The Wax of the Lost Wax Process
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Source: *American Journal of Archaeology*, Vol. 79, No. 4 (Oct., 1975), pp. 368-369
Published by: Archaeological Institute of America
Stable URL: http://www.jstor.org/stable/503070
Accessed: 02/05/2013 07:36

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Mr. Pomerance's last paragraph does not sound applicable to this kind of sampling.) In the summer of 1974 we collected suites of samples from several trenches at the dig at Phylakopi on Melos, with unimpeachable archeological control. Those samples are currently being studied, and if positive results are obtained they will be reported as promptly as possible.

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THE WAX OF THE LOST WAX PROCESS

PLATE 67

The lost wax or *cire perdue* process of casting metal was widely employed in antiquity, and objects of gold, silver, copper, bronze and lead were cast in this manner. The process apparently originated in the third millennium B.C. in the Middle East, and its use spread to Egypt, Greece and Italy.[1]

In the earliest and simplest form of the process a small object was modeled in wax which was then covered with a layer of damp clay allowing only a small hole to remain, preferably at the base of the object. After the clay had dried thoroughly this mold was inverted and heated slightly causing the wax to melt and run out the hole leaving a hollow cavity behind. (The wax was thus "lost"; hence the name of the process.) The mold was then heated still further until all traces of the wax were eliminated, and finally molten metal was poured in. When it solidified the clay mold was broken away leaving a seamless casting faithfully reproducing the wax original. Each casting was unique, and if a duplicate casting was required a new wax model had to be made and the process repeated.

As described the process was effective for small solid castings. However, for large castings there would be too great a waste of metal in casting them solid, and in cooling the subsequent shrinkage of the large amount of metal before it solidified would cause a flawed casting. Both of these problems were overcome by creating a casting around a central core. The core, made out of damp clay and sand, was first modeled in a rough approximation of the finished object, and then allowed to dry. Over it was formed a relatively thin layer of wax in which the artist modeled the details he wished to have in his final casting. The wax model containing the core was then covered with a layer of clay which was allowed to dry thoroughly. Of course one or more vents had to be allowed in the clay mold so that ultimately the wax could be melted out of it and the metal poured in. However, if the wax were to be melted without further preparation the central core would fall about loosely in the mold cavity, and the subsequent casting would be flawed. Therefore, while the wax was still in the mold, metal pins called chaplets were thrust through the outer wall of the mold passing through the wax layer and into the core material. A substantial number of chaplets were required to immobilize the core. The wax was then melted out of the mold and the chaplets held the core in its correct position in the center of the mold cavity. During casting the molten metal flowed around the core in the thin area formerly occupied by the wax and solidified around the chaplets. When the clay mold was broken away the protruding chaplets, which were usually made of the same metal as the casting, were filed level with the surface and thus were invisible. The core quite often was allowed to remain inside of the casting.

The lost wax process is such an effective method of casting that it has been used virtually unchanged up to the present day. Although the process has long been understood, an original wax model from antiquity has never been found, nor have we been sure of the type or composition of the wax that was used in ancient times.

Some years ago, quite by accident, while I was rummaging through a box of oddments in a dealer's shop I came upon two objects which at first I took to be made of old brown leather. On closer examination I realized that they were made of wax, and had been modeled as the head and crown of the Egyptian god Osiris. One was virtually complete, and of the other only his high crown of Upper Egypt was preserved (pl. 67, figs. 1 and 2a, b). They both are of the well-known type from the twenty-sixth dynasty, about 600 B.C. The largest piece is 7¼ inches in height, and in both the wax is about three-sixteenths of an inch in thickness. Both are shells in high relief, and apparently had been roughly formed by pressing a sheet of warm wax over a head form. Details such as the uraeus had been modeled free-hand in wax, and then applied while still soft.[2]

Wax has the unusual property of being fairly soft when it has been warmed slightly, and if it is kneaded at this temperature it becomes even more pliable. However, when it cools slightly the wax takes on a set and becomes rigid once again. Since wax is inert and virtually impervious to time both pieces are in an excellent state of preservation.

