THE MANUFACTURING TECHNOLOGY OF THE IRISH BRONZE-AGE HORNS

BY

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The Irish Bronze Age horns form the largest single group in the trumpet-horn family of instruments from the Bronze Age, their 90 or so extant specimens (from about 120 previously recorded) represent about 55% of the total of Bronze Age instruments of this type recorded from Europe and the Middle East.

Being classed by Hornbostel and Sachs (1914) as lip-vibrated aerophones, they share this grouping with the Scandinavian *lurs* — the second largest instrument group from the Bronze Age. As with the *lurs,* the generation of a vibrating air column is carried out by the lips of the player and the addition of these to an instrument recreates the combination used at the time of their manufacture and, possibly the authentic sound of the time. In the case of the *lurs,* however, a sequence of development is seen which produced a conical instrument with a developed mouthpiece, having a throat of small diameter. In all, these are very modern-looking instruments with all their formats harmonically related, i.e., capable of playing much like a modern brass instrument without its valves. The Irish horns, however, did not follow this pattern of development seen on the *lurs*; they never attained the length of the *lurs*; they never developed mouthpieces in the modern sense and "pairs" of instruments in the Irish context seem to consist of dissimilar instrument types. Nevertheless, the Irish instruments show sequences of development different from, but of comparable complexity to the *lurs* and one can only conclude that this development was equally directed but towards a different aim.

The common conjunction of similar instruments in pairs throughout the archaeological and ethnographic record and threes in the Roman and Celtic world, utilizes as far as one can gather, sets of identical instruments. This is not so with the Irish instruments, where a pair can consist of side and end-blown instruments. Not only is this combination unique, however, but the side-blow instruments themselves are unique in the archaeological record. Unlike the conventional instrument of their family, they have a blowing aperture on their tube wall somewhat downstream of the instrument tip where the mouthpiece of an end-blown instrument is normally found.

For more than 110 years, these instruments have been studied, first being listed in 1860 to be followed by Day (1875), Evans (1881), Coffey (1913) and MacWhite (1945). Most recently they have been studied by Coles (1963) who outlined the previous classifications and dating by these authors (*op. cit.* 349 ff). In addition, in this paper, Coles proposes a typology which is considerably simpler than those of Coffey and MacWhite and when related to the geographical spread of the instruments, shows a most convincing divergence between his Class I and Class II instruments (*op. cit.* fig. 3). This distribution map shows all the Class I horns to have been found either in the North-East of the island or at Dowris, while all but one of the Class II instruments are found in the South-West or at Dowris.

The Class I Horns

These have plain bodies or are decorated with ribs or domes. Their bell ends are decorated with ribs, grooves, zig-zags, domes or, less frequently, spikes. The end-blows have bell yards that ter-

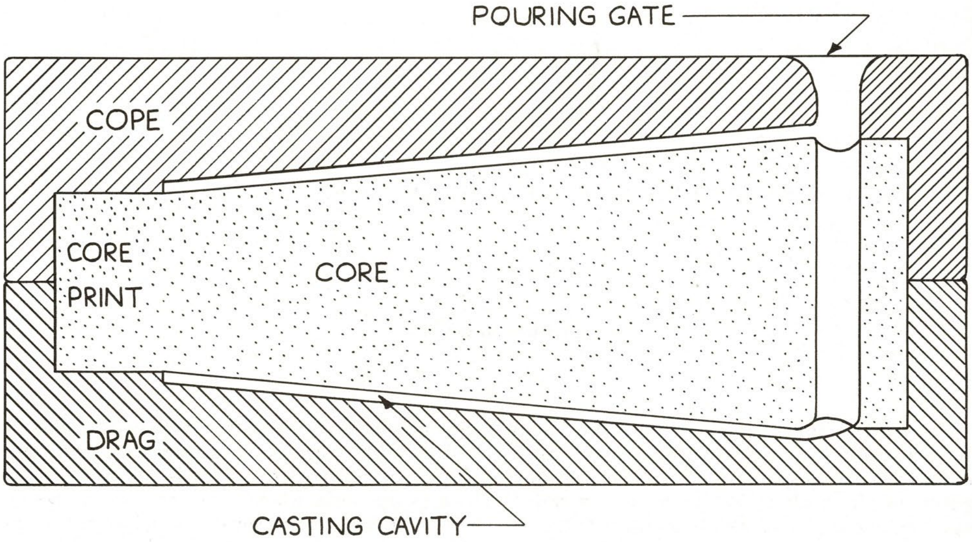

FIG. 1 — Possible reconstruction of a mould assembly.

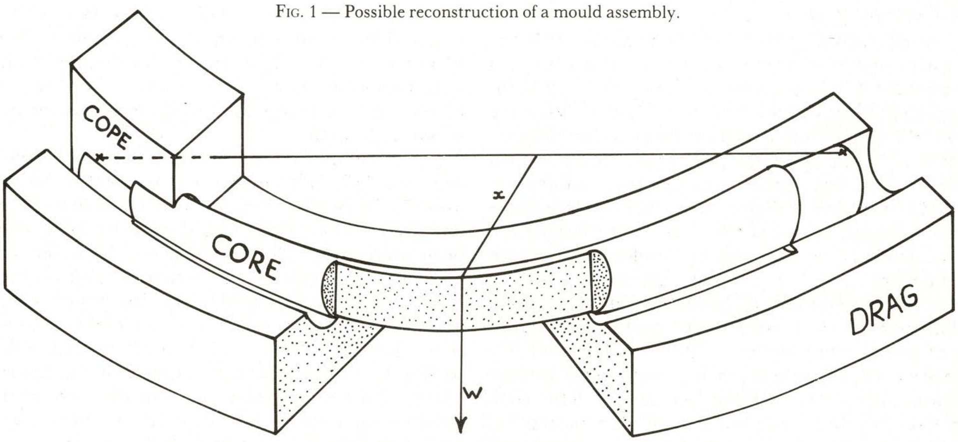

FIG. 2 — Mould assembly for a curved instrument.

minate in a male projection which fits inside the mating tube yard. The side-blows have a tip end terminating in a flare or bulbous projection frequently with a loop or added mount and ring.

The Class II Horns

Characteristically, these have large conical projections on both bell and tube yards, although the bodies of the instruments are not decorated in any way. Generally speaking, their carrying features are more complex than on the Class I instruments. The end-blows have bell yards that terminate in a socket, frequently with four holes and this fits over the end of the tube yard. The side-blows are generally larger than their Class I counterparts and have at their tip a large, stepped pyramid-like termination.

In this study, three sequences of development were observed and, although none of these can be directly related to a chronological sequence, they serve as a basis upon which to organize the material. The sequences are of:

Manufacturing technology
Organology
Aesthetic design.

