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Copper Ewers of Early Dynastic and Old Kingdom Egypt – An Investigation of the Art of Smithing in Antiquity

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(Tafeln 31–36)

Introduction

Studies of a number of ancient Egyptian gold and silver vessels served as the initial impetus for the examination of a Sixth Dynasty copper ewer (MMA 26.2.14), found at Saqqara in the funerary chamber of Tjetju, and now in the Metropolitan Museum of Art[1]). Particularly puzzling about the Tjetju ewer was its overall fabrication; to create a vessel with such broad shoulders and then to narrow the form to a very small opening is a tour-de-force of smithing. This difficult task has been thought to be beyond the range of possibilities for early metalworkers, who used only tools of stone, wood, horn and hardened copper or arsenical copper.

This type of ewer, called a *ḥsmny*[2]), was common in the Early Dynastic and Old Kingdom periods; with their accompanying basins, such ewers are generally described as being made of unalloyed copper[3]). RADWAN describes a relatively squat vessel with a wide open mouth and short

[1]) Ewer, MMA 26.2.14, 6th dynasty, from the tomb of Tjetju at Saqqara, unalloyed copper (?), ht. 12.5 cm, New York, Metropolitan Museum of Art, Rogers Fund, 1926; C. M. FIRTH & B. GUNN, *Teti Pyramid Cemeteries* 2 vols. (Cairo 1926) I, p. 30, fig. 31, bottom; W. C. HAYES, *The Scepter of Egypt* rev. ed., 2 vols (New York 1990), I, pp. 119f., fig. 74, right; W. K. SIMPSON, *Two Egyptian Bas-Reliefs of the Late Old Kingdom,* in: *North Carolina Museum of Art Bulletin* 11, no. 3 (12/1972) 4–13, p. 4, n. 5, fig. 6; and A. RADWAN, *Die Kupfer- und Bronzegefäße Ägyptens (Von den Anfängen bis zum Beginn der Spätzeit), PBF* II, 2 (München 1983) p. 59, no. 146 B, pl. 27. The restorations visible in the photographs in these publications have recently been removed.

[2]) *Wb,* III, p. 163.

[3]) It is generally stated that such hammered vessels are of unalloyed copper because bronze, excepting a handful of cases, was not in use in Egypt until the Middle Kingdom. A number of vessels in different collections have been analyzed. A recent catalogue of the Early Dynastic objects in the British Museum includes analysis of two ewers without provenance and a ewer with basin from the Second Dynasty tomb of Khasekhemwy, as well as a reference to analysis carried out on a crushed ewer (UC 8569) (sic!) and an unattached spout (UC 8572), both described as from the tomb of Khasekhemwy, in the Petrie Museum of Egyptian Archaeology at the University College Collection in London. According to BARBARA ADAMS of the Petrie Museum (personal communication, June, 1989), the association of the ewer with the tomb of Khasekhemwy is not certain and the accession number is UC 8570. The unprovenanced British Museum ewers (EA 29609 and 29610) were found to contain significant amounts of arsenic; the ewer from the Petrie Museum, the spout of one British Museum ewer (EA 29609) and the Petrie Museum Khasekhemwy spout contained 1% or less arsenic. The spout on the second unprovenanced British Museum ewer is unalloyed copper. The British Museum Khasekhemwy ewer and basin (EA 35571 and 35572) were found to be tin bronzes with a small amount of lead and the spout an arsenical copper. The basin also contained a substantial amount of arsenic. See A. J. SPENCER, *Early Dynastic Objects (Catalogue of Egyptian Antiquities in the British Museum,* vol. 5) (London 1980) pp. 83f., nos. 594–597, p. 88, pls. 67–68. Of the models from the sixth dynasty tomb of Impy at Giza studied by MADDIN, STECH, ET AL., including "hollow-ware" but no ewers, all were found to be unalloyed copper; R. MADDIN, T. STECH, ET AL., *Old Kingdom Models from the Tomb of Impy: Metallurgical Studies,* in: *JEA* 70 (1984) 33–41. A ewer and basin formerly in the Acerbi Collection and now in the Archaeological

spout, as the earliest *ḥsmny,* dating it to the middle of the Second Dynasty[4]). Other early vessels have similar open mouths, but also longer and more slender spouts. During the later Early Dynastic and Old Kingdom periods, the ewers become proportionately taller, their bottoms and openings relatively smaller, and the spouts considerably longer.

The ewers and basins are said to have been used in everyday life for washing one's hands at mealtimes[5]), but excavated examples all come from tombs.

Workshop scenes illustrating two steps in the manufacture of the ewers can be seen on the reliefs lining the causeway of Unas at Saqqara[6]). The ewers are shown as completed, in their basins, and it is not clear from the representations alone what exactly the workers are doing[7]). What appears to be a representation of the hammering of the bottom of a basin appears in the Fifth Dynasty tomb of Iymery at Giza[8]).

The extant metal ewers range in size from large-scale examples of greater than twenty centimeters in height to miniature models of less than two centimeters. Stone[9]) and terra-cotta[10]) ewers and basins have also been found in burials[11]), and there are examples of dummy ewer and basin sets, with the ewer sitting inside the basin and both carved from a single piece of stone[12]).

The ewers are believed to have been adopted for ritual use already during the Old Kingdom[13]). In a relief representing the funerary banquet of Perneb, from his late Fifth Dynasty tomb near Saqqara and now in the Metropolitan Museum[14]), two sets are seen. Both ewers have knobbed lids and are sitting in basins. In addition to representations of the ewers resting on tables or on the floor near the deceased, they are often seen being carried by priests[15]) and very occasionally being used in purification and libation rituals[16]). JUNKER links the domestic and ritual

Museum in Mantua have been reported as arsenical copper; G. ALESSANDRINI, E. BERNACCHI, ET AL., *The Egyptian Bronzes of the Acerbi Collection: Technical Examination,* in: *Arte Lombardia* 76–77 (1986) 118–30. Many examples of early Egyptian hammered copper or copper alloy objects, including the ewers and their basins, are heavily mineralized, causing difficulties both in their sampling and in the interpretation of analyses.

[4]) A. RADWAN, *op. cit.,* p. 17f., no. 45, pl. 8. He suggests that ewers were first manufactured in the First Dynasty (p. 17 and no. 2). There are two large copper vessels with bails and long spouts from grave 3471 at Saqqara, associated with the First Dynasty King Djer. W. B. EMERY, *Great Tombs of the First Dynasty I* (Cairo 1949) 20f., fig. 14 (3), pl. 8. A. RADWAN, *op. cit.,* p. 27, no. 66 A and B, pl. 13, classifies the vessels as "Sonderformen" but it is possible that they represent an earlier type of *ḥsmny.*

[5]) For discussions of these ewers and basins, see Do. ARNOLD, in: *LÄ* III, s.v. *Gefäße,* and ID. *LÄ* V, s.v. *Reinigungsgefäße*; H. BALZC, *Die Gefäßdarstellungen des Altes Reiches,* in: *MDAIK* 3 (1932): 50–88 (pt 1), 89–114 (pt 2), pp. 95–97, ID., in: *MDAIK* 5 (1934): 45–94 (pt. 4), pp. 45f.

[6]) S. HASSAN, *Excavations at Saqqara,* 1937–1938, in: *ASAE* 38 (1938): 503–22, pl. 96.

[7]) The inscriptions have been tentatively translated as "Die Schnauze (des Gefäßes) befestigen" and "Das Handwaschgerät aus Elektrum *tpj*-machen"; B. SCHEEL, *Studien zum Metallhandwerk im Alten Ägypten I, Handlungen und Beischriften in den Bildprogrammen der Gräber des Alten Reiches,* in: *SAK* 12 (1985): 118–77, pp. 149, 172f.

[8]) *LD* II, pl. 49; a completed ewer and basin are sitting on the shelf above the worker.

[9]) A. EL-KHOULI, *Egyptian Stone Vessels, Predynastic Period to Dynasty III,* 3 vols., *SDAIK* 5 (1978) s.v. "class X", I, pp. 366ff., III, pls. 90–91.

[10]) See *Meisterwerke Altägyptischer Keramik, 5000 Jahre Kunst und Kunsthandwerk aus Ton und Fayence,* exhib. cat., Sept. 16 – Nov. 30, 1978, Keramik Museum Westerwald, Höhr-Grenzhausen, Hachenburg 1978, no. 150.

[11]) Do. ARNOLD, Reinigungsgefäße, (see n. 5), pp. 213f.

[12]) See i.e., H. JUNKER, *Giza* III, p. 214, fig. 39, bottom right, for a limestone example.

[13]) H. JUNKER, *op. cit.,* pp. 104–06, fig. 10, no. 3, pl. II, fig. 15 (p. 146).

[14]) MMA 13.183.3; W. C. HAYES, *op. cit.,* I, figs. 52–53. Such representations are known already in the Second Dynasty as in, for example, a scene from Saqqara illustrated in W. S. SMITH, *Art and Architecture,* 1981, fig. 32.

[15]) H. JUNKER, *op. cit.,* II, figs. 9 (p. 119) and 15 (p. 146).

[16]) For example, if one accepts the spouted vessel held by a priest in a wall painting from the tomb of Kaemankh as a *ḥsmny*; H. JUNKER, *op. cit.,* IV, pl. 16, lower left. See also, G. A. REISNER, *The Servants of the Ka,* in: *BMFA* 32 (1934): 2–12, pp. 8f.

functions of the ewer in his discussion of an alabaster offering table from Giza. This table is carved in a single piece with a dummy ewer nested in its traditional round basin. The spout of the ewer hangs over a low rectangular offering basin that would receive the water libation[17]).

The shape of the vessels used for washing one's hands in daily life changes in the Middle and New Kingdoms[18]), but the Old Kingdom type continues to appear in ritual scenes through the New Kingdom[19]). The manufacture of the ewers also continues to be represented in workshop scenes where funerary equipment and ritual vessels are being produced[20]).

Representations of ewers with a variety of covers or tops can be cited[21]) but in spite of this, examples of the copper or copper alloy covers themselves appear to be unknown. It is possible that the covers were made from another, more perishable, material.