Lost wax bronze castings of the Egyptian god Osiris are quite common, and these wax originals readily could have been used to cast such pieces. However, if such had been the case these two pieces long ago would have been melted out of their molds, and we would not have them today. Their preservation is due to the fact that these two wax models had been used as inexpensive heads on miniature figures of Osiris, the bodies of which had been made of symbolic bags of grain

[1] Herbert Maryon and H.J. Plenderleith, "Fine Metal-Work," C. Singer et al., *A History of Technology* (Oxford 1958), Vol. 1, 624.

[2] The dealer was Fanaollah Sobhani, New York. Formerly the pieces were in the collection of Albert Eid, Cairo. The larger piece is 7 1/4″ in length and the smaller 5 3/8″. Both are now in the collection of the author.

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wrapped in linen bandages to simulate small mummies. Originally they had been enclosed in small wooden coffins. The wax face of Osiris was painted a dark green using as a pigment ground copper carbonate, because green was often employed to depict the features of this god of the underworld. It would have been quite possible to have used these wax heads as models for castings in bronze, but, for this ceremonial usage, the inexpensive wax head was sufficient. Complete specimens including the mummiform figure and coffin are in various museums including The Metropolitan Museum of Art in New York. However, I do not believe that a relationship between these ceremonial wax heads and the lost wax casting process has been previously noted.

Although it always had been assumed that beeswax was used in the casting process no proof of this had previously been obtained, nor did we know whether or not any additives might have been used with the wax to change its characteristics. Accordingly, an analysis of the wax of Osiris's head was made for me by the Central Research Division of The American Cyanamid Company, and the report was prepared by Messrs. D.W. Davis, D.G. Grabar, and N.B. Colthup of the microscopy and infrared groups. They reported that indeed it was beeswax, and it appeared to be pure and unadulterated. It dissolved completely in carbon tetrachloride, leaving only a few wood fibers and insect debris, approximately 1%. They stated that the wax was probably warmed and strained since it was very fine-grained and highly birefringent. The final proof was a comparison of the infrared spectrum of the wax Osiris head model, and a comparable infrared spectrum of fresh beeswax from North Carolina. The spectra were identical in every detail. Therefore, the sample was pure beeswax.

A close examination of many ancient castings shows that often there were failures in the lost wax process. If the molten metal was not hot enough it would chill and result in an incomplete casting. Bubbles of gas from some remaining wax would produce unwanted holes. Sometimes the chaplets did not hold the core firmly and it shifted making the casting wall too thin on one side. When failures occurred in a small casting it was more economical to abandon the piece and start over. However, on larger castings quite often these defects could be made relatively invisible by repairs. A bubble or incomplete spot in the bronze would be cut out and a small metal plug driven in and the surface filed smooth with the surrounding metal. Some life-size bronze figures from the Roman period which usually were cast in sections may have as many as a hundred of these repair patches in them. Thus, the errors in casting usually were eradicated by either melting the small pieces that were unsatisfactory, or cutting out the defects in the larger ones. In any event, few unaltered defective bronze castings have come down to us from ancient times.

An example of how a shifting core caused a casting accident which resulted in a defective bronze may be seen in the piece of a hand and part of an arm now in the author's collection (pl. 67, figs. 3-4). It dates from the Hellenistic era and was found in Egypt.[3] During casting the core unfortunately shifted toward the back of the arm, and the bronze could not run into such a thin area. On the inside of the arm the molten bronze broke the core and bubbled. When the caster removed the surrounding mold he found a defective casting which was fit only for the scrap heap ultimately to be remelted to reclaim the metal. Fortuitously this did not occur, and the piece has survived as an instructive bit of evidence in the history of technology.

