Lost wax casting using a steam caster
by John Wallace Banks

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF APPLIED ART
Montana State University
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Abstract:
The extensive interest in lost wax casting has created a need for a more practical and readily available casting method to replace the centrifugal casting machine.

Easily available, common materials and increased safety features for the operator are two important reasons for the author's enthusiasm for the lost wax, steam casting process.

The casting procedure, its comparison with other processes, and the construction of equipment are discussed. Tables, photographs and illustrations are included.

The results of steam casting research by the author show steam casting to be safer in operation than centrifugal casting. This work also shows that steam casting materials such as waxes, wetting agents and refractory investments can be made from locally available materials. The steam casting machine discussed is highly portable, easy to operate and does not require special mounting or permanent installation.
LOST WAX CASTING USING A STEAM CASTER

by

JOHN WALLACE BANKS

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of

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MONTANA STATE UNIVERSITY
Bozeman, Montana
June, 1967
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<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Relationships of Casting and Construction Techniques</td>
<td>3</td>
</tr>
<tr>
<td>Comparison of Casting Processes</td>
<td>3</td>
</tr>
<tr>
<td>Wax Working Techniques</td>
<td>6</td>
</tr>
<tr>
<td>Wax Formulas.</td>
<td>7</td>
</tr>
<tr>
<td>Wetting Agents for Wax Models.</td>
<td>8</td>
</tr>
<tr>
<td>Préparing The Wax for Modeling</td>
<td>9</td>
</tr>
<tr>
<td>Wax Tools and Models.</td>
<td>10</td>
</tr>
<tr>
<td>Investing and Burnout</td>
<td>13</td>
</tr>
<tr>
<td>Casting.</td>
<td>16</td>
</tr>
<tr>
<td>Causes of Common Casting Failures.</td>
<td>17</td>
</tr>
<tr>
<td>Conclusion.</td>
<td>19</td>
</tr>
<tr>
<td>Supply Sources.</td>
<td>20</td>
</tr>
<tr>
<td>Literature Cited.</td>
<td>21</td>
</tr>
<tr>
<td>APPENDIX.</td>
<td>23</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Number</th>
<th>Figure Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A centrifugal casting machine in a safety ring with the burned out flask in place (white cylinder).</td>
<td>25</td>
</tr>
<tr>
<td>2.</td>
<td>The steam casting machine with the casting flask (A) in position for melting metal prior to casting. The white disc in the foreground (B) is the hard asbestos steam head. The circle (from a previous cast) shows how the steam seal works. The two spring clamps (C) are used to hold the dampened steam head in place.</td>
<td>25</td>
</tr>
<tr>
<td>3.</td>
<td>Pouring the strained, melted wax onto a level sheet of heavy glass.</td>
<td>25</td>
</tr>
<tr>
<td>4.</td>
<td>Cutting the wax into various forms for production of wax models and sprues.</td>
<td>25</td>
</tr>
<tr>
<td>5.</td>
<td>Heating sources for wax tools. Figure 5A is an alcohol lamp made from a babyfood jar. Figure 5B is a propane tank with an eye dropper attached for smoothing the wax surface. Figure 5C shows the casting rings made of exhaust pipe and 5D is a metal can casting ring.</td>
<td>26</td>
</tr>
<tr>
<td>6.</td>
<td>Wax and wax working tools. 6A shows sprue wires cut from the wax sheet (6B). Figure 6C shows wax working tools. Figure 6D is a found form obtained by pouring melted wax into a bucket of cold water.</td>
<td>26</td>
</tr>
<tr>
<td>7.</td>
<td>The heated wax tool is being used to weld the sprue wires to the wax model.</td>
<td>26</td>
</tr>
<tr>
<td>8.</td>
<td>The casting flask, 8A is shown behind two wax models ready for casting. Figure 8B shows 6 separate wax models (a tree) sprued and standing in a plasticine sprue base, 8C.</td>
<td>26</td>
</tr>
</tbody>
</table>
LIST OF FIGURES
(Cont.)