This paper concentrates on the manufacturing technology sequence, considering, in particular, two of the sub-sequences observed. All the Irish horns appear to have been cast in two-piece moulds, i.e., moulds with a cope, a drag and a core. Fig 1 shows a core supported on core prints, which, when the mould is straight such as on some of the Dowris tube yards (Coles, 1963, fig 2 (14-P)), are capable of locating the core adequately with respect to the cope and drag. However, in the case shown on fig. 2, i.e., with a curved core, the centre of this is subjected to a moment Wx and twists in the mould to give a thin section on the centre of the curve (pl. 1). In addition to this force, the core experiences forces opposed to it when filled by molten metal. These are generated partly by the buoyancy of the core in the molten bronze which results from the density difference between bronze and clay (approximately 8:2) (hydrostatic forces). In part, too, they result from hydrodynamic forces acting on the core during the entry of molten metal into the mould. The situation is further complicated, as the mould is being poured, by the rapidly increasing viscosity of the metal as it is chilled by the mould surfaces. This constantly-changing system gives rise to a volume of molten and semi-molten metal varying vertically in viscosity. The resultant system leads to vertical displacement of the core upwards, opposed to that caused by gravity and giving rise to thin sections in the cope rather than the drag as one might expect from consideration of gravitational forces alone. However, restraint from the core prints (fig 2) combines with this vertical force to form a moment, Fx (where F is the hydrostatic force from the buoyancy effect) which twists the core and gives rise to a thin section in the cope. This is not at the top of the cope, however, but is displaced towards the outer curve of the instrument (pl. 1). Thin sections and section failures in this area are the commonest casting fault seen on these instruments and their prevalence must have led to the development of devices to support the core during casting.

While end-blown horns have apertures at both ends of the tube, allowing core prints to be used to support the core, this is not so with side-blown instruments. On these, the end is blocked by a tip-cone or bulb but some measure of support is gained from the protrusion of the core through the tube wall, thus forming the blowing aperture. Most of the blowing apertures of these instruments seem to have been formed in this way, although many have been cleaned up abrasively at some time.

The Provision of Core-Supporting Features

When the cope, drag and core are assembled prior to casting, the casting cavity is no longer visible. Indeed, when the core itself is simply laid on the cope or drag, this cavity can only be seen at the mould's joint-line. In order to check this gap, soft clay was probably placed between the mould halves and the core and mould assembled, dis-assembled and the clay thickness measured. This appears to have given rise to the use of small clay supports placed above and below the core which were left in place during casting. On removal, these left holes in the tube walls which were subsequently filled by cast-on bronze plugs. Two extant instruments, both from Dowris (14-F and 14-Z)* have such features cast-on around the curve of the instrument (pl. 2).

This technique must have proved incompletely effective as on Dowris 14-Z, the maker has augmented this core supporting feature by the use of surface chaplets spaced between the cast-on knobs. These are irregularly-shaped pieces of flat metal broken off from earlier castings which become integrated into the body of the casting and hence merit the title chaplets. They are of a wide variety of shapes frequently being 10-15 mm across their largest dimension (pl. 3) and having been fractured from the cast material have an irregular-shaped edge that frequently provides a good key-in to the surrounding casting. However, they are held in place, both during preparation of the mould and pouring, by the nip developed between the cope, drag and core. As these are of dried clay and do not yield readily, this nip has to be quite precise if they are to stay in place during handling and casting. Needless to say, a number of these surface chaplets

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*Numbers refer to catalogue entries in Coles, 1963, 350–356.

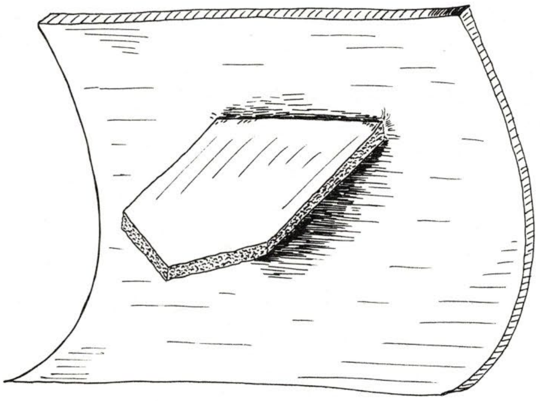


FIG. 3 — Large chaplets protruding in tube bore.

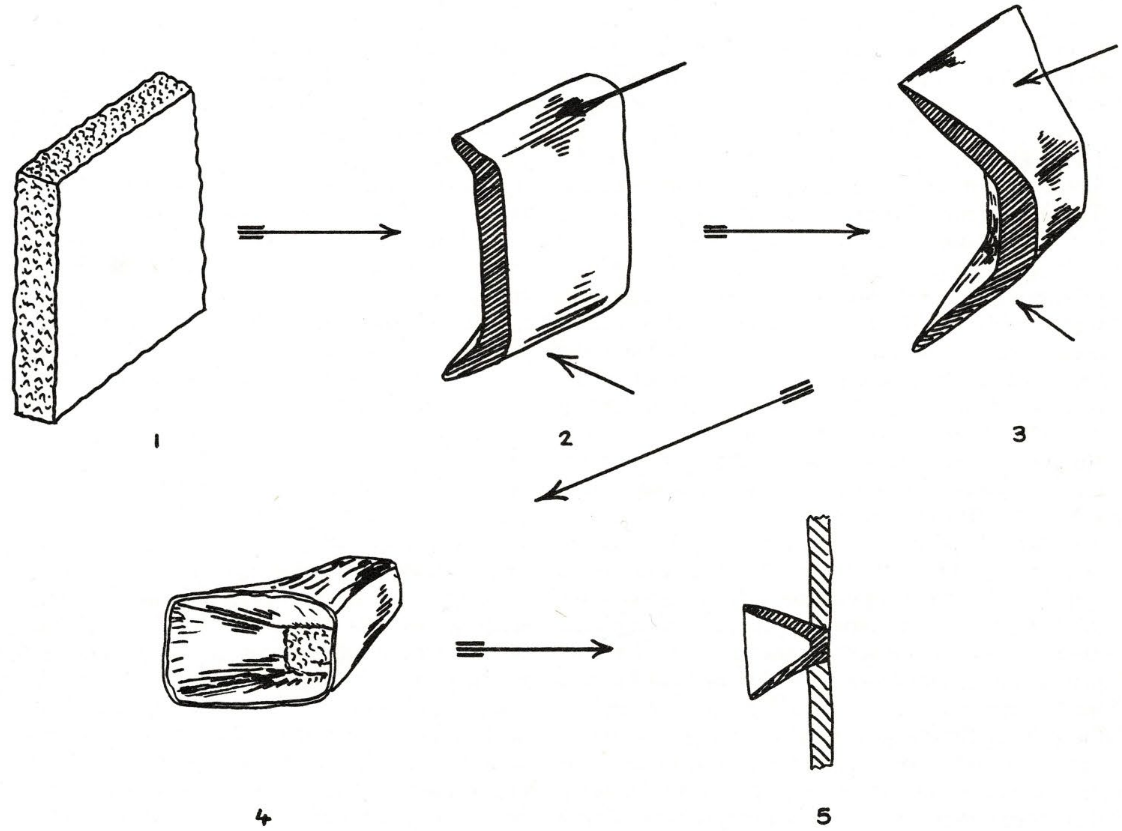


FIG. 4 — Stages in the manufacture and assembly of a tanged chaplet.

have slipped at some stage, only to be trapped by another more firmly located chaplet or by the mould joint-line (pl. 4). This reduces the efficiency of chapletting but can also cause disruption to metal flow and possible section failure if the chaplet lodges in an inopportune spot. (pl. 5).

To overcome this problem, surface chaplets were keyed into the core, thus fixing them more firmly (pl. 6). In this use, the chaplet no longer relied on cope/drag-core nip to hold them firmly but required very careful assembly of the chaplet in the core to obtain the exact protrusion of the chaplet. Where this dimension was too small the chaplet would give no support and where too large would not allow the cope and drag to mate securely. In spite of these problems, however, this type of chaplet proved very successful and remained the predominant form on the Class I instruments throughout the period of their manufacture. On all instruments where these chaplets were used, a trend to smaller chaplets developed with some of the more advanced keyed surface chaplets measuring only 5 mm or so across their largest dimension.