In all, sixteen ewers in several institutions were examined in the course of this study. In addition to the Tjetju ewer, three others in the Metropolitan Museum of Art were examined, including a second example (MMA 26.2.15) from Tjetju's tomb (pl. 31 a)[22]), another Old Kingdom example (MMA 26.9.13) acquired by purchase (pl. 31 b)[23]), and a New Kingdom "replica" (MMA 98.4.66) excavated at Dendera (pl. 32 a)[24]).

17) H. Junker, *op. cit.,* X, p. 145 f., fig. 53, pl. 22 a. Representations of *ḥsmny* continue to appear on offering tables throughout pharaonic times; a late example is one inscribed to Nectanebo in the Egyptian Museum in Cairo (*CG* 23114).

18) Do. Arnold, *Reinigungsgefäße,* (see n. 5), fig. 1. An example of a New Kingdom washing vessel and basin represented in a domestic context is seen in the tomb of Amenhotpesise; No. de G. Davies, *Tombs of Two Officials,* pl. 6.

19) A Middle Kingdom example is illustrated on the outer coffin of Djehuty-nakht from Bershah; E. L. B. Terrace, *Egyptian Paintings of the Middle Kingdom, The Tomb of Djehuty-Nekht* (New York 1968) pl. I, VIII. There appear to be no extant examples from unequivocably Middle Kingdom contexts. Ewers and basins from el-Lisht and Gebelein were found among material dating from the Old Kingdom through the Middle Kingdom and it is as yet unclear when they were manufactured and when or how long they were in use. The el-Lisht ewer was formerly in the Metropolitan Museum of Art (32.1.174) and is now in the Oriental Institute in Chicago (O.I. # 19455); A. Lansing, *The Egyptian Expedition 1931–32, BMMA* 28, sect. II (1933): 3–22, p. 22, fig. 19, and A. Radwan, *op. cit.,* p. 40, no. 107. The Gebelein ewer is now in the Museo Egizio in Turin (suppl. 13721); A. M. D. Rovari, ed., *Dal Museo al Museo: Passato e Futuro del Museo Egizio di Torino* (Turin 1989) pp. 101 f., figs. 18–19, and A. Radwan, *op. cit.,* p. 64, no. 168, pl. 35. There are a few known New Kingdom metal replicas, or "reinterpretations", of the Old Kingdom type, one of which is in the Metropolitan Museum and will be discussed below. Examples of two-dimensional representations of New Kingdom heirloom ewers appear in a ritual scene in the temple of Seti I at Qurneh and in the burial chamber of Sobekmose at Thebes; W. M. F. Petrie, *Qurneh* (London 1909) pl. 45, and W. C. Hayes, *op. cit.,* II, fig. 165. In New Kingdom representations, the ewers are generally seen on stands or resting directly on tables, rather than nesting in their basins.

20) P. E. Newberry, *The Life of Rekhmara* (London 1900), p. 37, pl. XVII.

21) H. Balcz, *Gefäßdarstellungen,* (see n. 5), pt. 1, fig. 13.

22) Ewer, MMA 26.2.15; 6th dynasty, from the tomb of Tjetju at Saqqara, unalloyed copper(?), ht. 21.5 cm, New York, The Metropolitan Museum of Art, Rogers Fund, 1926; Firth-Gunn, *op. cit.,* I, p. 30, fig. 31, top; W. C. Hayes, *op. cit.,* I, pp. 119–20, fig. 74, center; W. K. Simpson, *op. cit.,* p. 4, n. 5, fig. 6, and A. Radwan, *op. cit.,* p. 59, no. 146 A, pl. 27.

23) Ewer, MMA 26.9.13, 5th dynasty(?), provenance unknown, copper, with an arsenical surface, ht. 11.0 cm, New York, The Metropolitan Museum of Art, Gift of Edward S. Harkness, 1926; published by W. C. Hayes, *op. cit.,* I, p. 120, fig. 74, left, as Sixth Dynasty. A. Radwan, *op. cit.,* p. 40, no. 106, pl. 20, suggests that the ewer found by G. A. Reisner at Naga ed-Der, which he dates to the end of the Third Dynasty, is the one now in the Metropolitan Museum. A description of the cleaning of the Metropolitan Museum ewer and its basin, and what turned out to be at least partially inaccurate results of an early scientific investigation, appeared in C. G. Fink, A. H. Kopp, *Ancient Egyptian Antimony Plating on Copper Objects: A Rediscovered Ancient Egyptian Craft,* in: *MMS* 4 (1933): 163–67. The coating was reanalysed and identified as arsenical by C. S. Smith, *An Examination of the Arsenic-Rich Coating on a Bronze Bull from Horoztepe,* in: *Application of Science in Examination of Works of Art,* ed. W. J. Young (Boston 1970), pp. 96–102, see n. 5. The ewer and its basin are discussed, along with other copper artifacts with arsenical coatings, including ancient Egyptian mirrors, and a general overview of arsenical copper in the Mediterranean in antiquity, in: E. R. Eaton, H. McKerrell, *Near Eastern Alloying and Some Textual Evidence for the Early Use of Arsenical Copper,* in: *World Archaeology* 8, no. 2 (1976–77): 169–91.

24) Ewer, MMA 98.4.66, 19th dynasty, from Dendera, leaded bronze, ht. 13.7 cm, New York, The Metropolitan Museum of Art, Gift of Egypt Exploration Fund, 1898; W. M. F. Petrie, *Denderah* (London 1898) pp. 34, 65, pl. 24, no. 4, and A. Radwan, *op. cit.,* p. 123, no. 364, pl. 64. The ewer was found out of context, with a number of other vessels dating to

Additionally, a Second Dynasty ewer (U.M. E 14242) from Sedment (pl. 32b, d)[25]), a Third Dynasty ewer (U.M. E 9998) from Beit Khallaf (pl. 32c)[26]) and a model (or miniature) ewer (U.M. E 4726) from Abadiya dated to the Sixth Dynasty (pl. 36c)[27]) were loaned by The University Museum in Philadelphia. Two Sixth Dynasty model ewers from Giza, one (MFA 13.2947) from the tomb of Impy (pl. 33a)[28]) and a second (MFA, Giza field no. 14-2-95) from an unidentified tomb[29]), as well as a number of Old Kingdom model *nmst* vessels[30]) in the Museum of Fine Arts in Boston were also examined. *Nmst* vessels are related to the *ḥsmny* in shape and function[31]).

The study of these objects was done primarily through visual examination, x-radiography[32]) and replication experiments. As a result of these examinations, some of the various methods of raising, casting and joining proposed by earlier researchers for the manufacture of the ewers and their spouts could be evaluated.

Visual examination of Early Dynastic and Old Kingdom ewers in the Petrie Museum of Egyptian Archaeology of the University College in London[33]) and in the Musée du Louvre[34]) also

the New Kingdom, including another ewer inscribed with the name of Ramesses II; W. M. F. Petrie, *Denderah*, p. 34, pl. 24, no. 6.

[25]) Ewer, U.M. E 14242, 2nd dynasty, from tomb 560 at Sedment, unalloyed copper (?), ht. 11.0 cm, Philadelphia, The University Museum; W. M. F. Petrie, G. Brunton, *Sedment* 2 vols. (London 1924) I, p. 2, pl. 1 nos. 1, 5; pl. 2, no. 1, and A. Radwan, *op. cit.*, pp. 19 f., no. 57, pl. 11.

[26]) Ewer, U.M. E 9998, 3rd dynasty, from the tomb of Sanekht (K 2) at Beit Khallaf, unalloyed copper (?), ht. 7.0 cm, Philadelphia, The University Museum; unpublished.

[27]) Model ewer, U.M. E 4726, 6th dynasty, from tomb D 7 at Abadiya, unalloyed copper (?), ht. 2.0 cm, Philadelphia, The University Museum; W. M. F. Petrie, *Diospolis Parva, the Cemeteries of Abadieh und Hu* (London 1901) p. 37, pl. 25, top, middle, and A. Radwan, *op. cit.*, p. 64, no. 166, pl. 35.

[28]) Model ewer, MFA 13.2947, 6th dynasty, from the tomb of Impy at Giza, unalloyed copper (?), ht. 11.0 cm, Boston, Museum of Fine Arts, Harvard University-Museum of Fine Arts Expedition; G. A. Reisner, *New Acquisitions of the Egyptian Department: A Family of Builders of the Sixth Dynasty, about 2600 B. C.*, in: *BMFA* II (1913): 53-66, pp. 58 f., figs. 13, 15; G. A. Reisner, C. S. Fisher, *Preliminary Report of the Work of the Harvard Boston Excavation in 1911-13*, in: *ASAE* 13 (1913): 227-52, pp. 250 f., pl. IX, no. 13, and A. Radwan, *op. cit.*, p. 61, no. 153 A, pl. 28.

[29]) Model ewer, MFA not accessioned, 6th dynasty, Giza tomb no. 4733 E, field no. 14-2-95, ht. 6.5 cm, Boston, Museum of Fine Arts, Harvard University-Museum of Fine Arts Expedition; unpublished.

[30]) Included among these *nmst* vessels were nine from the tomb of Impy (13.2957, 13.2970, 13.2973, 13.2982, 13.3048, 13.3251, 13.3253, 13.3254, 13.3255) and one from each of the following two tombs: Sheikh Farag, tomb 5052 (MFA 24.740) and Giza, tomb 2360 A (field no. 12-11-20).

[31]) The *nmst* vessel, whose closed shape offers a similar technical challenge, relates to and finally merges with the *ḥsmny* in ritual functions; Do. Arnold, *Reinigungsgefäße*, (see n. 5), pp. 214 f.