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>A gram scale used to weigh wax models. The wax weight is converted to the amount of metal needed for casting.</td>
<td>27</td>
</tr>
<tr>
<td>10</td>
<td>Another method for determining the metal needed for each casting. The rise in water level determines the amount of metal needed.</td>
<td>27</td>
</tr>
<tr>
<td>11</td>
<td>A wax model being painted with investment. This is done if there are many undercut areas or if an aspirator or vacuum pump is not available to remove air bubbles from the investment.</td>
<td>27</td>
</tr>
<tr>
<td>12</td>
<td>The investment ring is tipped and the investment is poured down the side of the flask. This prevents unwanted air bubbles from being trapped in the investment as it is poured. Note the outside seal of plasticine clay at the base of the casting ring.</td>
<td>27</td>
</tr>
<tr>
<td>13</td>
<td>Figure 13A shows a water aspirator as the investment is being vacuumed. Figure 13B is the vacuum line which removes the air from the investment container.</td>
<td>28</td>
</tr>
<tr>
<td>14</td>
<td>A manufactured kiln, Figure 14B, with a pyrometer attachment, Figure 14A. The input control, Figure 14C can be set to hold the kiln at any desired temperature for burnout.</td>
<td>28</td>
</tr>
<tr>
<td>15</td>
<td>The burned out ring in place and the steam head seated to form the steam for a casting.</td>
<td>28</td>
</tr>
<tr>
<td>16</td>
<td>Photograph of a pin using sheet wax, which was modeled and textured.</td>
<td>28</td>
</tr>
<tr>
<td>17</td>
<td>The pin was cast using wax from a found form</td>
<td>29</td>
</tr>
<tr>
<td>18</td>
<td>This piece of jewelry was made by using hard wax, carving the desired design into the surface.</td>
<td>29</td>
</tr>
</tbody>
</table>
ABSTRACT

The extensive interest in lost wax casting has created a need for a more practical and readily available casting method to replace the centrifugal casting machine.

Easily available, common materials and increased safety features for the operator are two important reasons for the author's enthusiasm for the lost wax steam casting process.

The casting procedure, its comparison with other processes, and the construction of equipment are discussed. Tables, photographs and illustrations are included.

The results of steam casting research by the author show steam casting to be safer in operation than centrifugal casting. This work also shows that steam casting materials such as waxes, wetting agents and refractory investments can be made from locally available materials. The steam casting machine discussed is highly portable, easy to operate and does not require special mounting or permanent installation.
INTRODUCTION

As a practicing craftsman, the author has for sometime wanted to incorporate lost wax casting with other methods of making jewelry. Investigation of centrifugal casting showed this type of casting to be prohibitive in price, and later work proved that it was dangerous and required stationary installation.

An article in School Arts Magazine 1/, presented the idea for what has proved to be a simpler, more practical method of casting.

After developing a satisfactory casting machine, the author found that modeling waxes and refractory investment were higher in price and harder to obtain than anticipated. It was necessary to experiment until formulas were found for both materials which would give desired results.

For highly portable, easily operated equipment with readily available material, steam casting gives very satisfactory results. Some experimentation will be necessary by each operator to adjust the steam casting method to suit individual desires. The first experiences with steam casting (and the resulting products) should be regarded as experiments enabling

the jeweler to learn how materials and processes can be used effectively.

The following work deals mainly with methods of casting and construction of equipment. That construction and process are stressed does not imply that there is any separation from the creative process; these are part of this process. Mickey Story in his book, *Centrifugal Casting*, makes several references to the falseness in thinking that method and creativity can be separated.

To make lost wax casting a creative expression, the artist must use his background in all aspects of design and construction. This understanding of materials and methods allows effective combination of aesthetics and method to produce desirable results. If jewelry has an artistic impact on the viewer, then the artist has been successful in combining creativity and method.


