# Crucible or Damper?

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Some years ago, in a paper devoted to new evidence regarding bronze casting on the acropolis of ancient Pantikapaion, Michail Treister again picked up the old detailed reconstruction drawing of a metallurgical workshop found during the 1937 excavation season in Olympia,[1] and compared it with the smelting furnace and the casting pit for a mould of a statue found there, intended for the lost wax technique.[2]

This reconstruction (Fig. 1) by Kurt Kluge owes a great deal to the very realistic scenes of metallurgical workshops depicted on Attic black- and red-figure vases,[3] first and foremost on the famous "Foundry Cup" in the Berlin Museum, attributed to the Foundry Painter and dated c. 490 BC.[4] In spite of numerous adverse critical comments,[5] it is still used as a reference model (Fig. 2).

The foremost problem to solve concerns the identification of the curious vessel set on top of the furnace, at first interpreted as a "preheating crucible for alloy components". Theoretically, the separate preheating at lower temperature of the secondary components of bronze alloy would be somewhat illogical, because mixing tin – and possibly lead too[6] – directly with the charge of copper ingots lowers the melting point and the smelting is made easier.[7] However, many authors consider that bronze was obtained by simultaneous smelting of copper and tin ores, rather than by smelting ingots of these two metals together,[8] although Theophilos recommends the mixing with tin only after the melting of copper.[9] Thus, Greek bronze-makers may well have put a container for smelting tin temporarily on top of their furnaces, presumably at the end of the smelting process of copper, either to heat it separately before mixing it with the smelted copper,[10] or for brazing.[11] Conversely, one can exclude the hypothesis of a crucible intended for the direct smelting of bronze ingots either for casting[12] or soldering,[13] which would have required a temperature impossible to obtain at the upper level of the charge hole. However, as Oddy and Swadling already noticed,[14] the weight of such a crucible when filled with molten metal would be too heavy for easy handling. Even a wax content of a much lower density, intended for lost wax castings, as suggested by the same authors,[15] would have been very unlikely. Considering that the temperature at the mouth of the furnace must have been between 300 and 500°C, this material would probably have vaporized rapidly, even in a double boiler. As for the last possible liquid content