[32]) All radiographs made in the Objects Conservation Department of the Metropolitan Museum of Art (MMA and University Museum ewers) were shot with a Phillips-Norelco MG 300 Industrial x-ray unit with a 32" film-to-target distance. Exposures at 200 kilovolts and above were made with Kodak M-5 Industrial x-ray film between .005" lead filters. Lower exposures were made with Kodak Redi-pak Industrex M film. Radiographs made in the Research Laboratories of the Museum of Fine Arts were shot with a Phillips MGC-03 x-ray unit with a 1 meter film-to-target distance using Kodak Redi-pak film and a single .25" filter beneath the film. All films were developed manually using standard Kodak products. All radiographs were shots at 5 milliamperes. Kilovoltage and time of exposure of the radiographs illustrated in this article are noted in the respective captions.

[33]) The following pieces in the Petrie Museum of Egyptian Art were examined: UC 8569 (spout), 2nd dynasty, from the tomb of Khasekhemwy at Abydos, l. 3.0 cm; W. M. F. Petrie, *Stone and Metal Vases* (London 1937) p. 26, no. 1, pl. XXXIX, and A. Radwan, *op. cit.*, p. 19, no. 51 (attached to reconstructed vessel (UC 8570) of unknown provenance, see above n. 3); U.C. 8573, 3rd dynasty (?), provenance unknown, ht. 11.8 cm; A. Radwan, *op. cit.*, p. 40, no. 108, pl. 20; UC 8534, 3rd dynasty (?), provenance unknown, ht. 9.2 cm; W. M. F. Petrie, *Metal Vases*, p. 25, no. 3, pl. XXXIX, and A. Radwan, *op. cit.*, pp. 39 f., no. 102, pl. 19; UC 8570 (ewer without spout), 2nd dynasty, provenance unknown, reconstructed ht. ca. 7.5 cm; A. Radwan, *op. cit.*, p. 19, no. 51.

[34]) The following four vessels in the Louvre were examined: AE 25979, 6th dynasty, from the tomb of Isi at Edfu, unalloyed copper (?), ht. 6.4 cm; K. Michalowski, Ch. Desroches et. al., *Tell Edfou: Fouilles franco-polonaises III*, (Cairo

Table 1 Ewers (*ḥsmny*)

Collection	Acc. No.	Height	Date[1])	Provenance
Petrie Mus.	UC 8569[2])	3.0 cm.	2nd dyn.	Abydos
Petrie Mus.	UC 8570	(7.5 cm.)[3])	2nd dyn.	unknown
Univ. Mus.	E 14242	11.0 cm	end 2nd dyn.	Sedment
Univ. Mus.	E 9998	11.0 cm	3rd dyn.	Beit Khallaf
Petrie Mus.	UC 8534	9.2 cm.	3rd dyn.	unknown
Petrie Mus.	UC 8573	11.8 cm.	end 3rd dyn.	unknown
MMA	26.9.13	11.0 cm.	5th dyn.?	unknown
MMA	26.2.15	21.5 cm.	beg. 6th dyn.	Saqqara
MMA	26.2.14	12.5 cm.	beg. 6th dyn.	Saqqara
Louvre	AE 25979	6.4 cm.	beg. 6th dyn.	Edfu
Univ. Mus.	E 4726	2.0 cm.	6th dyn.	Abadiya
Louvre	AE 3912	17.3 cm.	6th dyn.	unknown
Louvre	N 887	18.3 cm.	6th dyn.	unknown
Louvre	AE 6926	16.6 cm.	6th dyn.	unknown
MFA	13.2947	7.0 cm.	6th dyn.	Giza
MFA	14-2-95[4])	6.5 cm.	6th dyn.	Giza
MMA	98.4.66	13.7 cm.	19th dyn.	Dendera

[1]) Dates of unexcavated objects after RADWAN.
[2]) Unattached spout.
[3]) Estimation by RADWAN; the vessel is entirely crushed.
[4]) Field number (not accessioned).

provided insight into these questions, although no radiographic examinations were undertaken. A register of the *ḥsmny* and *nmst* vessels examined appears in Tables 1 and 2.

Ewers are not well represented in the material surviving from the Fourth and Fifth Dynasties[35]), and no securely dated examples were available for inclusion in this study. This gap may misleadingly overemphasize some of the technical features described as characteristic of the Sixth Dynasty.

The two basic metalworking methods used in antiquity - hammering and casting - were employed in the manufacture of the ewers. In all of the examples examined, the vessels were made separately from their spouts. Three major steps in ewer production are considered: the manufacture of the vessels, the manufacture of the spouts and their attachment. For the sake of accuracy and consistency some terms used to describe metalworking methods, both those proposed by earlier researchers or those observed in the course of these examinations, will be defined in the discussions below.

1950) pp. 43 ff., 48, 191, pl. XXI, no. 10, and A. RADWAN, *op. cit.,* pp. 64 f., no. 169, pl. 36; AE 3912, 6th dynasty, provenance unknown, unalloyed copper (?), ht. 17.3 cm; A. RADWAN, *op. cit.,* p. 67, no. 180, pl. 40; N 887, 6th dynasty, provenance unknown, unalloyed copper (?), ht. 18.3 cm; A. RADWAN, *op. cit.,* p. 67, no. 181, pl. 41; AE 6926, 6th dynasty, provenance unknown, unalloyed copper (?), ht. 16.6 cm; unpublished.

[35]) A. RADWAN, *op. cit.,* includes one Fourth Dynasty ewer and basin set (p. 45, no. 119, pl. 22) and three ewer and basin sets (p. 52, nos. 129 A, B, 132 A, pl. 24) of the Fifth Dynasty. The Fourth Dynasty example is full-sized; the other three are all models, as are the bulk of cupreous vessels gathered by RADWAN for this period (p. 51).

Table 2 Vessels (*nmst*)

Collection	Acc. No.	Height	Date	Provenance
MFA	13.3254	5.3 cm.	6th dyn.	Giza
MFA	13.2957	5.1 cm.	6th dyn.	Giza
MFA	13.2973	4.8 cm.	6th dyn.	Giza
MFA	13.3048	6.3 cm.	6th dyn.	Giza
MFA	12-11-20[1])	6.5 cm.	6th dyn.	Giza
MFA	13.3255	4.8 cm.	6th dyn.	Giza
MFA	13.2982	4.5 cm.	6th dyn.	Giza
MFA	13.2970	6.3 cm.	6th dyn.	Giza
MFA	13.3251	6.5 cm.	6th dyn.	Giza
MFA	13.3253	6.5 cm.	6th dyn.	Giza
MFA	24.740	3.7 cm.	1st IP	Sheikh Farag

[1]) Field number (not accessioned).

The Manufacture and Attachment of the Spouts

Some spouts were made from mechanically-joined thin metal strips; others were cast in a single piece. Raising a spout from a single piece of metal either as an independant component or continuous with the walls of the vessel, although possible for a very accomplished smith, is not thought to have been undertaken by copper workers in the first half of the third millennium B.C.

Various examples of spouts constructed using rivets, small flaps or "tabs", and crimped edges, were found among the pieces examined, for example, the model ewer (MFA 13.2947) from the tomb of Impy at Giza (pl. 33a) and two of the large Sixth Dynasty ewers in the Louvre (AE 3912, N 887).

Hammered and mechanically joined spouts are generally made from two pieces of metal, one that is "U" or "V" shaped in cross-section forming the sides, and a flat sheet forming the top. Both pieces have flanges for attachment to the vessel itself. On Impy's ewer the top sheet, which is about two thirds the length of the whole spout, has two round edged tabs that fold over the sides and are held with small rivets where the spout is joined to the ewer. Two more small flaps with square edges, extending from near the end of the top, are crimped over the sides and the top edges of the side piece are crimped over the top sheet (fig. 1 and 2).

One small spout (UC. 8569) in the Petrie Museum was made from a single piece of metal carefully designed and cut out so that it could be folded and joined with a single tab on the top.

In view of the types of cast objects produced in Egypt in the Pre- and Early Dynastic Periods[36]) and the difficulties associated with casting unalloyed copper[37]), it is surprising to find that

[36]) The repertoire of early Egyptian copper and copper alloy objects is relatively small; beads, pins and borers were produced in the Badari Period and other small items, including needles, tweezers, rings, harpoon heads, etc., as well as weapons, appeared shortly thereafter. In the Early Dynastic period a large variety of weapons, domestic vessels and utensils, including mirrors and agriculture and manufacturing tools were produced. The few early copper sculptures found in Egypt include the very small Early Dynastic figures found at Abydos by PETRIE and a statue of the Second Dynasty King Khasekhemwy that is known only from documentary sources; cf. A. LUCAS, *Ancient Egyptian Materials and Industries* (London 1962[4]) pp. 212ff.

[37]) The addition of small amounts of arsenic to copper generally improves the working qualities - in particular the hardness - of the finished metal. Alloying makes the metal easier to cast by lowering its melting point and alloyed copper