Several of the experiments that took place in chapletting appear to have been done at an early point in the technological sequence. Two of the Dowris instruments, 14-J and 14-S, for instance, have large chaplets that penetrate into the bore in the curved portion of the horn. On one of these, 14-S, large knobs are present on the tube wall as skeuomorphs of the cast-on infillings from earlier clay core-supports. The two large chaplets on each of these instruments are of pieces of metal approximately 20 × 20 × 2.5 mm, crudely formed into a point and pushed into the core when wet. They were aligned along the axis of the tube and placed at the point where this curves, requiring considerable support (fig. 3). Such protrusion into the bores of instruments is not common, these two instruments being the only examples found. However, where the core is left in the instrument such as at the tips of side-blows, long chaplets were frequently used. Passing into the remnant core as they do, these cannot be seen and can thus be designed to support, neglecting aesthetic criteria (pl. 7).

Having established the value of chaplets that keyed well into the core, these became the standard on the more advanced Class II instruments. Sometimes these are little more than folded over pieces of metal and sometimes made of more elaborately worked material (pl. 8). Nevertheless, they are specifically manufactured to do the job of a chaplet.

One of the major criteria for a chaplet is that it penetrates the core readily when pushed into place — and stays there. This was achieved on a distinctive group of Class II instruments by the development of the hollow tanged chaplet. Manufactured from sheet, as shown in fig. 4, this had a hollow tang formed by metal flowed from the original sheet (pl. 9). Along the portion that keyed into the tube wall this has smooth facets produced by hammering which form a wedge shape opening out into the tube cavity. Because of this wedged shape and smooth surface, these chaplets were frequently lost, leaving behind a characteristic faceted hole.

Most chaplets cannot be seen when the core is assembled in either the cope or the drag, but one type did develop that, being spaced alternately either side of the joint-line, could be seen. Perhaps this chaplet position allowed for final fine adjustment of the core and it may be that these chaplets protruded from the core and fitted in slots on the mould joint-face. They are always small, made from 1-2 mm rod, protrude a maximum of 2 mm into the bore and on 37-A, for instance, are spaced at about 250 mm centres alternately each side of the joint-line. Thus, if the criterion of size is a valid indicator of evolutionary position these chaplets are among the latest in the technological sequence. On instrument 37-A, however, this type of chaplet is seen in conjunction with surface chaplets and, as several stages of evolution separate these two types, suggests that influence from another workshop had brought about their incorporation into this piece (pl. 10).

Several instruments show variety in chaplet forms showing that experimentation was going on at different workshops. On Dowris 14-D, for instance, the chaplets used protrude into the bore over the bulk of the instrument. Those which can be seen at the bell end, however, have been twisted round to form surface chaplets. It seems likely that the maker, well aware of the need for firm support at the centre of the instrument curve, put the most effective chaplets there and saw those at the instrument bell end as an additional provision but possibly not one that was absolutely essential. The Drumbest instruments (16-A, B and D) also contain different chaplet types and in their case too, the differentiation in use of these seems to have been for technical reasons. Of the six rows of chaplets, four are of the keyed surface type while

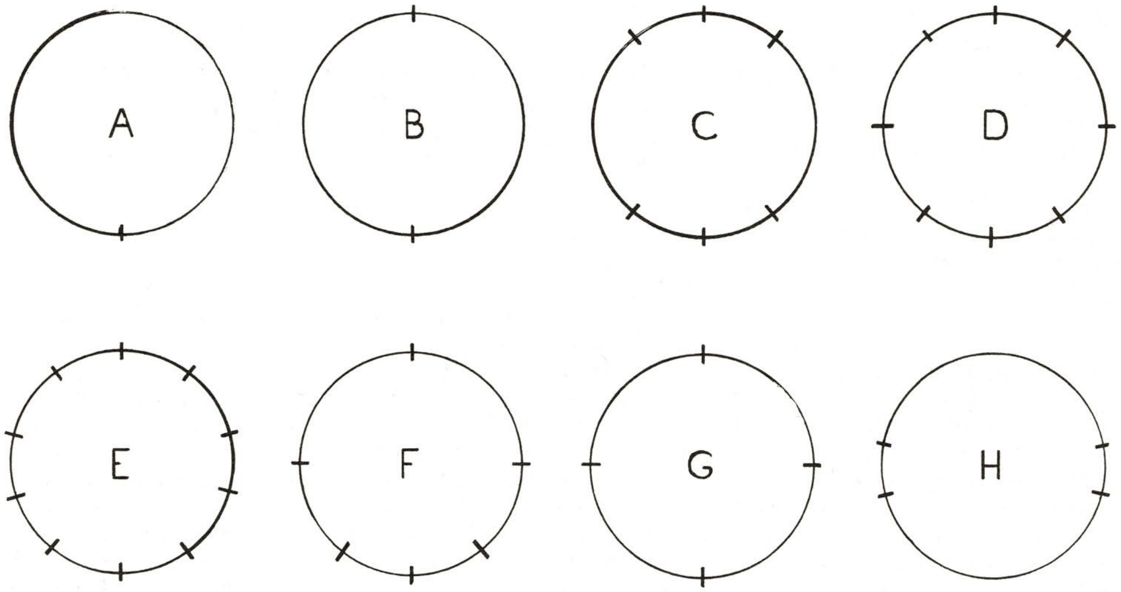


Fig. 5 — Chaplet configurations used on horns.

the two rows along the mould joint-line are simple surface chaplets. These latter ones were probably added on assembly, as on Dowris (14-D), for additional support.

Chaplet Configuration

Many patterns of chapletting emerged during the development of the manufacturing technology seen on these instruments. They represent a clearly directed development sequence, albeit a complex one. So complex indeed, that little can be said at this point in the investigation about sequential stages in this development and, more importantly, about the interrelationship between chaplet types and their configuration. Only two types have standard configurations, the small "round" chaplets which are always alternated above and below the joint-line ("H" on fig. 5 and pl. 10) (although always used in conjunction with other types) and the hollow tanged type always used in a 6-pattern configuration ("C" on fig. 5 and pl. 9).

Presumably the various patterns emerged to give support to the core during the whole process of manufacture. Initially this would be seen as a problem of overcoming gravity which pattern A (fig. 5) would do. Then core buoyancy and hydrodynamic lift during pouring would call for restraint on top of the core — leading to pattern B (fig. 5). Following this, thinner sectional thicknesses of the tube walls would call for more accurate restraint in both vertical and horizontal planes, leading to the more complex patterns seen on fig. 5.

The major parameter controlled by the chaplet provision is the uniformity of tube wall thickness, i.e., the degree to which the core is both accurately located relative to the cope and drag and held in that position while handled and actually poured. This parameter, however, is also controlled by the match of core diameter to cope/drag diameter and the quality of registration of the cope and drag. Hence, measurements of sectional wall thickness provide information on the overall ability of the founder and specific facets of his skill cannot always be identified individually. Nevertheless, the wall thicknesses of several instruments are very uniform and no instruments measured showed large random errors such as would be caused by gross mismatch of the core/mould shape.

On Dowris 14-E, six wall-thickness measurements at the bell gave values (in mm) of: 2.39, 2.36, 2.49, 2.49, 2.44 and 2.39, i.e., a measured value of 2.43 ± 0.065 mm. or a maximum variation in wall thickness of 0.13 mm. Similarly on Dowris 14-0, eight measurements around the blowing aperture gave a wall thickness value of 1.08 ± 0.075 mm, i.e., a maximum variation of 0.15 mm. Clearly, such accuracy is attainable only when core and mould halves match very closely.