3/ Ibid.
Relationships of Casting and Construction Techniques

When casting is compared with other methods of jewelry construction the main difference lies in the manner in which the metal achieves its final shape. Construction methods involve attaching, often by soldering, pieces of metal which have been rolled, drawn, sawed, forged or raised while in the hard or solid state. Casting is a liquid method of handling the work, since the actual design is done in wax. The actual cast form is not handled until after the casting is complete, when the minor finish work takes place. The jewelry piece cannot be altered once the work progresses past the wax model stage. Because the material for the model is supple and the metal is fluid when poured, the author feels the design is influenced by the process.

The casting process is intriguing and should be presented as a process growing out of the limitations of other jewelry construction methods. Too often there is little sequential relationship shown between casting and other methods of forming jewelry. Casting should be presented as an outgrowth of, and related to other methods of jewelry construction.

Comparison of Casting Processes

In comparing the steam process with the centrifugal process the obvious advantages of steam casting are: (1) ease
of preliminary installation of equipment; (2) no danger from propelled molten metal; (3) the equipment itself is much simpler; (4) the cost, therefore, is less.

When the centrifugal process is used the following items must be considered and completed in order to produce castings: the casting arm and flask must be balanced and counterweighted; the machine must be leveled so the casting arm swings freely, and the base must be securely fastened to the table. Since the casting arm moves in horizontal or vertical circles depending on the type of machine, a splash guard to prevent molten metal from hitting people near the centrifuge should be attached to the machine. If the sprue reservoir is not correctly shaped, if there is more metal in the crucible than the flask can hold or if there is a small gap between the crucible and flask hot metal may be thrown in a complete circle about the room. The arm must be wound prior to casting. When the flask has been burned out it is attached to the arm of the casting machine. With the flask in place the metal is melted in the crucible that is attached to the arm of the machine, the arm is released and the molten metal is thrown into the burned out flask.

When the steam method of casting is used (See Figure 2, Appendix) the installation of equipment is cut to a minimum.
The steam caster is portable enough to be set on any convenient table top. There is no balancing, leveling or special mounting needed. The rapid movement of metal is eliminated because the flask serves as the melting crucible. No splash guard would be necessary if the jeweler checked the flask to be sure the investment stopped flush with the top and bottom of the investment flask. The only movement of the steam casting machine is that of the steam head moving downward for approximately two to three inches. The steam caster is portable and can be used with no preparation other than wetting the steam head. The steam caster can be taken from storage, set up anywhere, the jewelry cast and the caster returned to storage in less time than it takes to secure and level the base of the centrifugal casting machine.

The greatest disadvantage of the steam caster occurs when multiple castings are made in one large flask. In a flask five by five inches or larger the steam casting flask must be increased one to two inches in height to hold the silver reservoir. This does not happen when a centrifuge is used.

The author prefers steam casting because of the minimum cash outlay for equipment, the simple, uncomplicated operation, the lessened physical danger to the operator and the elimination of special preparation preliminary to casting.
Wax Working Techniques

In the casting procedure the making of the wax itself allows the craftsman considerable freedom. Wax making is also one of the least critical of the casting steps.

The only technical criteria that the wax must meet are (1) that the wax burns out "clean", leaving no carbon deposits in the mold, (2) that the wax is not too brittle or dry, so it can be shaped and sprued without damage to the actual model.

The wax may be used in its natural color or be colored to suit the user's purpose. Waxes are often colored to help the craftsman emphasize dark-light contrasts that will appear in the finished product. A good grade of wax crayon is probably the most easily available coloring agent.

A variety of formulas are listed because individual preferences in wax differ.