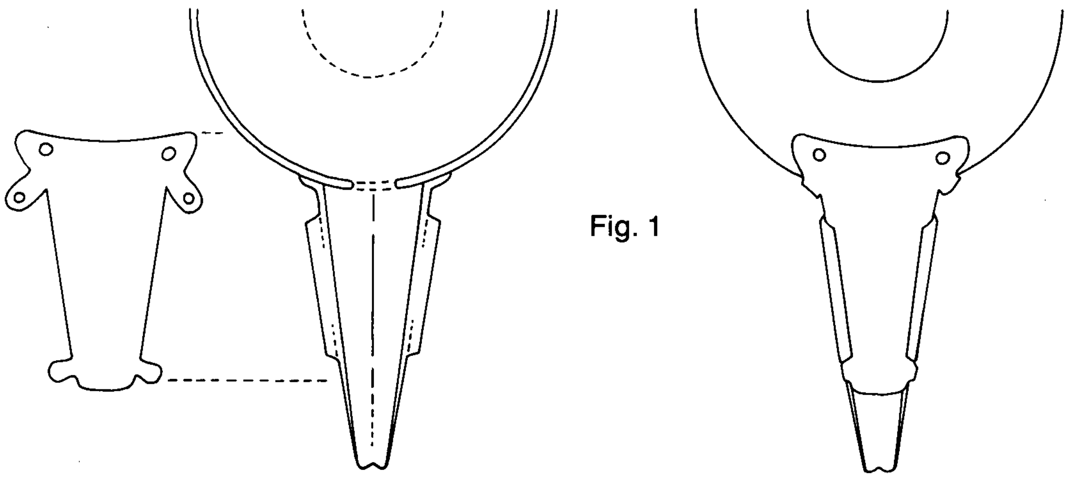

Fig. 1

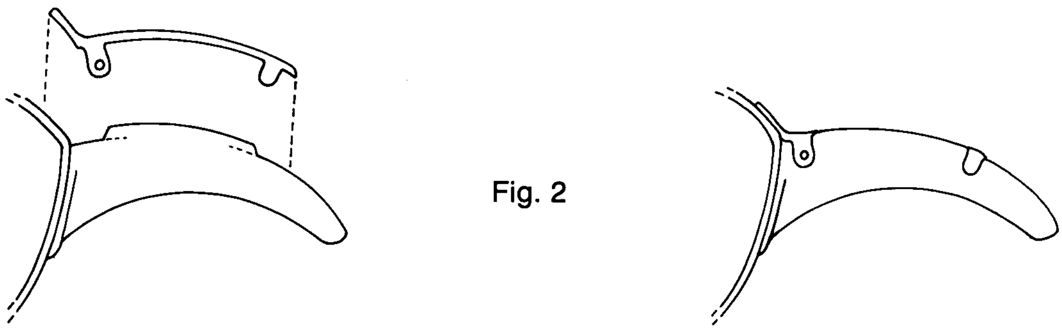

Fig. 2

Fig. 1 and 2: Construction of spout from ewer (MFA 13.2947), top and side views (see pl. 33a).

the majority of the spouts were cast; in fact, this method of manufacture had been suggested in a number of earlier descriptions[38]). Cast spouts seem to be more typical for the earlier pieces, that is from the Early Dynastic Period to the beginning of the Fourth Dynasty or Fifth Dynasty.

Appearing at a time when copper or copper alloy casting in Egypt is not particularly sophisticated, these hollow cast spouts, and particularly the ones with two separate channels[39]), seem quite innovative. The radiograph of the spout of the Beit Khallaf ewer (U.M. E9998), as well as its general appearance, indicate that it was cast (pls. 32c; 33b). However, the radiographs of most of the spouts believed to be cast, for example, those of the Sedment ewer (U.M. E14242) and the unprovenanced Old Kingdom ewer (MMA 26.9.13) in the Metropolitan Museum of Art, reveal little positive evidence supporting this assumption. In the absence of metallographic examina-

artifacts generally have less porosity than unalloyed ones. Different alloying components can be responsible for several different conditions or mechanisms, for example, improved pourability or deoxidation of the melt, that would result in a less porous casting.

[38]) See, i.e. A. Radwan, *op. cit.*, p. 19, nos. 52–54; A. Lucas, *op. cit.*, p. 215, and A. J. Spencer, *op. cit.*, p. 83, no. 594.

[39]) A. Radwan, *op. cit.*, i.e., pls. 10, 17. These spouts become less common in the Third Dynasty and then seem to disappear entirely.

tion[40]), it is mostly the lack of any evidence of assembling that leads one to conclude that these spouts were cast. The spout of MMA 26.9.13 (pl. 31 b) was sampled for metallography at some time before 1933 and is reported to be cast[41]).

* * *

Generally, for the joining of metals there are two possibilities: mechanical and metallurgical. The latter encompasses several methods, including soldering, casting-on, forge welding and autogenous welding. For the sake of clarity each of these four methods is defined below.

Soldering is the process of joining two pieces of metal using a second metal or alloy called a solder, which fluxes at a lower temperature. Soldering is carried out at a temperature sufficient to at least partially liquefy the solder, allowing it to run into the join. It solidifies upon cooling. The metals are bonded together not mechanically, but by the interdiffusion of the metal atoms between the solder and the substrate metal that occurs at elevated temperatures. Soft and hard solders refer to low and high melting solders; the term brazing, generally used in modern industrial contexts, and sometimes found in discussions of ancient technology, refers to high temperature soldering.

Lucas discounted the use of solder for Old Kingdom ewers although he cites other cases of soldering in ancient Egypt[42]). In fact, there is only sporadic evidence for any kind of soldering in antiquity before the first millennium B.C.[43]) Whereas high temperature soldering clearly posed a number of difficulties for ancient craftsmen, it is intriguing that low-melting lead or lead-tin solders were not used earlier than this time. The necessary materials were available and the technology is relatively unsophisticated. The presence of lead solder - or even its traces - is easy to recognize in visual, and especially in radiographic, examinations.

Welding can be described as the joining of two pieces of the same metal without the addition of a second, filler metal or alloy; this usually takes place at an elevated temperature. The term forging is often used, particularly by practising metalsmiths, to indiscriminately describe both forge welding, and the hammering processes (i. e. raising, sinking) carried out at ambient temperature for the purpose of shaping metal. To avoid confusion, processes carried out at room temperature are better called cold working.

Forge welding is the process of joining by hammering the pieces while heating them, and its use in antiquity has thus far only been demonstrated for iron and steel. Von Bissing suggests that cast spouts were attached to their ewers by forge welding, while using the word "Löthflächen" to describe the flanges "soldered" in this manner[44]). His observations and terminology are repeated by Radwan[45]). In fact, due to the high melting point of the copper oxide formed at elevated temperatures, intimate contact on an atomic level between the two pieces to be joined does not occur, and this method may be considered unlikely in the case of the ewers.

[40]) As mentioned previously, many Old Kingdom vessels are entirely mineralized. Whereas some investigations have focused on the metallography of entirely corroded bronze artifacts, where the now-lost metallic structure can be sometimes seen in tin corrosion products, little work has been carried out in the examination of similarly highly corroded unalloyed copper or arsenical copper cross sections.

[41]) C. G. Fink, A. H. Kopp, *op. cit.,* pp. 164 f. The whereabouts of this section is unknown.

[42]) A. Lucas, *op. cit.,* pp. 215 f.

[43]) A well documented case of the hard soldering of silver in the beginning of the third millennium B.C. in Iran is found on a small kneeling silver cow in the Metropolitan Museum; D. Hansen, *A Proto-Elamite Silver Figurine in The Metropolitan Museum of Art,* in: *MMJ* 3 (1970): 5-14, and K. C. Lefferts, *Technical Examination,* pp. 15-24. See also, P. T. Craddock, *Tin and Tin Solder in Sumer: Preliminary Comments,* in: *MASCA Journal* 3 (1984-85): 7-9.

[44]) F. W. von Bissing, *Metallgefäße CG* (Vienna, 1902) pp. VII f.

[45]) A. Radwan, *op. cit.,* p. 18.

Autogenous welding, also known as colloidal hard soldering, fusing, or the granulation technique, is generally restricted to gold and silver. Modern fusing is carried out by securing the pieces temporarily with a gum or glue and applying a copper salt around the area to be joined. Upon heating, the proximity of the copper causes a localized reduction of the melting point of the metal pieces[46]), facilitating interdiffusion of the copper and gold or silver atoms. Because the metal at the join has a different composition than the object itself, autogenous welds can be misidentified as solder joins if superficially studied.

Casting-on, as the name implies, is the process of adding one or more metal components, while in the molten state, to an existing object. The investment for the added piece is fixed onto and around the point of joining and the molten metal is poured in. Generally the pieces to be joined are physically keyed but the join results, in part, from the interdiffusion of the metal ions at an elevated temperature. Casting-on, and its variant used for making repairs, casting-in, have occasionally been reported in ancient Egyptian metallurgy. A few examples, though not for the attachment of spouts on ewers, have been observed in the Metropolitan Museum, one of which will be discussed below[47]).

The spouts of all of the ewers examined have flanges that abut the outer walls of the ewers, and all, with perhaps one exception[48]), were held in place by one of two mechanical methods. The first, and visually most obvious method, is the use of rivets, which were observed, for example, on the Tjetju ewers (MMA 26.2.14, 15) (pl. 34d and 31a). The rivets generally are circular in section, and were presumably made by hammering; their size varies but they tend to follow the scale of the vessel for which they were used. The method was particularly popular in the Sixth Dynasty, with only a few scattered examples from the Early Dynastic Period until that time.

The attachment of the spout of one of the Sixth Dynasty Louvre ewers (AE 6926) may be a personal variation of this solution; a metal "lace" that is visible running across the top flange, enters the vessel through two holes and is folded in along the inside walls with the right end crimped around the end extending from the left side (fig. 3).

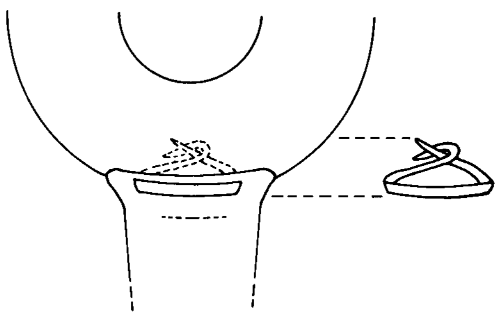

Fig. 3: Diagram of spout attachment of ewer (AE 6926) in the Musée du Louvre, Paris.

[46]) Solid state diffusion of the copper and noble metal occurs until an alloy is formed whose melting point is less than the ambient temperature.

[47]) A cast-on spout has been suggested by A. J. SPENCER, *op. cit.,* p. 83, no. 594, also, see above n. 3, for at least one of the two unprovenanced arsenical copper ewers in the British Museum (EA 29609). This method was also suggested by W. M. F. PETRIE, *Metal Vases,* pp. 25 f., pl. XXXIX, no. 5.

[48]) The exceptional piece is the unprovenanced Old Kingdom Metropolitan Museum ewer (MMA 26.9.13). Although the join clearly depends on cold working, one of the mechanical methods described below, there are unexplained radiopaque spots in the area of the join that might refer to some type of solder.

