San Fernando Valley State College

HOLLOWARE AND CAST METAL DECORATION
OF
BERYLLIUM COPPER

A thesis submitted as partial satisfaction of the requirements for the degree of Master of Arts in Crafts
by
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ABSTRACT

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The history of holloware forming in metal has been left incomplete as to the techniques various artists have used. The hammered bronze bowls of the Greeks and Romans may have been born of the same techniques as the gold goblets of the Incas or Ancient Mayas and other pre-Columbian art but few words have recorded the processes used. The decorative rims, bases, and bodies of these objects often have been of intaglio or bas relief repoussé, with an occasional, separately cast symbol or three dimensional figure added. These latter could have been formed by the lost wax process, gravity poured in sand, earth, or baked clay, and techniques similar to those used by Benin craftsmen during the last few centuries. However, it remained for the artisans of our twentieth century to introduce and perfect the techniques of centrifugal and vacuum casting of metal and its attendant faithful reproduction of the minutest detail put into wax models.

Modern industrial production utilizes many of these new methods. Vulcanized rubber molds for quick reproductions of original designs, cold or catalyst set flexible plastics for molding, water soluble waxes used as hollow cores for difficult reproducing, and shell molding, are only some of the newer processes.
To select from these processes one or more which would be practical for an individual contemporary artist seemed to be a problem worth investigating. My thesis exhibition in Gallery 2 is a result of this research.

The problem was to design holloware objects to be made by the crimp raising technique and add centrifugal cast objects for decorative effect. These decorative objects would be made by a method of hollow casting completely closed objects with a "floating" core, and with constant wall thickness throughout. The main research to be explored in the work for this thesis was hollow castings with constant wall thickness.

The first bowl is shown in figure 1. Before the work began the silhouette or outline was first sketched the full size of the proposed form, figure 2.

Not more than a general concept of the finished object was allowed to develop at this time. Although animated figures to be used as decorative motifs were part of the consciousness that lay behind the general idea, these actual figures came into more specific development as the bowl itself was being formed.

The method of metal forming called crimp raising was used. The approximate diameter of the sheet copper needed for the bowl was determined by the arc A B C D, figure 3. This was cut out in circular form, of 18 gauge metal, and the edges de-burred and rounded by filing for safety in handling, as well as to keep the rim from splitting while being formed.
The first hammer contact with the metal was to raise a starting circle of about 1-1/2" radius marked off from the center of the copper disc. This circle was formed over the rounded end of a hardwood block, figure 4. From this starting point the first fluting was done around the whole bowl on the opposite grooved end of the hardwood stake, figure 5. Reversing the stake, the crimping part of the operation was done starting again at the 3" diameter inside circle and working around and around the bowl, crimping the metal with each hammer blow. This slightly compresses the metal with each strike. The whole starting circumference of approximately 53 inches was compressed to a finished circumference of 38 inches, a reduction or compression at rim edge of 15 inches.

This crimp raising makes the metal very hard and since this process was repeated about six times, it was necessary to make the metal soft before each raising by heating the bowl to about 1200 F. It is quenched or immediately cooled in water or "pickle", an approximately 5% acid solution. This pickle removes the major oxides formed while heating. The bowl may also be pickled (cleaned) after quenching in water. A protective coating of powdered boric acid suspended in alcohol also may be used as an oxidizing retardant, if it is painted on the bowl just after crimping and before heating. Both these techniques are presented in the color film accompanying this showing, which records the making of the third bowl of this series.

When the bowl had been crimp-raised to the desired form and shape and after a final heating to make it workable, it was ready for the hammer treatment called planishing, or flattening small areas of the crimped metal. This is done with a small flat hammer with a polished face of about 3/4" diameter, over a metal T stake, figure 6.
These rows after rows of planished metal run continuously around from center bottom to completed top edge, each blow overlapping the other.

This planishing is usually a tedious and somewhat mechanical operation, and while it is progressing, the creative core of the mind functions well in other areas. This was when I planned the parts for the rest of the design. Animated figures have always been of artistic interest to me, and an interesting challenge would occur in their being incorporated into use as part of a bowl design. The design subject, therefore, became horses and figures, used in a decorative way, and cast hollow by the lost wax or cire-perdue process.

Though there seems to be little information in print, several times in discussions of "lost-wax" methods, with other craftsmen, I had heard of the technique of hollow casting. This is casting a thin walled object entirely enclosed around a hollow core. Perhaps there are many reasons for its not being done, not the least of which is its impracticality, but the subject had always intrigued me and this was felt to be an opportune time to try it.