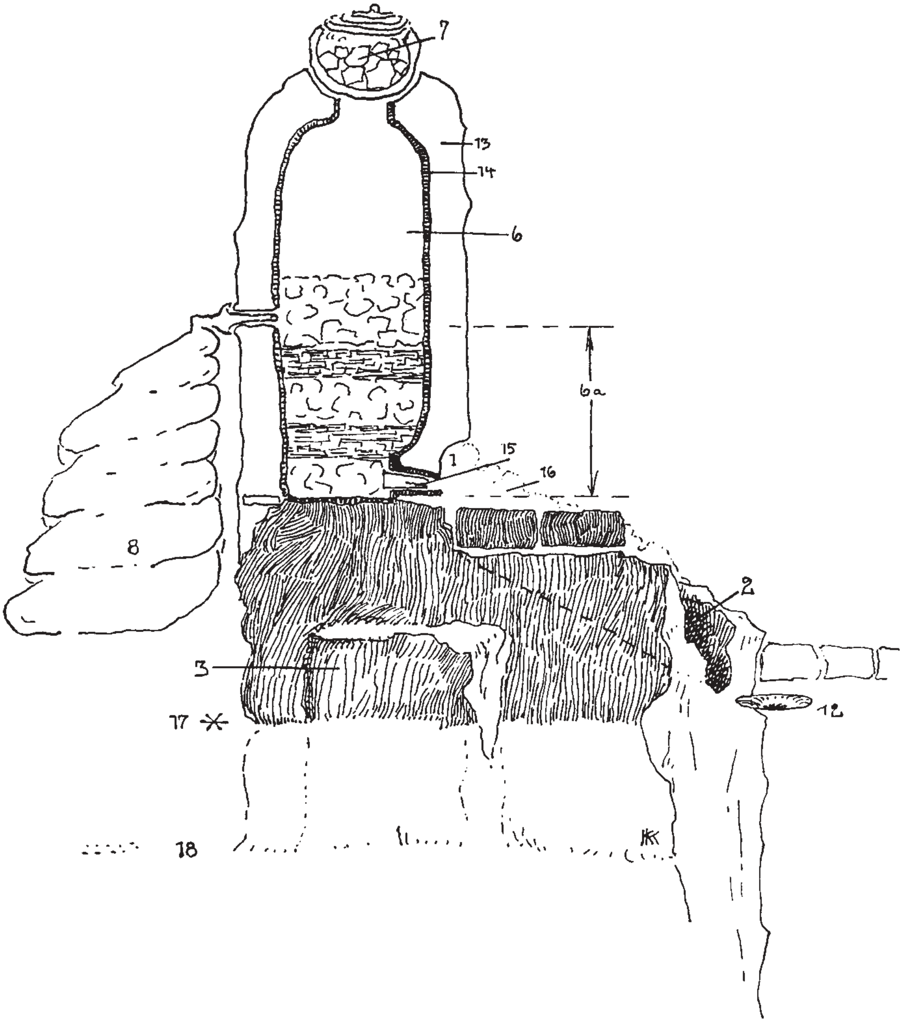


*Fig. 1. Bronze-smelting furnace at Olympia as reconstructed by Kluge (*JdI *52, 1937).*

proposed, namely water, used as humidifier within the (usually open air!) workshop,[16] its evaporation would have been even faster!

It is a pity that none of these large-sized vessels have survived in situ: both the bronze cauldron discovered in a foundry context within the Samian Heraion,[17] and the one from beneath the so-called Pheidias-workshop at Olympia[18] may well have been used for several different purposes and not solely as crucibles. As mentioned above, their existence is attested only in figured scenes on Greek vases. In addition to the Foundry Cup, it occurs on other pots as well,[19] most of the time crowning in an upright position the charge hole of the furnace, but sometimes at a slight angle. As on the Berlin

*Fig. 2. Representation of a bronze-making workshop. Foundry Cup. Berlin Museum.*

pot, we are faced with the same type of bulging container, the design of which is related to the shape of Greek cooking-pots.

At this stage, it is worth noting that in all representations, without exception,[20] this vessel is covered with an odd stepped pyramidal lid, fitted on top with a ring- or knob-grip. Two questions arise concerning the purpose and the manufacture of this lid: 1) In what cases or for what type of contents was such a device needed? 2) Are we dealing with a regular lid? If the vessel is really a container, two purposes are conceivable: either as a crucible for smelting copper, bronze alloy or tin and possibly lead, or as a kind of cauldron intended for pickle for brazing. Except in the event of a caustic pickler agent to be heated gently and carefully, it seems, at first sight, that there is basically no obvious necessity to cover the container with a lid, a *fortiori* with a special lid. Still, one must bear in mind that such metals as tin or lead are miscible with copper only in a reduced state, and for that reason, a lid would have been required to avoid oxidization inside the crucible.

Nevertheless, Attic vase-painters seem to have deliberately rendered a stacking of separate circular elements of decreasing diameter and supposedly fitting into each other, rather like the concentric rings on old-fashioned kitchen-stoves. If such was the case, it would recall the somewhat enigmatic circular implements, flat and slightly slanting in section, and of various diameters, obviously with the same clay properties as the kitchen-wares found on several sites, for example at Akragas,[21] Kamarina,[22] and Miletos.[23] These have been interpreted as stacking-devices to separate pots inside the firing-chamber of the potter's kilns (Fig. 3).