LUCAS deduced the other method of mechanical joining from his examination of the ewer excavated in the Fourth Dynasty tomb of Queen Hetep-heres, now in the Egyptian Museum in Cairo[49]). Cold working appears to have been the most common method of attachment, especially prior to the Sixth Dynasty. It is clearly the method used to attach the spouts of the two Third Dynasty(?) ewers (UC 8534 and 8573) in the Petrie Museum. Cold working can be used to describe any hammering process carried out at room temperature. In terms of joining, cold working describes the practice of hammering and annealling pieces of metal so that they are forced by mechanical deformation to fit without an adhesive or metallurgical join. It seems that cast spouts could be attached with equal ease by either mechanical method. Mechanically assembled spouts were generally observed to have been attached to the ewers with rivets[50]).

It can be proposed that a spout to be joined by cold hammering was cast with its outer flange nearly as it would be after attachment and with a "proto" flange for the interior (fig. 4). The spout would be inserted and the inner flange hammered out and down and the entire piece annealled and hammered until the walls of the vessel were tightly crimped between the two flanges (pls. 33 b, c; 34 c; fig. 5). Visible inside the spouts of both University Museum vessels (U.M. E 14242 and E 9998) are marks indicating the use of a long narrow tool used to help wedge the spouts in place (pl. 33 d).

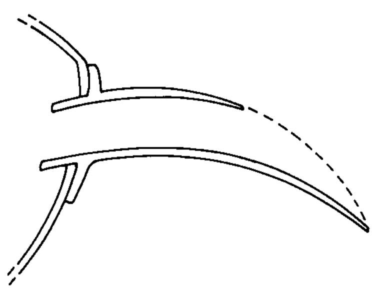

Fig. 4: Diagram of cast spout before mechanical attachment.

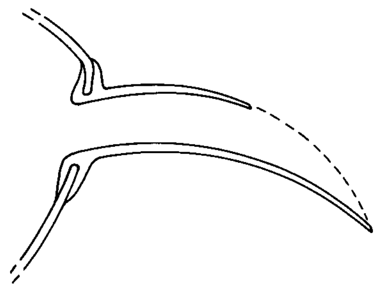

Fig. 5: Diagram of cast spout after mechanical attachment.

The inner flanges are usually larger than the corresponding outer ones and little care was taken for the sake of their appearance. One observes, therefore, thinning and cracking around the edges that is characteristic of this hammering process and the stresses it creates in the metal (pls. 33 b, c; 34 c). The outer flanges are generally neater; one can only suppose that the join was hammered on both sides of the vessel wall to facilitate a tight fit, but in most cases the outer flanges have a regular shape and their edges are not thinned (pl. 34 a).

Excessive hammering and the resultant thinning of the metal of the outer flange, for example on the Beit Khallaf ewer (U.M. E 9998) (pl. 34 b), may have been necessary if getting a tight fit proved particularly difficult.

[49]) J.E. 52450; A. LUCAS, *op. cit.*, p. 215.

[50]) F.W. VON BISSING, *Metallgefäße*, pp. 1 f., no. 3427, describes one case in which a mechanically assembled spout was joined by cold working. This may be the case for one of the ewers in the Louvre (EA 25979).

The Fabrication of the Vessels

As mentioned earlier, there were two methods used in antiquity in the production of metal objects: hammering and casting. All of the ewers examined were formed by hammering[51]), that is, a form with volume is created from a flat sheet of metal. The two methods for creating seamless vessels by hammering are raising and sinking. In the sinking process, a simple method that is generally used for making shallow objects, the metal is hammered against a yielding surface, which results in its stretching and thinning.

The ewers were generally made by raising, which entails the contraction and compression of metal such that its outer diameter decreases as its height increases[52]). This occurs when the metal is hammered against an unyielding material, which in antiquity was probably copper or copper alloys, wood or horn[53]).

There appear to be two raising methods for the overall fabrication of the ewers and similarly shaped vessels. A third hammering method was observed in one example. As mentioned briefly earlier the critical feature relates to the degree of "closedness" or the amount of compression necessary to bring the metal of vessel walls in upon itself to terminate with a narrow opening on the top.

Conventional raising, the first of the two methods, was clearly easier to carry out successfully for the more open-mouthed vessels of the earlier periods. The method can be recognized in the radiographs first of all by the lack of any seams as, for example, in the cases of the Metropolitan Museum of Art unprovenanced Old Kingdom ewer (MMA 26.9.13) and the ewers from Sedment (U.M. E 14242) and Beit Khallaf (U.M. E 9998) (pls. 34 c; 33 c). Particularly characteristic are cracks, often with overlapping edges, leading off from, and perpendicular to, the rim, which are visible on the surfaces of the cleaned vessels (pl. 32 d) and in radiographs.

The overlapping of cracks on the rim is clearly from the time of original manufacture, and must represent what was an acceptable compromise to a perfectly raised vessel. The spreading cracks may be from the time of manufacture but also could have developed much later, as a result of mishandling in daily use or during burial, in the areas with residual stresses. The larger Tjetju ewer (MMA 26.2.15) was patched in ancient times on the underside of the rim area[54]).

[51]) One thick-walled *nmst* vessel (Giza Tomb G 2360 A, field no. 12-11-20) in the Museum of Fine Arts was probably cast, but this supposition can only be confirmed with a metallographic examination. F. W. von Bissing, *op. cit.*, p. 2, no. 3428, describes a 10 cm high ewer as cast.

[52]) These descriptions for sinking and raising are adapted from R. Finegold, W. Seitz, *Silversmithing* (Radnor, Pa. 1983), pp. 3–12.

[53]) There are a number of Middle and New Kingdon tomb representations showing metalworkers using hand-held stone hammers to work vessels over long stakes supported on the ground; see i.e., P. E. Newberry, *Rekhmara*, pl. XVII. Stakes in use in the Old Kingdom are seen on a relief from the causeway of Unas (S. Hassan, *op. cit.*, pl. 96) and in the tomb of Iymery (*LD* II, pl. 49). In spite of inscriptions describing the work or phrases uttered to or by the workmen, the majority of contemporaneous representation of metal workers are difficult to interpret. The artists who made the reliefs were not necessarily well acquainted with actual workshop practices. It is not always possible to know what stage in the manufacture is being carried out because the objects are represented in their completed form and more importantly because the tasks are not clearly indicated. For example, hammering for the purpose of raising, that is, contracting and forming a vessel, is generally indistinguishable from planishing, hammering used to even and smooth the walls. In spite of the textual material it is also sometimes unclear which metal is being worked. The most comprehensive studies of Old Kingdom metalworking scenes and their inscriptions appear in B. Scheel, *op. cit.*; for the latter periods, see B. Scheel, *Studien zum Metallhandwerk im Alten Ägypten II, Handlungen und Beischriften in den Bildprogrammen der Gräber des Mittleren Reiches*, in: *SAK* 13 (1986): 182–205, and id., *Studien zum Metallhandwerk im Alten Ägypten III, Handlungen und Beischriften in den Bildprogrammen der Gräber des Neuen Reiches und der Spätzeit*, in: *SAK* 14 (1987): 248–264.

[54]) It is not clear how this metal patch was attached to the inside of the vessel wall.

The initial radiographs (pl. 35 a) of the smaller Tjetju ewer (MMA 26.2.14) (pl. 34 d) were a source of great confusion. In particular the area of extreme radiopacity at the bottom of the vessel could not be satisfactorily interpreted[55]). An overhead view indicated a highly radiopaque material with casting porosity.

When the vessel, which had been restored using a variety of synthetic adhesives, was disassembled, it was possible to view its interior; at this point an explanation for the radiographic appearance of the vessel and its construction became obvious. Covering most of the bottom of the vessel is a layer of lead[56]), approximately 3–4 mm in thickness, with a dendritic pattern on its surface. Visible on the lower edges of the inner walls are traces of a flange, approximately one centimeter high, whose presence was obscured in the radiographs in part by the lead and by the accumulation of corrosion on the inner and outer surfaces of the vessel (pl. 35 a). Cracks on the exterior bottom of the vessel parallel to the outer edge could now be understood as the separation of the inner cup from the side walls as a result of corrosion. Cracks on the top of the vessel relate not to problems of compressing the metal during raising, but are the result of damage to the ewer after it had become entirely mineralized, and therefore extremely brittle, during its millennia of burial.

The vessel had been raised upside down and a hole was cut into what became the top. The spout was riveted over a small hole cut into the side, and then the bottom was closed off by a small cup. This technique could not be conclusively confirmed for any other Sixth Dynasty ewers examined, but separately made bottoms were noted on three model *nmst* vessels from the tomb of Impy (MFA 13.3254, 13.3255 and 13.2982) (pl. 35 b–d).

Two of these bottoms (MFA 13.2982 and 13.3255) were also cup-shaped. It can be proposed that the bottoms of these vessels as well as that of the small Tjetju ewer (MMA 26.2.14) were inserted in the annealed state and then cold worked into position through the hole in the top of the vessel[57]). Probably the join was completed by grinding and polishing the bottom, which evened up the edges and smeared the metal. The bottom of the third model vessel (MFA 13.3254) appears to have been a flat sheet held in by flanges extending from the bottom of the metal walls (pl. 35 d).

Lead was not found in the bottom of any other vessels and its presence is not easily explained. The lead cannot be thought to relate to the domestic or ritual functions of the vessel and it has not been used as solder. The dendritic pattern indicates that the metal was molten and the surface not subsequently worked. It could have been poured in through the small opening on the top of the vessel but this seems unlikely. More plausibly, pieces of lead were placed in the bottom before it was inserted in place and the ewer heated until the lead flowed, covering most of the bottom.

Ewers of the Sixth Dynasty, with their elongated and therefore relatively heavy spouts, tend to be somewhat top heavy. It is possible that the lead was used to steady the ewer. However, the

[55]) In radiographs of vessels laid parallel to the film plane the bottom usually appears more radiopaque than the side walls because the bottom is viewed edge on. The degree of radiopacity alters as the vessel is angled. For example, compare the two radiographic images in plates 33 c and 34 c.