The simplest waxes to use and obtain are beeswax and paraffin, (the grocery store for the paraffin and the nearest beekeeper for the beeswax). These two waxes can be used in various proportions. More beeswax and less paraffin make a soft wax. The reverse makes a harder wax. Cocoa butter or tallow can be added to keep the wax from becoming brittle; rosins, balsam, pitch, and turpentine add a suppleness or bend strength to the wax; ceresin and carnauba add hardness to the wax; the plastic bag recommended in the fourth wax formula on
Wax Formulas

1 pound rosin
2 pounds beeswax
6 tablespoons turpentine

1 pound paraffin
2 pounds beeswax
2 ounces cocoa butter

1 pound beeswax
\( \frac{1}{2} \) pound powdered rosin
\( \frac{1}{2} \) tsp. Canadian balsam
1 tsp. tallow
1 tsp. cocoa butter

1\( \frac{1}{2} \) pounds beeswax
1 pound paraffin
\( \frac{1}{2} \) pound powdered rosin
1 small clear plastic bag without printing
2 ounces cocoa butter

10 parts beeswax
10 parts ceresan
15 parts carnauba
64 parts paraffin
Wetting Agents for Wax Models

90 isopropyl alcohol
10 sulfonated castor oil

50 USP liquid green soap
50 hydrogen pyroxide


* Formula used by author.
Preparing the Wax for Modeling

Once the wax materials have been gathered, the wax can be melted in several ways. The traditional method is melting it over boiling water using a double boiler. A second hand, electric deep fat fryer works very well. I would suggest putting the materials in whatever container is available and heating them until they are well melted. Add color if desired and mix thoroughly. As the wax is poured, it should be strained to remove any foreign material. A silk stocking works well, as does a very fine metal mesh strainer.

Before the liquid wax is poured into sheets, see Figure 3, Appendix, there are several steps to keep in mind. A smooth, level surface; such as stone or double strength glass is covered with a thin coat of liquid green soap, and care should be taken to see that bubbles do not form as the soap is smoothed on. After the liquid wax is poured onto the slab and cooled, the wax is picked up and the green soap is washed from the underside with cold water. The sheet may be cut into desired shapes which will include the thin sprue wires, Figure 6A, Appendix.

Another treatment of the wax produces what are often called "found forms". If liquid wax is poured from various heights into a container of water, the solidifying wax will produce
some pleasing forms for casting, Figure 6D, Appendix.

Wax Tools and Models

Wax tools can be obtained in many ways. Often dentists throw away tools that can be used. Commercially made wax tools are available. Decorative carpet tacks, nuts, screws, etc., can easily be adapted for wax work. See Figure 6, Appendix.

Wax tools can be made from either heavy gauge iron wire or welding rod that has been cut into six inch lengths. One or both ends of the wire may be flattened on a metal surface by using a hammer. The tips of the tools can then be filed or ground to the desired shape. Dents and burrs may be removed by sanding to a smooth finish. The center portion of the tool may be wrapped with heavy tape or the tool could be inserted into a wood handle to keep the heated metal from burning the user.

To heat the tools and wax the following are recommended; natural gas (bunsen or stove burner), bottled gas (propane hand torch), or an alcohol lamp.

When the design emerges as a wax model it should be as exact as possible. All surface texture will reproduce so the model must be checked carefully to make sure there are no unwanted textures. An eye dropper or hypodermic needle tip packed with cotton and inserted into a flexible rubber hose that is attached
to a gas outlet is most effective for smoothing small areas. A hard surfaced cloth and cold water will give good results in smoothing the wax.

When the wax model is complete it must be sprued. Spruing serves two purposes: one is to provide channels through which the metal can flow (the shortest, most direct route by which the metal may reach the mold cavity); the second is to hold the wax pattern in the center of the flask while the investment is poured around it.

Usually jewelry has two or more sprues, see Figure 7, Appendix. More sprues will be needed if the jewelry is heavy or if there is any distance between the main sprue and the outer limits of the form. The more sprues a cast has the more time will be spent on finish work.

The amount of metal necessary for the casting must be determined before the sprued model is invested. There are two methods used to determine the amount of metal needed. The completely sprued model may be weighed with scales, see Figure 9, Appendix, then the weight of the wax model multiplied by ten for silver and fifteen for gold. The water displacement method is the second way of determining the amount of metal needed for casting. A glass container is partially filled with water and the water level marked. The wax model is completely submerged and the level again marked. The wax model
is removed and metal added to the container until the second mark is reached.

