This profile develops (potentially) from at least three different sources:

1. The surface oxidation and subsequent pickling may enrich the surface and leave a degree of porosity behind. There seems to be ample evidence that surface enrichment after castings are pickled may reach significant levels.

2. Various stresses and strains during the burnout and casting process may deteriorate the surface quality of the cavity. Plastic or other rigid modeling materials are often blamed for various defects, and at least in theory this could be the source.

3. Finally, it's obvious that there must be some openings in the surface of the cavity if air is to be excluded. The question is rather or not these openings are large enough to provide a degree of surface texture in the metal. Obviously, they are far smaller than the metal can move freely through. However, experience with viscous liquid suggests that there is at least, a possibility that the surface may be composed of small raised areas corresponding to any pores in the surface of the model.