[56]) Instrumental analysis detected the presence of no elements other than lead. The following describes the equipment and procedure for the elemental analyses reported in this article: analyses were carried out with a Kevex 7000 energy-dispersive x-ray spectrometer attached to an Amray 1100T scanning electron microscope using the ASAP analysis routine. Samples were removed with a scalpel and mounted on carbon disks. The freshly exposed metallic surfaces were scanned at 30 kv for two hundred seconds. In the analysis of metallic samples using the equipment described, the minimum limits of detection are estimated to be between .02 and .05 w/o, depending on the element under consideration and the matrix.

[57]) Pitch or another similar material could have been used to seal the bottom if it failed to be watertight.

ewers are generally represented as nesting in their basins, eliminating the need for weighting them down when not in use.

The heirloom ewer (MMA 98.4.66) of the New Kingdom is an extremely closed type (pl. 32a) and an interesting variant to the method of raising upside down and adding a separate bottom. In this case, the bottom is cast-in; the evidence that the pieces are joined and the fine porosity of the cast-in bottom are visible both on the surface and in the radiographs (pl. 36a, b)[58]).

The following method can be proposed for the manufacture of this ewer: when the raising was completed a small hole was cut in the top of the vessel and the cast spout was attached to the vessel wall with rivets. The vessel was overturned and banked in some refractory material like sand, which was used to fill the interior to just below the upper edge. The top of the sand may have been covered by a layer of fine investment material[59]), as the inside of the bottom of the ewer is not pitted and it would have been difficult to polish. Molten metal was poured in and the exterior was ground and polished. Splashes of metal on the walls of the vessel near the bottom, visible on the interior and as radiopaque patches in the radiographs, appear to be the result of metal that ran into the sand and became continuous with the side walls.

The New Kingdom ewer has a traced line[60]) on its shoulder concentric with the opening of the vessel. RADWAN suggests that a second, similar ewer found at Dendera, which is inscribed to Ramesses II and now in the Cairo Museum, has a round plate with an opening in the middle soldered to its shoulders in order to make the opening of the vessel smaller and to support a cover that is now lost[61]). He sees the line drawn on the Metropolitan Museum ewer as a reference to this so-called "Öffnungsscheibe"[62]). A second possibility is the fusion of the forms and functions of the *ḥsmny* and *nmst* vessels. *Nmst* vessels usually have a thickened band around their openings, delineated on metal versions with a scribed line, that may be the model for the line observed on the shoulder of the New Kingdom piece.

The third hammering method was observed on the model ewer (U.M. E4726) from Abadiya (pl. 36c). The vessel is a sheet of metal shaped and crimped into a cylindrical form that is nearly closed on the top. A representation in the Fourth Dynasty tomb of Nebemakhet at Giza of the manufacture of a vessel, probably a ewer, by this method, is cited by KLEBS[63]).

The bottom of the Abadiya ewer is a separate flat sheet of metal around whose outer perimeter the lower walls of the vessel have been folded under (pl. 36d). Its spout is a solid rod with a squarish cross section. The means of attaching the hemisphere of metal surrounding the spout where it enters the ewer is unclear from radiographic and visual examination.

* * * * *

[58]) On account of its unusual manufacture, and facilitated by the survival of much metal which has been exposed by overcleaning, samples were removed from the main part of the vessel, the bottom and the spout, and analyzed; see above, n. 56 for details concerning instrumentation. The composition of walls and the bottom of the vessel were found to be similar, containing a relatively high amount of tin and traces of arsenic and lead. The spout is a leaded bronze.

[59]) That is, a fine-grained mixture, that would be used as the first layer in investing a wax model for casting.

[60]) Tracing refers to the technique of compressing, rather than cutting the metal surface. It is generally believed that before the introduction of iron tools, linear decoration on ancient surfaces – if it was not cast in – was traced.

[61]) A. RADWAN, *op. cit.,* p. 123, no. 345, pls. F and 64. RADWAN includes a reference that implies this to be the method of manufacture for three Eighteenth Dynasty silver *nmst* vessels in the Metropolitan Museum (MMA 18.8.20–22), but a recent technical examination has not confirmed this. Available illustrations of the inscribed Ramesses ewer in Cairo seem to indicate that a separate ring does exist.

[62]) A. RADWAN, *op. cit.,* p. 123, no. 346, pl. 64.

[63]) L. KLEBS, *Die Reliefs des Alten Reiches (2980–2475 v. Chr.)* (Heidelberg 1915) p. 85; Illustrated in *LD* II, pl. 13. Analogous methods of assembling sheet metal have been observed in a model *ḥst* (MFA 13.2976) and another tall slender model vessel (MFA 13.3241) from the tomb of Impy.

The results of the examinations carried out on the copper or copper alloy Early Dynastic, Old Kingdom and New Kingdom *ḥsmny* and selected *nmst* vessels are reported in Table 3. These observations indicate the degree of variability and ingenuity brought to the task of creating this complex form.

In the manufacture and attachment of the spouts there is clearly a trend from cast and cold joined spouts in the Early Dynastic Period through the Fourth Dynasty or Fifth Dynasty to mechanically assembled and riveted-on spouts of the Sixth Dynasty. These technological changes

Table 3 Observations: selected *ḥsmny* and *nmst* vessels

Collection/Acc. No.	Fabrication, presence of cracks on rim	Spout (manufacture + attachment)
EARLY DYNASTIC		
UC 8570	raised[1])	NA[2])
UC 8569	NA	assembled[3]), riveted (?)
U.M. E 14242	raised, cracks	cast, cold joining
THIRD DYNASTY		
U.M. E 9998	raised, cracks	cast, cold joining
UC 8534	raised	cast, cold joining
UC 8573	raised	cast[4])
FOURTH-FIFTH DYNASTIES		
MMA 26.9.13	raised, cracks	cast, cold joining (?)
SIXTH DYNASTY		
MMA 26.2.15	raised, cracks	assembled, riveted
MMA 26.2.14	raised w/separate bottom	assembled (?), riveted
MFA 13.3254	raised w/separate bottom	NA
MFA 13.2947	raised, cracks	assembled, riveted
MFA 14-2-95[5])	raised	(heavily restored)
Louvre AE 3912	ND[6])	assembled, riveted
Louvre N 887	ND	assembled, riveted
Louvre AE 6926	raised ?, cracks	assembled, riveted
NINETEENTH DYNASTY		
MMA 98.4.66	raised w/separate cast bottom	cast, riveted

[1]) Because of the overall damaged condition of this ewer it is not possible to determine if there are cracks perpendicular to its rim relating to manufacture.

[2]) NA = not applicable.

[3]) Assembled = made from two, or exceptionally one, hammered sheets of metal, joined mechanically with rivets and flaps.

[4]) Uncleaned condition makes it impossible to determine method of joining.

[5]) Field number (not accessioned).

[6]) ND = could not be determined from superficial examination.

may relate to a seemingly contemporaneous change in form, from smaller to larger spouts. The return to casting for the spout of the Nineteenth Dynasty ewer is also likely to relate to its slender shape and extremely narrow interior.

The evolution of the ewers' overall proportions from the Early Dynastic and Old Kingdom Periods relates to the development of a new manufacturing method: the separately formed bottom observed on several of the Sixth Dynasty examples. More careful measurements of the later vessels, and perhaps a set of proportions, i. e. relationships of the height and the diameters of the opening, the bottom and the shoulders, derived from them, may provide grounds for understanding why specific vessels were made in one manner or another.

One question not explored in this study relates to the use of copper versus copper alloyed with arsenic. Arsenical coppers appear in Egypt in the First Dynasty, if not already in the Late Predynastic Period, without ever entirely supplanting the use of unalloyed copper[64]). Although the addition of arsenic would be advantageous for the casting of spouts, it does not facilitate raising. In fact, the Metropolitan Museum ewer with an arsenical coating (MMA 26.9.13) is severely cracked, both at the rim, which is characteristic for the type of stresses inherent in the raising of the form, and on the sides, which may result from embrittlement due to the arsenical coating. It seems likely that the arsenic was employed for aesthetic reasons, in order to impart a silvery color to the surface of the ewer, and not to obtain some metallurgical advantage. Analyses of the other vessels may provide insight into this question of possible relationships between manufacture and composition.

Acknowledgements

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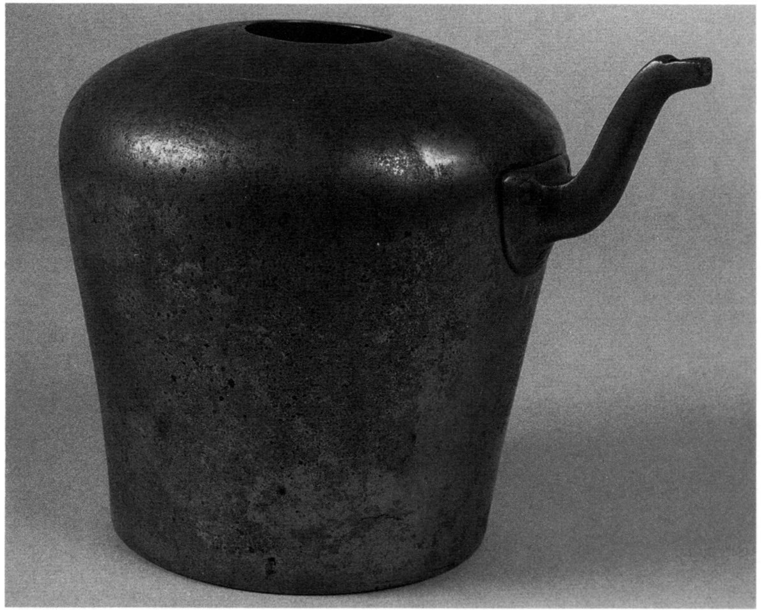
Special thanks to Nathan Bell (†).

[64]) See i. e. R. M. Cowell, *Scientific Appendix I: Chemical Analysis,* in: W. V. Davies, *Tools and Weapons I. Axes* (*Catalogue of the Egyptian Antiquities in the British Museum,* vol. 7) (London 1987) pp. 96–118.