The spruing of a model requires a flat base such as a jar lid. A sprue former which is made from plasticine clay is attached to the flat base. The sprue former, in addition to holding the wax model now, will later serve as the metal reservoir for casting. The sprue former is generally shaped into a half sphere with a flat bottom centered and firmly attached to the jar lid with a downward pressure. The main sprue runner (a thick sprue wire) is inserted into the plasticine clay, see Figure 8, Appendix, and with a hot wax tool the sprued model is attached to the sprue runner. A casting may be a single model or multiple models, depending on the size of the model and the size of the flask. With the sprued model in place, the investment flask is centered around the model. There should be approximately one-fourth inch clearance around the sides and from one-fourth to no more than one-half inch clearance from the top of the flask. The casting flask (ring) can be of several types of metal. The stainless steel ring is preferred by professionals because it will not break down under repeated firings. However, stainless is expensive and lengths of auto or truck exhaust pipe work very well. The pipe should be cut so that the top and bottom cuts are made exactly parallel
to each other. Tin cans (not aluminum) may be used for a single cast if they are bound in several places with iron wire. Prior to putting the flask in place, a strip of thin, wet asbestos paper (furnace tape) may be inserted as a flask lining which should stop one-half inch short of each end of the flask. This sheet asbestos absorbs any investment expansion during hardening and heating of the investment. The asbestos is not necessary, but it will keep the investment from slipping out of the casting flask. When the ring is in place on the base, the outside contact point between the ring and base should be firmly sealed with a collar of plasticine clay. The model is now ready to be invested.

Investing and Burnout

The investment serves as the mold around the wax model, and it will withstand heats up to approximately 1350° F. before it starts to break down. Investment can be purchased commercially, and if an investment such as cristobalite is used it should be purchased in amounts of fifty to one hundred pounds to realize any savings. A suitable investment can be made from easily obtained ingredients. Most ceramic studios have the necessary ingredients, or they can be obtained through ceramic supply houses. Basically investments are a combination of plaster and silica (often called flint or quartz).
Von Neuman, in *Design and Creation of Jewelry*, gives the ingredients of investment as plaster (used as a binder), silica (cristobalite, flint, quartz) for uniform thermal exchange, and graphite (to prevent oxidation). A mixture of one part plaster to two parts silica will make a very simple investment. Another formula for investment contains one-half part graphite, three and one half parts boric acid, forty-six parts silica and fifty parts plaster. Both formulas should be dried slowly and burnout temperatures raised slowly. For flasks four to six inches in diameter or height it would be advisable to use a commercial investment such as cristabolite. The investment is mixed with water in the ratio of one part water to two and two-tenth parts investment. The investment is sifted into the water and allowed to stand until it has absorbed the water; then it is stirred for one to two minutes. If a vacuum pump is available the investment should be vacuumed to remove all large air bubbles trapped in the water during mixing and pouring. If a vacuum pump is not available, a water aspirator, Figure 13, can be used for the same purpose. The article in the October, 1965, issue of *Gem and Minerals Magazine*, page 19, shows how to build a water aspirator. If none of the above methods is available, the container of mixed investment can be struck on the sides to loosen air bubbles. The wax model can be given a light brushing of debubblizer, which will cut down the chance

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of air bubbles forming on the wax model when the investment is poured. If the wax model has extremely minute detail or many undercut areas, it is advisable to paint a coat of investment on the model before the investment is poured into the flask. The investment is gently poured down the wall of the flask, Figure 12, Appendix, until the flask is level full. Then the filled flask is vacuumed, or the flask is tapped again to loosen the trapped air bubbles. When the investment has set, the sprue base and the plasticine sprue former can be removed. If the flask is small and a commercial investment has been used, the flask can be burned out immediately. Small flasks (less than 4" in height) can be burned out and ready for casting in from one to three hours. The recommended procedure for burnout of a flask using the author's investment is as follows:

1. The flask is placed in a kitchen oven or small kiln with the sprue opening down and the flask elevated above the floor or shelf of the kiln.