These figures cannot claim to be truly representative of the instruments as a whole, nor of the generalised wall thickness over their whole surface. Nevertheless, they do indicate that at the limited stations measured, the makers were able to form both core and mould to match accurately. Many more examples need to be examined to build up a picture of the dimensional qualities of these instruments. However, if the repeatability of dimensions is as good as the work carried out to date suggests, more sophisticated metrological devices than simple hand tools will be needed to carry out the next stage of this investigation. The roundness in particular may well turn out to be of great importance when examining these instruments.

Many items are made "round", i.e., of a form which, when judged by eye or hand is considered round. However, the ability to discriminate between levels of roundness is limited by the size of the minimal perceptual increment for a particular individual under particular environmental conditions. Thus, the degree of roundness to which an object can be made using visual and tactile inspection methods is limited by perceptual factors. Only when a process is used which produces inherently round objects, i.e., a generating process such as turning on a lathe, will this degree of roundness be exceeded. Unfortunately, no figures are currently available to give an indication of the likely range of threshold levels that differentiate between forming and generating processes. Perhaps when the results of experimental work into this problem, currently being carried out in conjunction with this investigation, are available, it will be possible to reconsider the likelihood that the Irish Bronze Age smith used a lathe to generate the form of these horns. The measurements of "roundness" carried out in a rather simplified way on Dowris, 14-0, gave measurements of diameter at the bell of (mm): 25.79, 25.53, 25.75 and 26.19, i.e., maximum variation of 0.66 mm. This figure re-enforces the view that these instruments are worthy of further detailed metrological study.

Clay Shrinkage Problems in Mould/Core Design

Once the development of chaplets that key into the core had taken place, the assembly of the core itself became a complex operation. For the chaplet to penetrate the core readily, without cracking it, the core would need to be in a wet, green state (i.e., wet, unfired clay). At this stage, the protrusion of the chaplet from the core would need to be set to obtain the desired casting cavity and, hence, the desired tube wall thickness. However, at this stage, the core cannot be offered up to the mould to obtain a measure of this dimension, as in order to fit the mould once dry it would have been made oversize to allow for shrinkage while drying. This shrinkage itself is complex as, not only will diameters be reduced by it, but the overall form of the core will similarly change. Thus, to attain a uniform casting cavity when the three dry parts of the mould assembly are put together, the core must have been made accurately to a standard which was larger than the dry core by the appropriate amount.

A solution adopted to overcome the bulk morphological change during drying of the mould and core is frequently seen on Class I instruments. These are of an "L" shape, sometimes with an included angle of only 120° or so and having the curvature limited to the centre of the instrument only. When a core of this shape shrinks, the reduced form

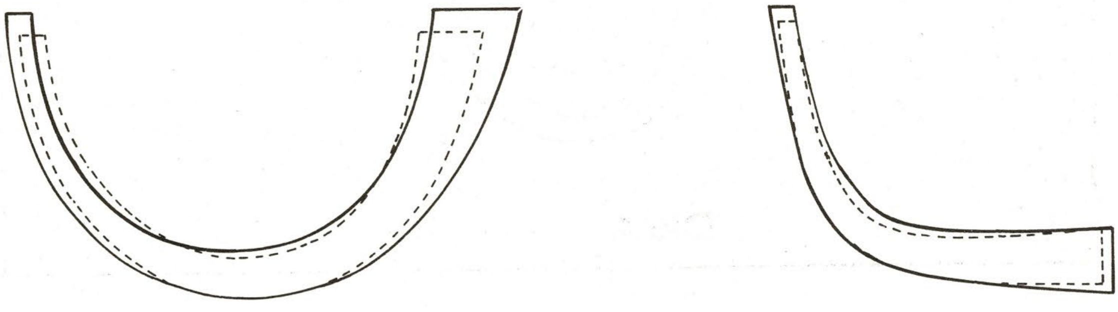


Fig. 6 — Core shapes for curved and "L" shaped instruments — dotted line shows form of core after shrinking.

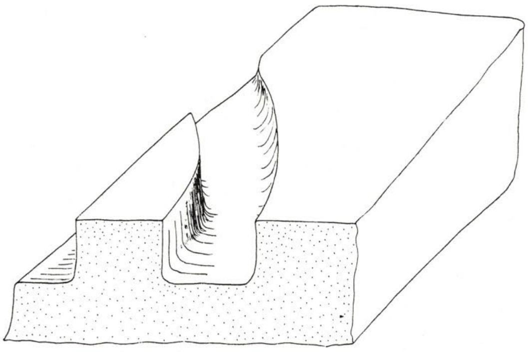


Fig. 7 — Portion of core forming loop aperture.

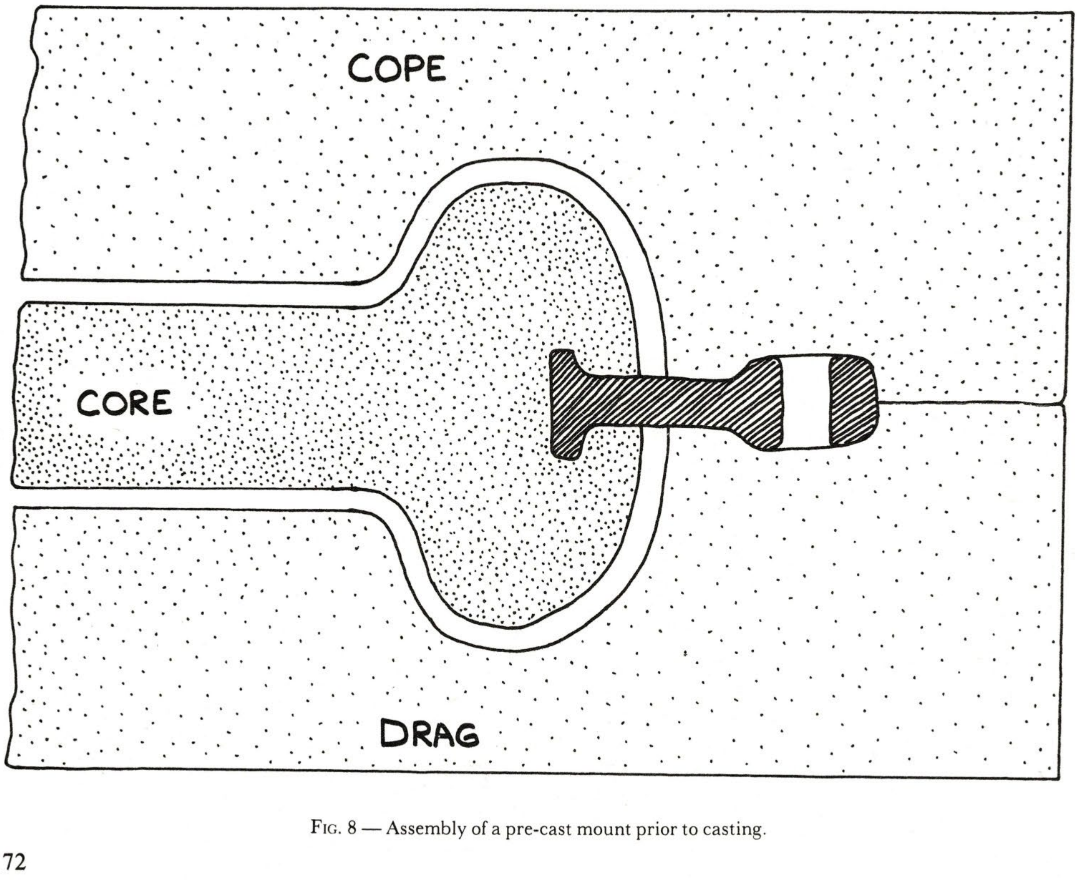


Fig. 8 — Assembly of a pre-cast mount prior to casting.

still fits inside the shape from which it shrunk, easing the problem of defining the original wet clay form required to obtain a specific final dry core (fig. 6). With the technologically more complex Class II instruments this problem seems to have been overcome, removing this constraint from the instrument designer.