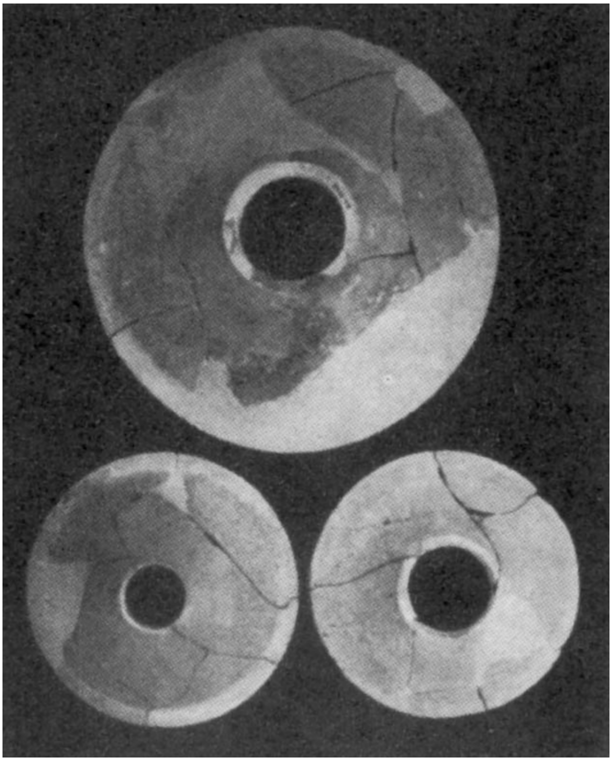

*Fig. 3. "Valvole di fornace" from Agrigento (after E. de Miro,* MonAnt *46, 1963).*

As a matter of fact, authors have mainly focused their attention on the content of the vessel, without actually noticing that when fitted into the upper charge hole of the furnace-shaft, the rounded "vessel" would have shut off, quite hermetically, the draught of the furnace,[24] and for that reason cannot have stood there permanently. The bellows operated by an attendant blew fresh air into the lower part of the shaft, but to maintain a normal draught for obtaining the required smelting temperature, a vent-hole is required at the top of the furnace[25] without a stopper.[26] Inversely, too much draught would induce overheating and prevent the forming of a reducing atmosphere, especially during the conversion of copper sulphide $Cu_2S$ into copper. For that reason, our modern blast furnaces are fitted at the mouth with some kind of damper, not only intended for draught regulation but also as a valve flap to regulate gas pressure within the shaft of the furnace (the so- called "cup and cone" exhaust valve). Therefore, the "vessel" on top of the furnace might well correspond to a gas regulation system, consisting of a bottomless fireproof vessel of kitchenware type, the rounded walls of which allowed close fitting into the charge hole and which could, to a certain extent, be swivelled round, according to the direction of wind. In order to regulate airflow and inner gas pressure, the mouth of this vessel may have been lidded by a set of concentric rings, removable when required. Unlike

Oddy and Swaddling, the present author cannot see any reason why the fact that such a device was inserted rather than being an integral part of the body of the furnace would render such an interpretation invalid. At the same time, this accessory could also have played the role of a charge-hopper, the lower part of which being perhaps funnel-shaped and not rounded.[27] Even the less hard burnt upper section of the furnace was subjected to acute weathering and thus a removable edge piece would have been required.

To sum up, the purpose of the "vessel" now seems restricted to two possibilities: a crucible for secondary components (tin, lead) of the bronze alloy, or an adjustable damper intended for draught control inside the shaft of the furnace. In the first case, one cannot exclude the possibility that, at determined stages of the smelting process (viz. each time a reducing atmosphere was required),[28] it was possible to insert a lidded (sieve?-) crucible into the top of the furnace, intended for heating secondary components of the bronze alloy with low melting point, viz. tin or lead. In the second case, there seem to be good reasons, when excavating ancient Greek metallurgical workshops, for keeping a watchful eye on the possible occurrence of a significant number of clay discs, calibrated to regulate the updraught in the case of a damper. Most important would be to determine the exact shape of the bottom of the vessel, for which evidence is still completely lacking. This would clarify our understanding of Greek bronze-making immensely.[29]