So, while the bowl was slowly taking shape, the horses were being formed in carving wax. The base, or supporting horses, were made first, and were planned to be about three inches high.

The model for these horses was carved solid out of wax, split in half when nearly complete and the inner part of wax was hollowed leaving about a .040" thickness of wall. Assembled again, the wax model was finished to satisfaction, then separated again into two halves. The main half was cast into sterling silver, lightly finished,
and the other wax half of the original horse was fitted onto the
sterling half with perfect alignment. Separated again, wax from
silver, the second half was invested and cast.

After casting the separate parts of the sterling silver original horse
and grinding or finishing where necessary, each piece was "laid up"
in a molding frame, figure 7, to be heat-cured between latex rubber
pads, restrained by the molding frame and put under pressure in a
molding press to assure getting the most minute detail.

When cured and split into two parts, the mold was injected with
molten casting wax. This allowed the reproduction of several wax
horses which, animated into suitable positions, became the first
step toward hollow casting our decorative "larger" horses.

One of the problems was that of securing the inner core of investment.
This was first attempted with removable pins. The halves and all
inner spaces of the horse were spatuia filled with casting "investment":
a powder, water-plasticised into a thick paste for this part of
investing. While still in a non-set state all wax parts of the horse,
now filled with the wet investment, were reassembled into their
original form and welded at the joints with molten wax. Short pins
of stainless steel were inserted through the outer shell of wax,
through the inner core of investment and cut through the wax shell on
the other side, extending about 1/2" beyond, figure 8. The pins were
to hold the core in place when metal was cast into the needed cavities.

Now the investment cored figures with inserted pins was set-up for
regular casting, figure 9. Vacuumed investment was poured around
the flapped or tube enclosed figure held on a sealed base and
vacuumed again to remove the possibility of trapped air bubbles from all detailed or textured areas of the sculpture.

After one hour setting time the flask was put in a 300°F electric burnout oven, and slowly raised to about 1400°F over a period of eight hours in order to burn out all the enclosed wax and carbon residue.

Two pounds of beryllium copper was melted in a centrifugal casting machine and molten metal spun into the awaiting cavity, figure 10. The casting was allowed to cool slowly. Since it was apparently successful, the next two base horses were cast using the same techniques.

After about ten minutes cooling the castings were removed from their flasks by applying water to break away the still hot investment. Pulling out the core-locking pins came next. Running water forcefully through the core holes pried most of the investment from the inside cavities. Liquid hone blasting finished the clean-out job, and beryllium copper rods were pushed through the body holes and hardened into place with silver solder.

Thus the three large horses of the first bowl, completed by soldering brass bolts to the bottom of the hooves for assembling ease, were finished and made ready for mounting.

Next, the rim horses were wax formed in two halves as before but then were slightly cut away in back and cast in the traditional centrifugal manner, needing no core locks. The small boy figures were small enough to cast solid and so offered no new problems.
Now, by soldering onto the bowl the two circular rims, a frieze area was made into which the latter horses and figures were individually attached. This concluded the first bowl, except for an added welded base of steel with copper overlay.
THE SECOND BOWL

I decided to make a somewhat smaller covered bowl, which presented new problems to be solved. A few scaled sketches were made as shown in figure 11. One idea was favored and 16 gauge copper was selected for the material. Crimp raising of the bowl itself was started and worked toward the selected silhouette. The design called for several more horses of varying sizes and styles. The largest that was needed, two inches in height, was started in wax. As before this model was carved, split and hollowed.

The first half was cast and the second half was fitted in its wax form to the first half sterling model. The second half of the model was cast, finished and soldered side by side with the first half for molding. Then, as before, a vulcanized latex mold was made, figure 12.

Now, four of these horses were prepared for hollow core casting by the following method. Four wires were placed into the inner cavity of each horse; three through a hole about 3/8" large cut into the side of the wax and the fourth through the open mouth, figure 13. All were stainless steel and extended from the innermost reaches of the core through the holes, outside about two inches. This assured complete and secure locking of the inner core of investment. An advantage of this method was the elimination of the necessity of first core filling with spatulated investment. Instead, the vacuumed investment, using this method, may be applied as in regular investing technique. Then the whole object is encased in investment at one time, for the slurry will penetrate every hollow because of the vacuumed state.
After casting, all core pins were pulled out and the investment was cleaned from the inside by water pressure, liquid hone, fluor-boric acid soak, or a combination of all three treatments.

In order to simplify this particular part of the bowl I decided to group the three base horses together with a top piece attached to the heads.