2. It must be heated for two or more hours at 200°F as the water moisture has to be driven off gradually. If the mold is heated too rapidly, cracks may appear in the investment which will later show as "fins" on the metal casting.

3. After several hours most of the wax will have melted out and the flask can be turned upright to allow any collected gasses to escape. The heat now can be advanced about 200°F every hour until 1200°F is reached. If the initial burn-out is done in an oven, the flask must be
3. The flask is ready to cast when the investment has a white, clean appearance; there is a visible red glow in the cavity of the mold, and the temperature has reached 1200° F. A pyrometer may be used to check this part of the casting procedure. If one isn't available, a suitable temperature indicator can be made from an aluminum nail. Most aluminum alloys melt at approximately 1200° F. Therefore, an aluminum nail placed at a slight angle in a small wad of ceramic clay near the flask will bend at the required temperature.

Casting

When the flask nears the pouring temperature, the steam head, a hard asbestos circle, Figure 2B, Appendix, should be submerged in water for five minutes. While the steam head is soaking the craftsman should mix a small amount of powdered asbestos with water until it forms a thick dough. When the steam head is removed from the water the asbestos mix is pressed onto the surface of the asbestos steam head and smoothed out to a uniform coating of approximately one-fourth inch in depth. The steam head is then attached to the caster with two spring clamps. If scrap metal is used it should be placed on a charcoal block and melted. A hand blowtorch, propane torch, acetylene or natural gas torch may be used. The flask is then removed from the kiln and placed, sprue up, on the apron in front of the caster, Figure 2A Appendix. The metal is transferred...
to the sprue reservoir and heated until the metal becomes fluid. While the metal is fluid the flask is moved directly under the center of the steam head. Immediately after the torch is withdrawn, the steam head is moved down on top of the flask and held there with firm downward pressure for two or three minutes to form a seal. The steam head is then raised to allow the flask to cool from three to seven minutes, depending on the size of the flask, after which the flask is placed in a bucket of cold water which causes the investment to break away. The sprues are cut off, and any traces of investment can be removed with a stiff brush. The casting can then be finished by regular methods.

Causes of Common Casting Failures

Everyone will experience some failures especially when first using this casting method. The main causes for casting failures are haste and carelessness in any stage of the procedure. A craftsman must learn to be meticulous and methodical in all phases. Some of the more common casting failures and causes are listed below.

1. Partial Casting
   a. Sprues are too small or there is a lack of sprues to extended areas of the model.
   b. There is too much investment around the model to allow gas pressure to escape.
c. Burnout is not complete, leaving some moisture as steam to form backpressure.

d. Metal or flask is too cold.

e. There is too little steam pressure because of poor seal between flask and steam head.

f. Foreign materials (pieces of investment) have fallen into and blocked sprue passages.

2. Surface Distortion

a. Fins from too much water in investment or too rapid a burnout will cause a fracture of investment.

b. The casting metal and/or the flask is too hot.

c. The incoming metal strikes a flat surface and spins.

d. The model is too close to sides, top or bottom of the flask.

e. The metal has impurities.

f. The sprues are too large or incorrectly placed to allow uninterrupted rapid entry of metal.

g. There are air bubbles in the investment from incomplete mixing or careless pouring of investment into the flask.

h. Air bubbles are trapped when brushing on debubblizer or investment.

3. Oxidized Casting

a. There was incomplete burnout of the wax.

b. The metal was overheated (spinning) in the sprue reservoir or the flask was too hot (above 1220° F.)
Conclusion

The more obvious benefits of steam casting are the difference in price (steam caster $10.00 versus $110.00 for a centrifuge), less danger to individuals during casting, and ease of operation. Steam casting enables the artist to produce jewelry and small metal sculpture economically.