The Provision of Instrument Carrying Features

A further aspect of manufacturing technology to be considered is the provision of carrying features on the horns. Starting as he did, from the standard technology of the time, the maker adopted the loop as a carrying feature. By placing one of these towards the tip of the instrument, he mirrored almost exactly the application of loops to bronze axes and similar items. However, as on these items, the problems of coring out the cavity of a loop, to provide the aperture would frequently produce loops with the aperture completely closed by flash that has run between the mould halves. The problem is simple to appreciate as the small *inselberg* of clay that serves to form the loop aperture is a weak structure and is readily fractured off or distorts during drying of the core (fig. 7). A simple solution to the problem is to chip out the flash with the attendant risk of fracturing off the loop, or to drill it out as has been done on Dowris 14-K, to produce a strikingly round hole (pl. 11).

A slightly different problem arose at the tip of side-blown instruments where the loops provided are generally somewhat larger than on the tube wall. These loops are rooted in the end wall of the horn and, where this is accidentally thinned during casting by poor longitudinal registration of the core, these loops frequently pull out at their root when heavily loaded. Being seen as failure of the root to support the loop, a design evolved which provides a root on a separately cast mount and was used on both tip and tube. This piece was set into the core during its manufacture and left to protrude from the end of this. When assembled in the mould it is then cast into the horn tip as an insert during the normal pouring of the mould (fig. 8). A secondary, but nonetheless, important feature of this practice is that the mount itself provides considerable support for the core at its tip during the pouring of the mould.

As a technique, this proved quite successful in that most mounts fixed in this way remain in position. However, it is the root that retains them and not bonding of any form between the cast tube wall

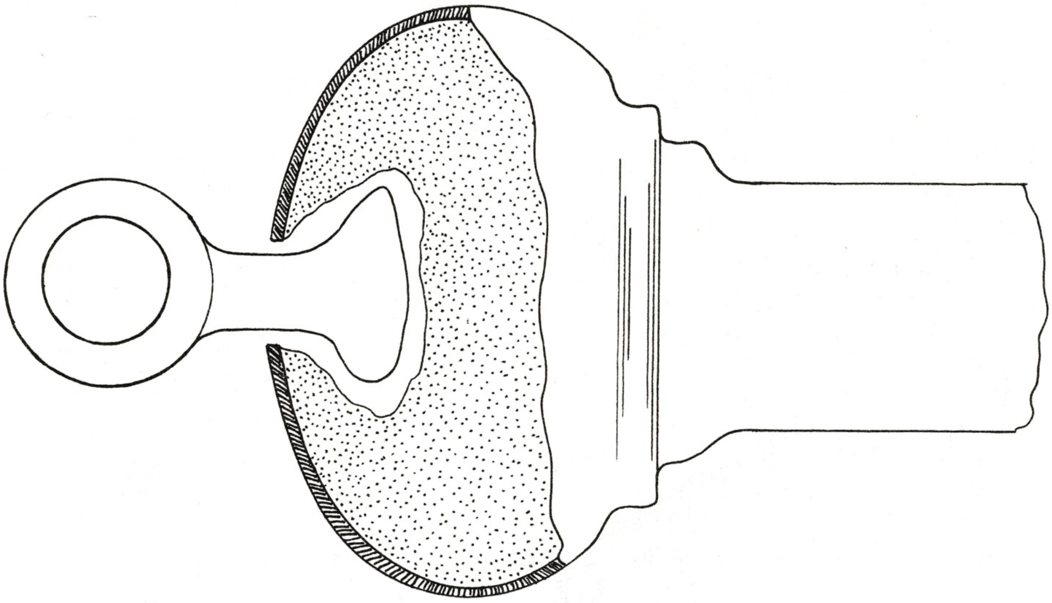


Fig. 9 — Wear of a horn tip end and core following extensive use.

and the pre-cast mount. Thus, when the mount is subjected to lateral stress, it pivots on the edges of the tube wall and begins to wear away both tube wall and core (fig. 9; pl. 12). Eventually the mount becomes very loose and rattles around in the tube. To cure this the maker fixed the mount firmly in place, generally seating it somewhat lower than it had been previously and poured in molten metal to hold it in position.

The discovery that such a process could be effective was clearly important as the addition of parts to a sub-assembly in this way represents a simple form of brazing. Further development led to the adaption of this technique by preparing a hole in the tube wall and a corresponding cavity in the core. Into this was placed a pre-cast or wrought mount and metal was then poured around it (fig. 10, pl. 13). In adding mounts in this way, the maker broke away from the old loop form to arrive at a new design that allowed him to thread a ring into the mount, prior to assembly. Molten metal is never easy to handle and the problem of constraining the metal flow during these fabrication procedures must have been considerable. It is most