## Notes

1. Treister 1984, 150-151, fig. 3-4.
2. Kluge 1927, 13, fig. 5; Hampe & Jantzen 1937, 28-41.
3. Listed by J. Ziomecki 1975, 98-102, 154, no. 29, fig. 19, 148, no. 8, fig. 23, 155, no. 36, fig. 25; Oddy & Swaddling 1985, 43-52.
4. *CVA Deutschland* 21, pl. 72-73; Villanueva-Puig 1992, 78 (good colour illustration).
5. See recently, Vidale & Prisco 1997, esp. 110-112.
6. On the practice of adding a significant amount of lead (12.5%) in the bronzes used for statues, see Plin. *HN* 34.95, 34.97.
7. The melting temperature of a bronze alloy containing 20% stain is lowered by c. 180°C.
8. Grébénart 1988, 19. However, one cannot see how it was possible to estimate the right proportions of copper and tin ores for obtaining the type of bronze alloy needed for each purpose.
9. Theophilos, *Schedula diversarum artium* 85. But just after mixing, the temperature of the new alloy is still too close to that of the molten copper, involving a risk of solidifying too soon during the pour (Craddock 1977, 113).
10. Possibly in using some sieve-crucible pierced with one or several holes in the bottom, from which molten tin would have dripped down into the molten copper at the bottom of the shaft, as reconstructed by Kluge (1985, fig. 5).
11. The vessel may also have contained some pickling agent for surface cleaning of bronze parts before brazing.

12. Hauser 1932, 81-86.
13. Mattush 1996, 18; Heilmeyer 1993, 13-28. Ancient Greek founders actually joined the different parts of their castings by soldering them with added bronze alloy and not by brazing them with tin.
14. Oddy & Swadling 1985, 48.
15. Oddy & Swadling 1985, 48-49.
16. Vidale & Prisco 1997, 112.
17. Schmidt 1972, 77.
18. Mallwitz & Schiering 1964, 43-45.
19. Especially on the black-figured *oinochoe* British Museum B 507 (c. 510-500 BC) (Jenkins 1986, 65, fig. 85) and on the red-figured cup Ashmolean Museum 518 (by the Antiphon Painter, c. 480) (*CVA Oxford* 1, pl. 2.8; Villanueva-Puig 1992, 80).
20. The only unlidded example illustrated by Schwandner, Zimmer & Zwicker 1983, 69, fig. 8f (=black-figured *lekythos*, Providence, Museum of the Rhode Island School of Design, inv. 25.109), obviously corresponds to a simple cauldron for providing public baths with hot water.
21. De Miro 1963, 156, fig. 71-72 ("valvole di fornace"). Diameters ranging from 3.3 to 29.7 cm.
22. Di Stefano 2001, 32, fig. 2 ("coperchi").
23. Recent excavations at Miletos have produced quite a number of such rings, seemingly still unpublished. For this piece of information, I am indebted to Dr. P. Hommel.
24. No other vent hole is visible in the upper part of the furnace, and on the Berlin Foundry Cup the vase-painter even rendered hot fumes emanating from under the vessel.
25. Pliny twice points out the importance of the flaming up – "in ipso fornacium ore, qua flammae eructantur" (34.101) and of the emission of copper particles "ac repente vehementiore flatu exspuitur aeris palea quaedam. Solum, quo excipiatur, stratum esse debet marilla" (34.130).
26. However, Dioskorides (5.84) reports the insert of some wire-netting to collect the *cadmea*.
27. Kluge 1927, 13, fig. 5.
28. Stopping operating the bellows meant that the resultant atmosphere was not reducing enough.
29. I am much indebted to André Cochet, Michel Fournier and Maurice Picon for kind information and advice. The illustrations have been processed by Yves Montmessin.

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