Of greater importance are some less tangible benefits of steam casting. Using this method of casting there is a personal involvement throughout the entire process that I find very satisfying and that is not present when I cast by centrifugal force. The materials used and the simplicity of the casting machine contribute to the personal involvement. As more sophisticated machines and methods of casting are used the feeling of individual involvement, control, and relationship to the final work produced diminishes. With the use of complex machines and equipment the search for beauty of design often becomes secondary to the function and/or involvement with the equipment.

The creation of a piece of jewelry should be the result of a search for beauty. To me, the processes used in steam casting contributes to this search of and fulfills the intent of creating beauty that least separates the craftsman from creative control throughout the product formation of the original expression.
Supply Sources

Anchor Tool and Supply Co., Inc.
12 John Street
New York, New York, 10038

Casting Supply House
62 West 47th Street
New York, New York

Central Scientific Company
1700 Irving Park Road
Chicago, Illinois, 60613

Grieger's Inc.
1633 East Walnut Street
Pasadena, California, 91106

Kerr Manufacturing Company
6081-6095 12th Street
Detroit, Michigan

Southwest Smelting and Refining Company
Box 2010
Dallas, Texas, 75221

Van Howe Ceramic Company
1185 South Cherokee
Denver, Colorado, 80223
Literature Cited

BOOKS


Davis, Mary L. and Greta Pack, Mexican Jewelry, Austin, Texas, University of Texas Press, 1963.


PERIODICALS


PERIODICALS


STEAM CASTER DIAGRAM
Figure 1. A centrifugal casting machine in a safety ring with the burned out flask in place (white cylinder).

Figure 2. The steam casting machine with the casting flask (A) in position for melting metal prior to casting. The white disc in the foreground (B) is the hard asbestos steam head. The circle (from a previous cast) shows how the steam seal works. The two spring clamps (C) are used to hold the dampened steam head in place.

Figure 3. Pouring the strained, melted wax onto a leveled sheet of heavy glass.

Figure 4. Cutting the wax into various forms for production of wax models and sprues.
Figure 5. Heating sources for wax tools. Figure 5A is an alcohol lamp made from a babyfood jar. Figure 5B is a propane tank with an eye dropper attached for smoothing the wax surface. Figure 5C shows the casting rings made of exhaust pipe and 5D is a metal can casting ring.

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Figure 8. The casting flask, 8A is shown behind two wax models ready for casting. Figure 8B shows 8 separate wax models (a tree) sprued and standing in a plasticine sprue base, 8C.
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Figure 11. A wax model being painted with investment. This is done if there are many indercut areas or if an aspirator or vacuum pump is not available to remove air bubbles from the investment.

Figure 12. The investment ring is tipped and the investment is poured down the side of the flask. This prevents unwanted air bubbles from being trapped in the investment as it is poured. Note the outside seal of plasticine clay at the base of the casting ring.
Figure 14. A manufactured kiln, Figure 14B, with a pyrometer attachment, Figure 14A. The input control, Figure 14C can be set to hold the kiln at any desired temperature for burnout.

Figure 13. Figure 13A shows a water aspirator as the investment is being vacuumed. Figure 13B is the vacuum line which removes the air from the investment container.

Figure 15. The burned out ring in place and the steam head seated to form the steam for a casting.

Figure 16. Photograph of a pin using sheet wax, which was modeled and textured.
Figure 17. The pin was cast using wax from a found form.

Figure 18. This piece of jewelry was made by using hard wax, carving the desired design into the surface.
CASTING RING ASSEMBLY

CASTING RING
ADDITIONAL SPRUES
ASBESTOS LINING
SPRUE BUTTON
MAIN SPRUE
PLASTICENE CLAY SPRUE BASE
WAX MODEL
REFRACTORY INVESTMENT
PLASTICENE SEAL
REMOVABLE BASE

DIAGRAM FOR RING SPRUEING

BOTTOM OF SPRUE RESERVOIR SHOULD BE FLAT
CORRECT SHAPE FOR PLASTICENE SPRUE BASE
Lost wax casting using a steam caster