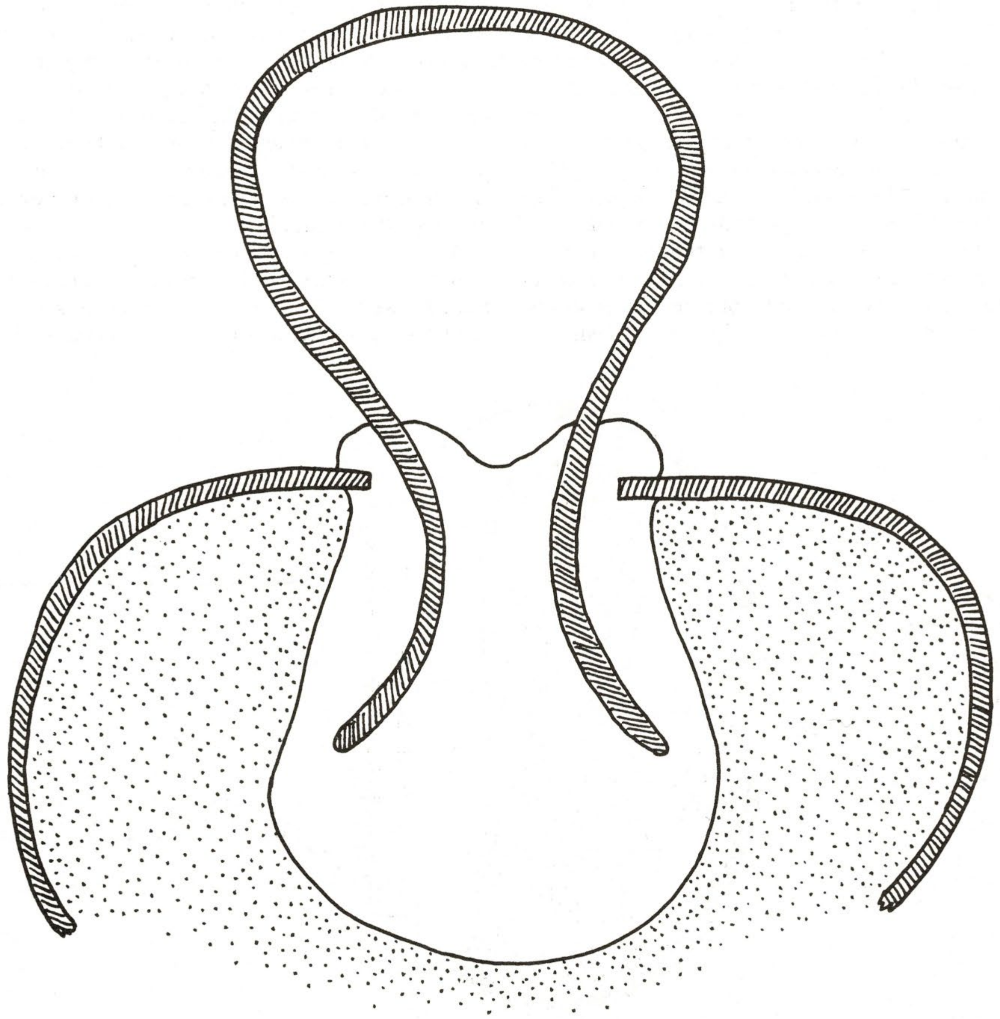


Fig. 10 — The casting-in of a fabricated tip mount.

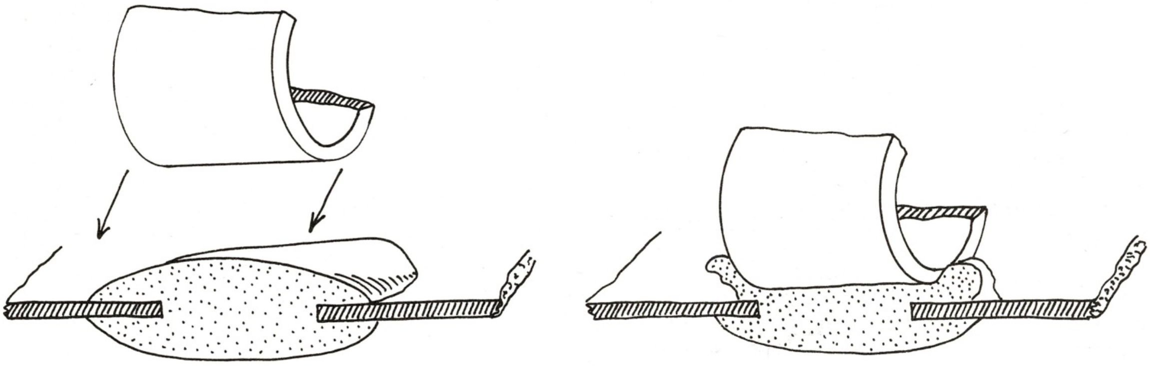


FIG. 11 — The seating of a mount in molten metal.

likely that a mould form was built up around the mount holding this firmly in position. Several mounts seem to have been added in this way and some of these have a hole on their top surface which, judging from metal splashes around this, could have formed part of the metal feeder system. This would undoubtedly be a fairly elaborate procedure but no less a one than has been practiced at many other times during the construction of these instruments.

Another method adopted utilised molten metal to join a mount which lacked a loop. In this a pool of molten metal was made on the tube (instrument 36-B), possibly having made a hole in the tube wall and having excavated a cavity in the core and the pre-cast mount was then pressed into this (fig. 11, pl. 14).

Clearly, the problems involved in the addition of rings and mounts to instruments gave rise to much experimentation and much careful thought. One solution in particular, demonstrates that its originator had approached the problem in a logical way. Faced with the problem of maintaining an adequate core through the loop when casting, he must have realised the similarity between the *inselberg* of material that formed this aperture (fig. 7) and the core that formed the bore of the instrument itself. Perhaps he tried to make a loop by coring out the aperture and faced with the problem of locating a core normal to the mould joint-line, abandoned his attempt. However, he then reapplied this solution, having first twisted the loop core through 90°, i.e., so it lay parallel to the tube core and thus could be located in its own particular core prints in the cope and drag (fig. 12). Only one example of this novel solution to the problem has survived, Dowris 14-I, (pl. 15) and, although the core was displaced vertically in the mould, giving a thin section on one half of the mount, it is, generally speaking, a successful casting.

The Provision of Decorative Spikes

Many other methods of fabrication were developed by the makers of these instruments, for adding mounts, decoration and for assembling instruments from sub-assemblies. During the course of these developments great skill developed in making complex moulds and in the control of molten metal during casting-on.

In the case of the decorative spikes at the bell ends of instruments, for instance, the earliest provision of these seems to have been made by casting them on, while on the technically more advanced instruments, these were integrally cast. It is clear that a design relationship existed between these spikes and the holes, a common configuration being of four of each. On Dowris 14-A the bell end has three drilled holes, spaced as for four. One of these remains in the drilled condition, a second has been infilled with bronze which bears signs of both hammering and abrasive working while the third contains a bronze rod of approximately 4.5 mm diameter. This was set-in by pouring molten metal around the rod while it was placed in the drilled hole. Protruding from the tube surface by about 10 mm, the outer end of this rod is peened over somewhat.

It appears, therefore, on this instrument, that the holes were provided as sockets to hold these rods while casting them in. A further possibility exists, of course, that a change of use of the holes occasioned their filling-in in this manner. A similar

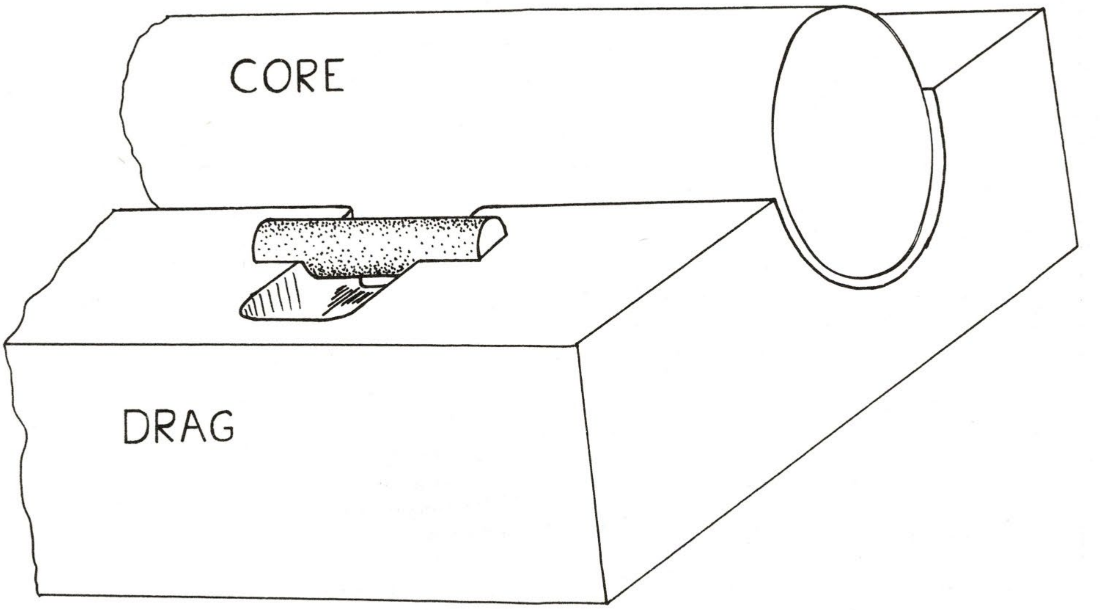


Fig. 12 — The coring-out of a mount aperture.