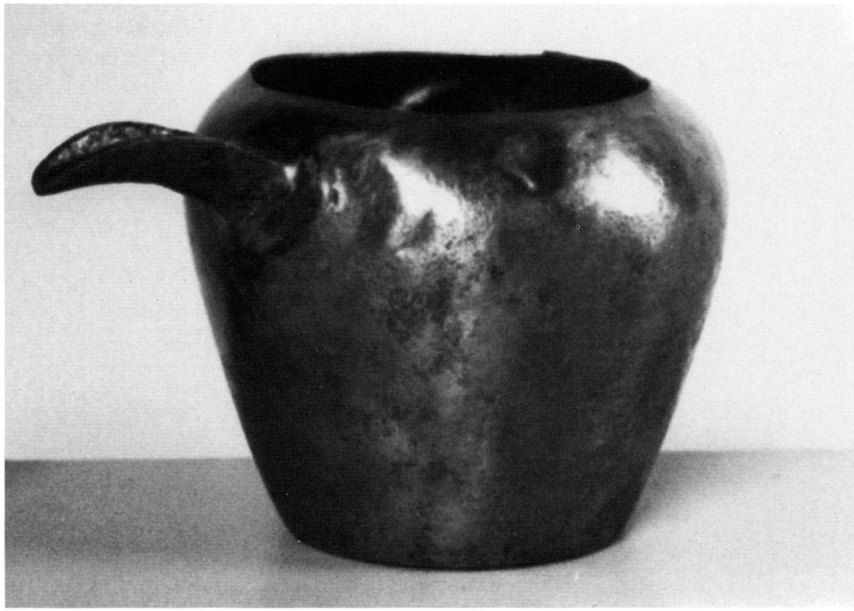
a) MMA 26.2.15 (Photo: Schorsch, by permission of The Metropolitan Museum)

b) MMA 26.9.13 (Photo: Schorsch, by permission of The Metropolitan Museum)



a) MMA 98.4.66 (Photo: Schorsch, by permission of The Metropolitan Museum)

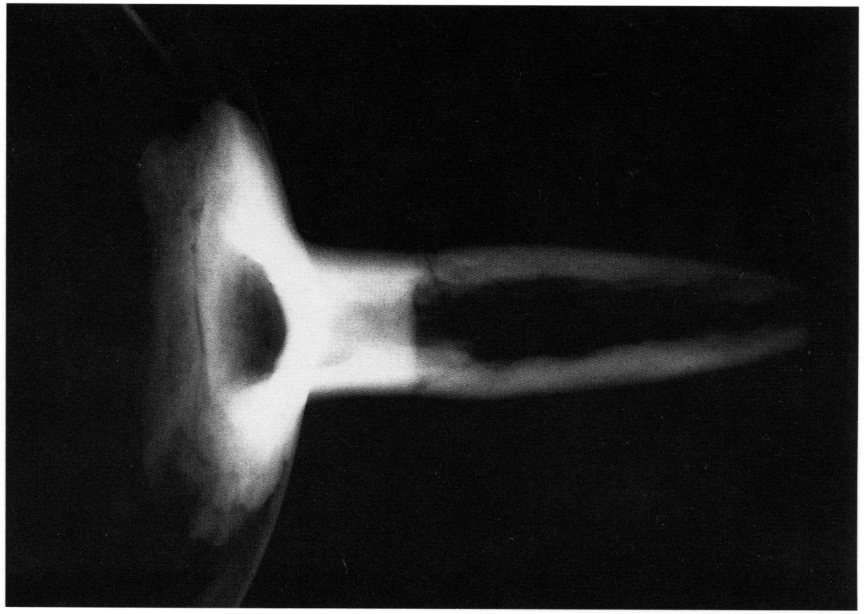
b) U.M. E14242 (Photo: The University Museum, University of Pennsylvania, neg. # 31570)



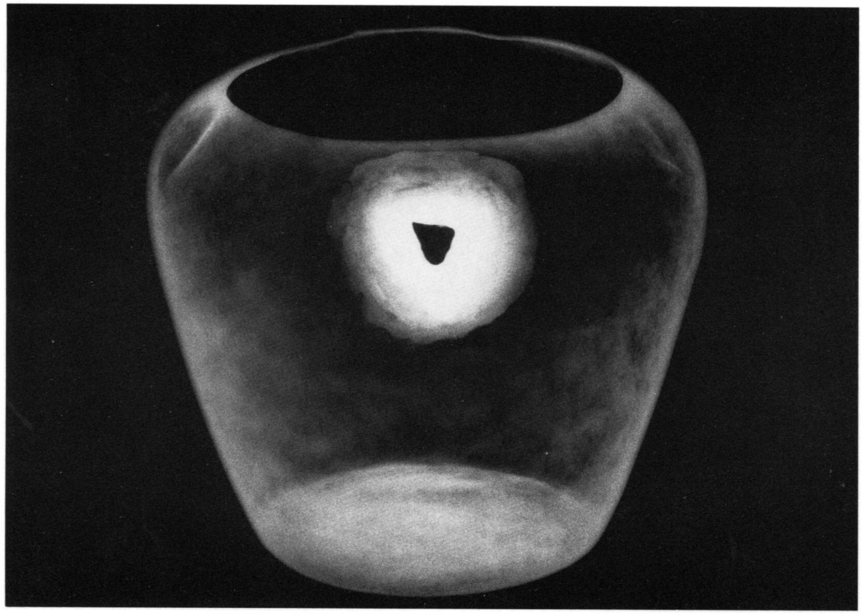
c) U.M. E9998 (Photo: The University Museum, University of Pennsylvania, neg. # 31570)

d) U.M. E14242 (see pl. 32b), overhead view (Photo: Schorsch, by permission of The University Museum)

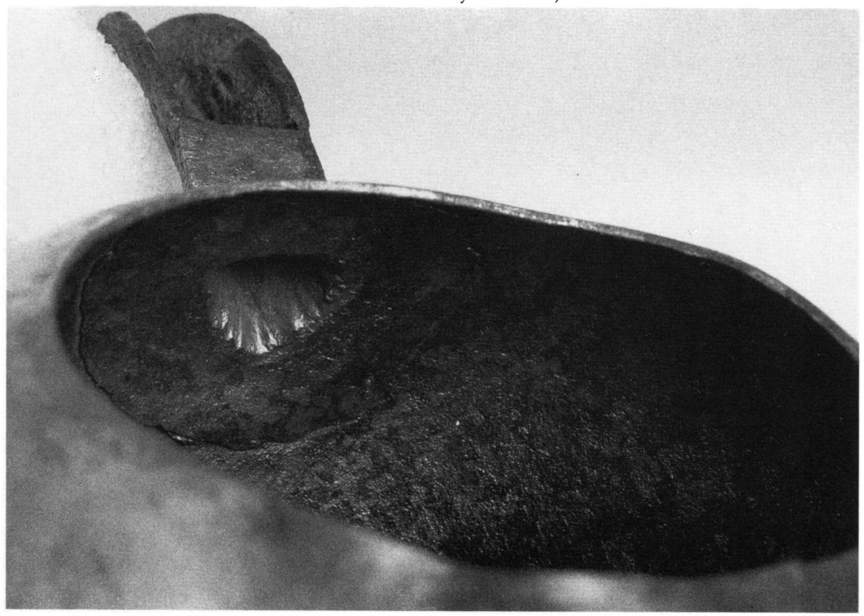
a) MFA 13.2947, overhead view (Photo: Schorsch, by permission of the Museum of Fine Arts)



b) U.M. E9998 (see pl. 32c), detail of radiograph (150 kv, 60 sec.) (Photo: Schorsch, by permission of The University Museum)



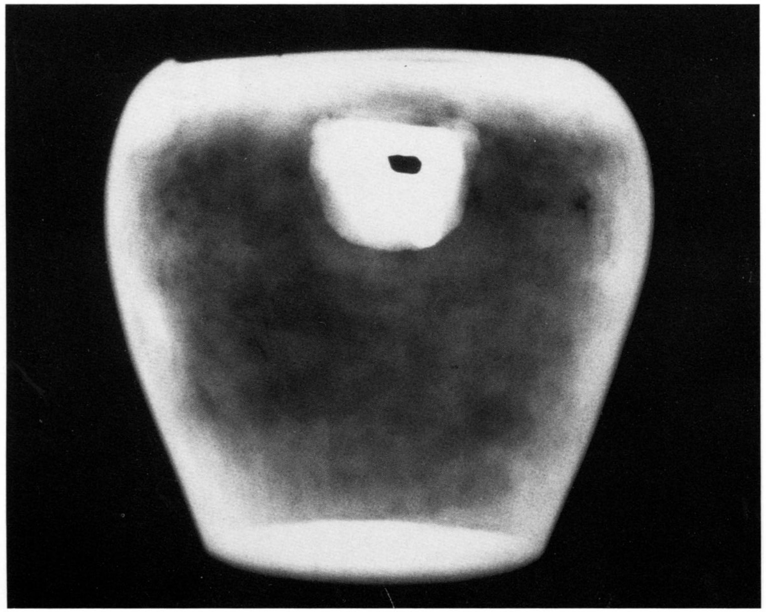
c) U.M. E9998 (see pl. 32c), radiograph (150 kv, 60 sec.) (Photo: Schorsch, by permission of The University Museum)



d) U.M. E9998 (see pl. 32c), detail of interior (Photo: Schorsch, by permission of The University Museum)