JOSEPH VEACH NOBLE
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THE ARCHON FLAVIUS STRATON (VI) PAIANIEUS

In the *Annuario* III/V (1941/1943), 102-103, No. 20, Silvio Accame published with photograph a votive fragmentary inscription, consisting of twelve fragments from the island of Lemnos (= "Iscrizioni del Cabirio di Lemno") and attributed its lettering to the first century after Christ. Three of the fragments [(1) ο/ων; (2) ο; and (3) *hedera*] Accame left unassigned, but this writer joined them to the main text of the inscription, when it was recognized (= 5—VIII—74) that the inscription from Lemnos referred to the archon Flavius Straton of *IG* II² 2124 [= 'Αρχ. 'Εφ. 1971, p. 68, No. 3], lines 2-3: ἐπὶ Φλαβίου Στράτωνος/ ἄρχοντος, who is being identified as Flavius Straton (VI) (Paianieus), with the new inscription from Lemnos confirming this, in a study to appear in the 'Αρχ. Δελτίον (see NOTE below) and belongs to the second half of the last decade of the second century after Christ, that is, A.D. 194/195-200/201, for archons have been assigned to the years A.D. 189/190-193/194 in the forthcoming study in the 'Αρχ. Δελτίον [J. Kirchner: *inter a. 190-200 p.*].[1]

After the manuscript's acceptance for publication in this journal, it came to my attention recently through an offprint, which Mlle. Simone Follet kindly sent me, that she had restored independently lines 2-4 of the inscription from Lemnos in the *Revue de Philologie* XLVIII (1974), p. 33. Consequently part of the original manuscript (up to the NOTE) was revised. Mlle. Follet left line 5 unrestored, but she did discuss the word παραπαίζων (= pp. 32-34), which must be restored in that line. My model for restoring line 5 has been *IG* II² 4787 (*s. II p.*): [Ἰού]νιος/ Ἀγαθόποδος/ Μαραθώνιος/ Διονύσῳ παραπαίζοντι = Elias Kapetanopoulos, *The Early Expansion of Roman Citizenship*

[3] The bronze hand still contains the casting core. Total length 4 1/4″.

[1] J.A. Notopoulos limited this ephebic text to about A.D. 196/197 in *Hesperia* 18 (1949) 53, and P. Graindor to A.D. 193/194-208/209 in *Chronologie* . . . , 208, No. 155. J.H. Oliver seems to prefer a date around A.D. 194 ('Αρχ. 'Εφ. 1971 [above]).

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FIG. 1. Two wax models of the head and crown of the Egyptian god Osiris

FIG. 2a

FIG. 2a and b. Interior of the wax models

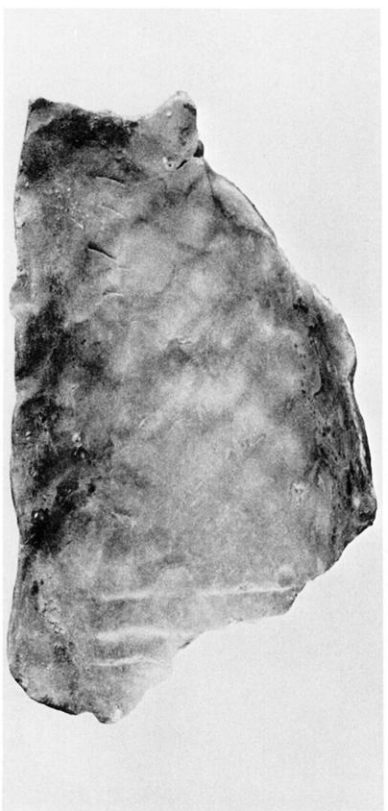

FIG. 2b

FIG. 3. Defective Hellenistic period bronze casting of a hand

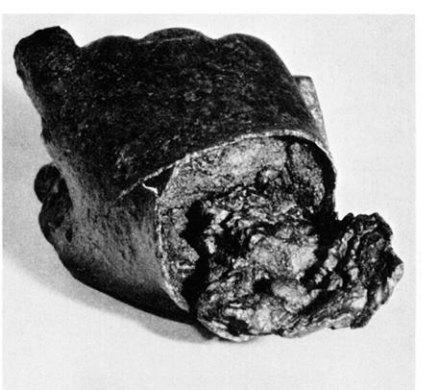

FIG. 4. Interior of defective casting

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