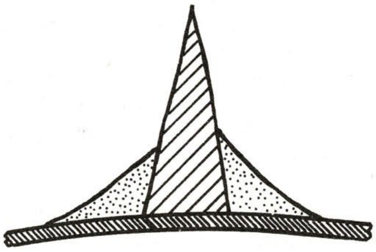


Fig. 13 — The casting-on of a conical "spike".

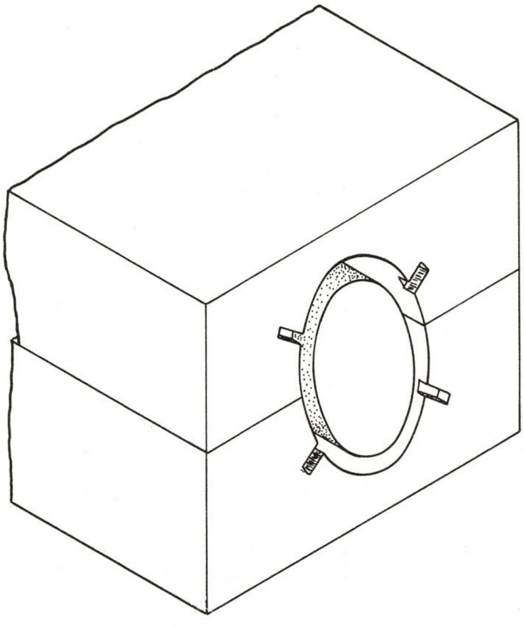


Fig. 14 — End-face of a mould provided with rectangular "spikes".

type of construction, i.e., casting-on, was utilised on Dowris 14-F, 14-K and Drunkendult 17-A although on these, the spikes are conical in form. On 14-K, these are fairly sharp cones and their junction with the tube is obscured by a build-up of cast-on material (fig. 13).

Similar features are seen on the large Bronze Age cauldrons such as those in both Dublin and Belfast museums. On these, the spikes have generally been identified as rivets and this may, indeed, be part of the story. However, some casting-on has taken place around these features as witnessed by the deposits of cast material around the spikes themselves. The casting-on of small features such as spikes is technically quite difficult for not only must the cast-on material be restrained to give the right form but it also contains little heat and is, therefore, very readily chilled by the metal with which it comes into contact. Such problems are eliminated when the spikes are cast integrally as was done on most of the technologically more complex instruments. However, the earliest attempt to provide integral spikes seems to have formed these directly on the end face of the bell itself. These are seen on only one instrument where four rectangular "spikes" are spaced with each set between the sprue junction and the joint-line and their end-face is common with the instrument bell end. To form the mould cavity for these, material had been removed from the end face of the mould halves, and the containing wall re-formed by the core butting up against the mould end face (fig. 14).

Dowris 14-L has "spikes" spaced around the periphery of the bell in a similar way but these are generally set in by a millimetre or so from the instrument end face. Hence on this instrument, the "spikes" had been formed by pressing a cylindrical former into the mould to form these cylindrical features. It appears that on this mould assembly, the core print diameter was greater than that of the bore itself and butted up against the end face of the mould halves. Thus, the form of the earlier mould was retained, even though the butting-up of the core was no longer essential to give form to the mould. Having formed the spikes in the mould in this way, the way was clear for their "migration" downstream to the commonly found location a few centimetres from the instrument's bell edge. The restrictions on the form of these rivets was also removed in that, whatever form could be pressed into the mould and then satisfactorily retracted could be used — and a conical form was ideal for this. Thus, many later instruments have conical, integrally cast, spikes spaced around their circumference, some of these having hollowing underneath.

The process of casting-on appears, in the case of the spikes, to have been progressively refined and its function eventually to have been taken over by the mould itself. This suggests that the elaboration of moulds that took place was the result of local improvements in manufacturing technology which were applied to these moulds stage by stage.

Joining by Casting-on

Casting-on was also utilized to join together yards of instruments. On Dowris 14-I, for instance, a tube yard was cast-on to a bell yard and the presence of separate joint-lines on both the original yards and the cast-on section gives evidence that two-part moulds were used for the casting-on process. However, the workmanship on this particular instrument is not too good and significant improvements on this were made both for repair and assembly. Several side-blown instruments (e.g., 13 and 14-0) had broken across the tube at their weakest point, where the blowing aperture reduces the tube cross-section considerably. These were repaired very successfully by casting-on material around this fracture.

At its highest level, casting-on was used on the Drumbest instruments (16-A and B) to join the tube and bell yards together. Only close examination now reveals that the tube-bell joint is cast-on, as it maintains its mechanical integrity and runs very smoothly into the tubes. The joint appears to have been made in four stages as outlined on fig. 15, these being:

i) Casting of the tubes.
ii) Casting-on of the raised mouldings around their tube ends.
iii) Assembly of two tubes.
iv) Casting-on of the thin wedge of material between the two tubes.

It is interesting that in stage (ii), the cast-on supporting piece that forms the feature on the tube was produced in two parts, the tapered portion, on the right in (ii) (fig. 15), being cast-on to the mating tube rather than continuous with the cast-on feature itself. Clearly, the maker had previously experienced problems with this part, either from the tapered end of the tube fracturing off or from it not filling adequately in the mould during casting. His solution, the casting-on of this as a separate piece, overcame these problems, although presenting him with a further one of locating the tapered portion accurately on the tube. In doing this task he played safe by casting this portion on nearer to the tube end than was necessary to ensure that the two butted pieces mated. This left an annular gap between the two tube ends which, as it is now only visible when using fibre-optic inspection equipment, is not likely to have bothered the maker!

The similarity between the two Drumbest instruments (16-A and B) is remarkable and there is little doubt that these instruments were made in the same workshop, most probably by the same craftsman.

The Finishing of Cast Instruments

Not only was the smith of the period able to manipulate molten metal very ably, but he also became adept at finishing off the instruments to a comparably high standard. This shows up well in the case of holes produced in the tubes and loops of these instruments. Admittedly, among the large number of instruments there are those which have holes that are very crudely made. Some of these are produced by abrading through the tube with a coarse abrasive used at right-angles to the axis. On others this form of slotting has been used to make an initial breach through the tube, in much the same way as one might centre punch and drill today prior to drilling a hole.