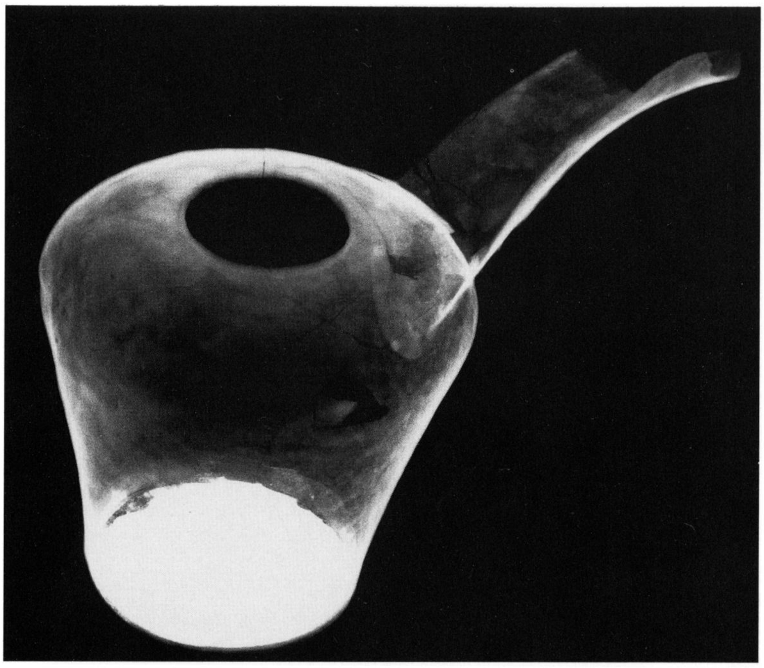
a) U.M. E14242 (see pl. 32b), detail of spout and flange (Photo: Schorsch, by permission of The University Museum)

b) U.M. E9998 (see pl. 32c), detail of spout and flange (Photo: Schorsch, by permission of The University Museum)

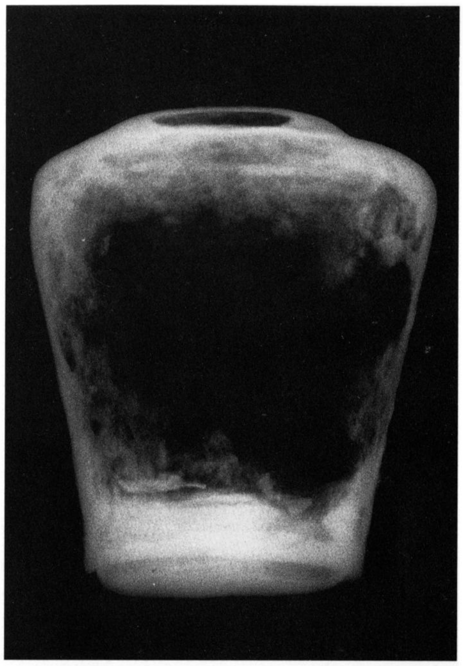


c) U.M. E14242 (see pl. 32b), radiograph (150 kv, 60 sec.) (Photo: Schorsch, by permission of The University Museum)

d) MMA 26.2.14 (Photo: Schorsch, by permission of The Metropolitan Museum)

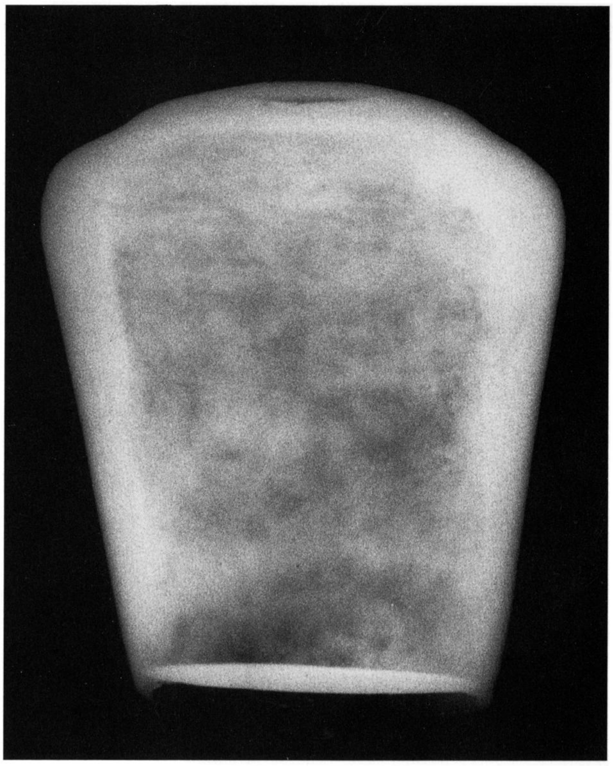


a) MMA 26.2.14 (see pl. 34d), radiograph (210 kv, 30 sec.) (Photo: Schorsch, by permission of The Metropolitan Museum)

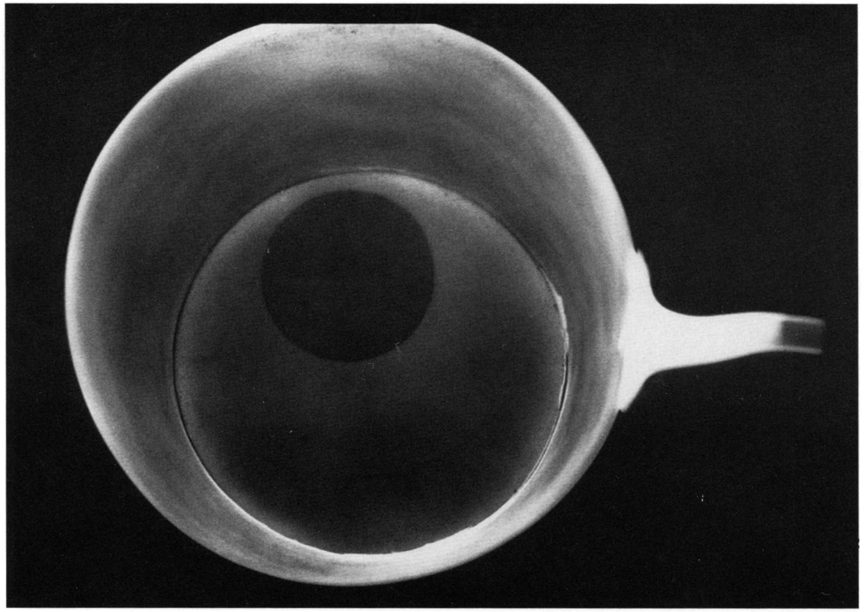


b) MFA 13.3255 (see pl. 35c), radiograph (150 kv, 60 sec.) (Photo: Schorsch, by permission of the Museum of Fine Arts)

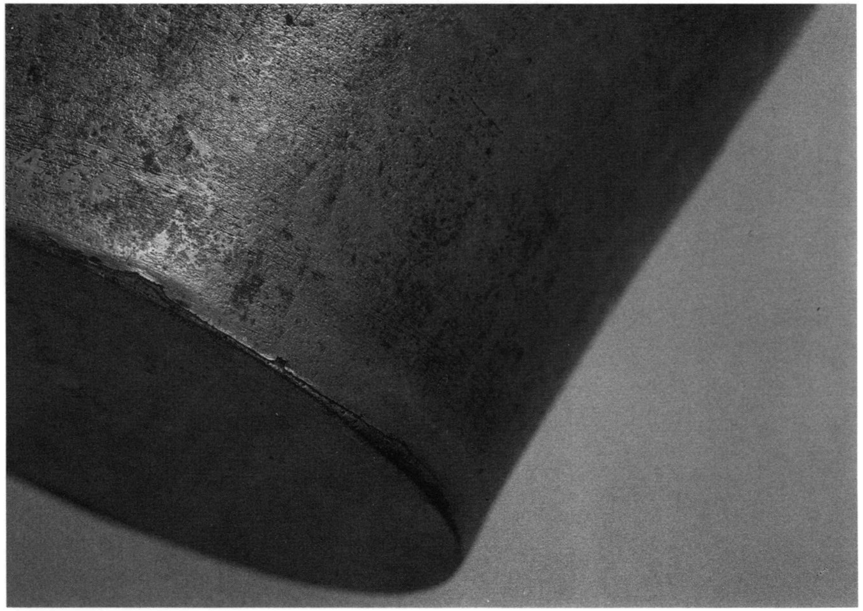
c) MFA 13.3255, view of bottom (Photo: Schorsch, by permission of the Museum of Fine Arts)



d) MFA 13.3254, radiograph (150 kv, 60 sec.) (Photo: Schorsch, by permission of the Museum of Fine Arts).

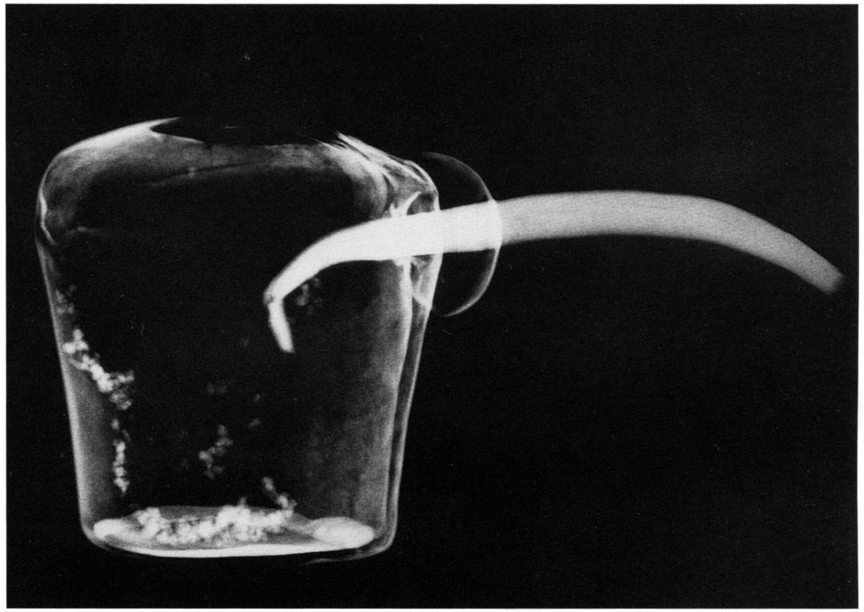


a) MMA 98.4.66 (see pl. 32a), radiograph, overhead view (250 kv, 45 sec.) (Photo: Schorsch, by permission of The Metropolitan Museum)



b) MMA 98.4.66 (see pl. 32a), detail of bottom (Photo: Schorsch, by permission of The Metropolitan Museum)

c) U.M. E4726 (Photo: Schorsch, by permission of The University Museum)



d) U.M. E4726 (see pl. 36c), radiograph (150 kv, 60 sec.) (Photo: Schorsch, by permission of The University Museum)