A base felt to be complementary to the bowl form was now crimp raised allowing a flared bottom ledge with raised letters. This latter necessitated designing in wax models all the letters of the alphabet which were basic in form and from which all others could be quickly made. These were then cast into a sterling combination model, molded, and the needed parts cast into the word groups decided upon in beryllium copper, figure 14.

For the decoration band the flat, stylized horses were hard-soldered to their background, making the bowl ready for its supporting base and decorated lid, figure 15.

An inner lip for this kind of lid is usually formed of two pieces, a flat rim joined to a collar-like, lap-joint soldered form. However, I chose to form the lip and collar from a single rim-shaped piece of 18 gauge metal and stretch raise the collar, which in its turn fit inside the rim of the main bowl. When completed, this piece was hard soldered onto the lid, figure 16.

While the knob or top handle section was being stretch raised over metal stakes, the wax carving for the third size horse of one and one quarter inches in height was completed. This wax model was
split, hollowed, and sterling cast into three wax-fitted halves, left side, right side and head, figure 17.

Soldered together, a single rubber mold was vulcanized and cut away from the model. Four beryllium copper reproductions, re-animated, were lost-wax cast, one single, but three together, using the pin-through-core technique with stainless steel pins straight through rump, shoulder and neck, three such anchors per horse.

The grouping of three was put on a common, textured wax base, with a top knob-fitting wax-textured rim running around the top manes, and was cast as one unit, figure 18. Lightly finished, after purging of the core investment, beryllium copper pins were inserted and hard soldered, and the whole top three horse unit was hard soldered to the waiting knob. After cleaning and polishing, this top assembly was tin-soldered to the lid.

Next, the three largest horse base assembly, which also had been cast as a single unit, was tin soldered to both its base and the main bowl.

A stabilizing, ten-gauge disc of copper, had been hard soldered to the inverted shaped base bottom. Now as the final assembly, the seven word groups or sections were tin soldered to the base rim.

This completed the making of the second bowl except for the heavy plating of silver, which was done by a commercial plating company.
THE THIRD BOWL

During the making of the second bowl, several new ideas were developed that seemed interesting. A larger bowl would be made with an open decorated rim with either pierced or three dimensional figures in a cast frame, and the bowl base would be entirely cast with added non-supporting figures. Additionally, while making the bowl perhaps it would be interesting to make a color film record of its development. The film was produced and is on view with the exhibition.

The bowl proceeded in similar fashion to the other two, except that with this largest one, the effort was multiplied, and made more complicated by the use of the larger quantity of wax work. The base, modeled in sculptor's wax, was too large to cast intact, so after being formed and fitted to the bowl, it was split down the center. Its bottom rim was taken off and divided in two, sprued and gated so that it could be cast in one container or flask.

The top rim, after wax forming, was also cut apart, but this time into separate pieces, each with its own individual small horse in position. These sections also were grouped into combined gatings so that two or three together could be cast in a single flask.

Next, the four medium sized horses were prepared for the base, each set up in its own flask. In fact, for the benefit of the filming, all of these waxes, including the top rim sections with small horses, and the four split base sections were mounted on sprue bases to be invested at the same time.
Figure 19

Bowl 2
After casting, I water cleaned the used investment from the figures and forms. My first reaction was that some parts were lost through non-filling of molten metal, while most of the others, especially the rim sections were hopelessly stuck together. A fluorboric and sulphuric acid cleaning corroborated my first impression, and the parts were set by my work bench for possible future repair.

At a later date the parts were successfully separated and missing parts re-waxed, cast anew and repaired or joined with the aid of hard soldering. Also, I used in the process of repair a new direct-current carbon rod welding technique with a tin-bronze, flux-coated rod. The bowl was assembled as originally planned, but with some added elements, with the top rim sections welded together, and the top letters weld-formed and ground, figure 19.
CONCLUSION

In reviewing these methods of casting completely enclosed objects with hollow cavities I offer a few conclusions. The second method, where the core-locking pins all are inserted through one hole and the investment is applied only once, is the simpler, less complicated technique.

I also would recommend less complicated grouping of motifs in wax for one time casting. Separating the wax assemblies into their smallest units and casting these separately, assures better casting and easier finishing. Soldering or welding these castings after finishing, into the final planned assembly offers more control of all processes.

I trust that any of the preceding may be accepted as it was offered, an exploratory investigation, for art-craft use of several techniques for use in creating hollow-core, completely enclosed objects. If this record has added to general appreciation or motivates toward the use or teaching of some of these methods, then I have accomplished a third part of my original objective; the first, to create some interesting art objects; the second, to explore some new techniques; the third, to pass on any useful information for the use of others.