On many instruments, however, holes are very carefully — and expertly — drilled. Their sizes range from about 2 mm to 7.5 mm in diameter and are generally of a consistent size on a particular instrument. The diameters of several holes measured

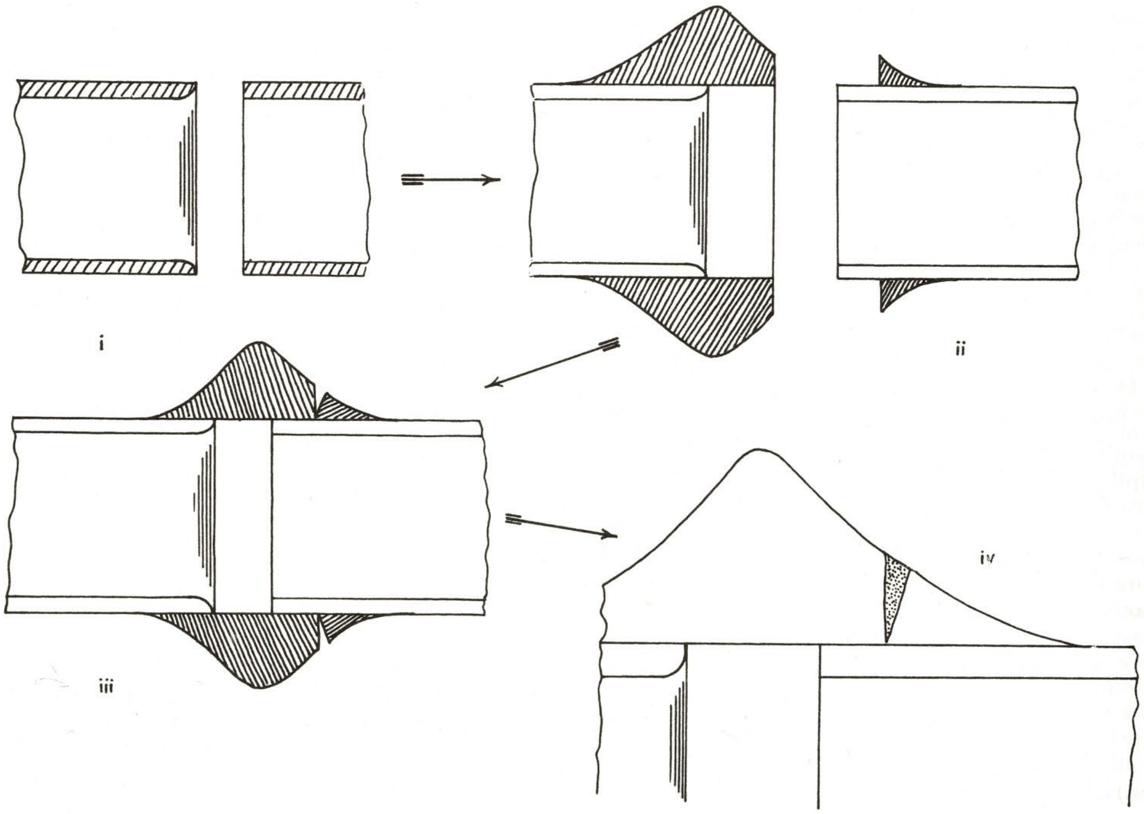


FIG. 15 — Assembly of the tube and bell yards on the Drumbest end-blow instruments.

on these instruments are, (in mm):

7E	7.4, 6.8, 7.4, 7.4
7G	5.3, 5.4, 5.3, 5.4
13	6.6, 7.5, 6.7, 7.3
22B	5.2, 5.7, 5.2, 4.4
41	5.0, 5.2, 5.0, obscured by casting-on.

These figures show a general repeatability to within about 0.7 mm suggesting that in each case the holes were cut by the same tool, that it was a fairly sophisticated cutting device and that the maker was both able to and intent on cutting the holes to the same diameter. One of the key features of such a device would be the primary cutting faces of the drill-bit end. These would need to be sharp, formed at the same angle and in such a way that the point of the drill lay on the centre-line of its axis. Where this point lies off-centre, the outer cutting edge cannot follow the path defined by the drill centre and will exert a horizontal force on this, causing chattering (i.e., the production of a polygonally-shaped hole with many small facets) or lobing (the production of a polygon with few, usually three, faces). Thus, on instrument 7-G (dimensions above), the geometrical form of the drill tip must have been very carefully defined and produced, resulting in the production of eight holes all within ± 0.05 mm of 5.35 mm diameter. A strikingly well-drilled hole, drilled in a difficult position, is seen on SD 14-K where the tube-mounted loop has been drilled out to clear the flash (pl. 11). Fig 16 shows the possible form of a suitable drill tip, which could be made in a hard fine-grained material such as flint or quartzite and would derive sufficient central control from the tip form to allow a round and parallel hole to be drilled. The alternative process of abrading out a hole using a flat-ended drill and an abrasive would not produce circular holes to the degree seen here, nor would it produce burrs of the size seen on many instruments.

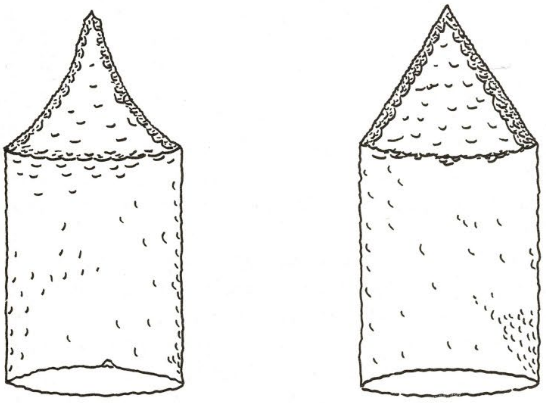


FIG. 16 — Possible form of drill-bit used to drill tubes.

The Use of the Horns

Both side-blow and end-blow instruments are clearly developed metal analogues of an animal horn plus a Tube. As such, they share a common heritage with the vast number of other instruments of this type and one's view of their usage tends to be conditioned by the usage pattern of these other instruments. The side-blow instruments, however, although they bear some resemblance to contemporary and recent side-blown instruments have none to any archaeological material. As musical instruments, both types of horn suffer from the lack of a mouthpiece, a feature that is not seen in Ireland even on the Iron-Age instruments. Contemporary societies were using instruments with mouthpieces in Scandinavia and possibly Italy and Spain but there is no evidence that these spread to or were developed indigenously in Ireland.

Thus, when trying to blow one of these instruments, a player privy to the modern tradition finds them poor organologically. However, there is no continuous tradition of playing such instruments in Europe and the mixture of modern *embouchure* and Bronze Age 'mouthpiece' seems to produce little useful effect on these instruments. Fortunately the two Drumbest instruments (16-A and B) retain sufficient of their authentic mouth-supports to show that these had no throat, i.e., no restriction downstream of the mouth-support. The combination of this with a rim of large diameter produces an instrument that is well nigh impossible to sound above F_5. However, that is the negative view of the qualities of this instrument as the very features that preclude the production of higher notes permit and favour the production of lower ones. Hence, Drumbest (16B) sounds a very full and resonant F_2 when played with a relaxed *embouchure*. In this mode of blowing the lips vibrate with a large amplitude and the use of the peripheral muscles around the *Orbiculoris Oris* (the muscle that surrounds the lips) allows the tone colour of the note to be changed while blowing. In addition, voiced sounds generated by the vocal apparatus can be injected into the air stream and considerable variety thus introduced into the sound produced. This manner of blowing an instrument, in the variable tone-colour mode is best known from its use by the Australian Aborigine in blowing the *didjeridu*. Interestingly, experimentation with this mode of blowing the large orchestral brass instruments is taking place at the moment, releasing these instruments from the straight-jacket of modern orchestral form.

Used in this way, the Bronze Age horns spring to life, changing from a straight four-note instrument to one capable of generating the almost infinite variety that characterises modern *didjeridu* playing (for account of modern performance of the *didjeridu* see Jones, 1957, 8). The acceptance of such a use of these instruments gives logic to the years of experimentation that led to the production technology seen in the later instruments. The effort was not directed to producing single-note instruments but to the development and production of a basic sound producer capable of laying down a harmonic and rhythmic base for communal music-making activity.

The Overall Context of the Horns

The Irish horns are thus unique organologically and show a considerable sequence of development from a fairly simple technology to one of a highly specialised form. The Class I instruments generally, utilize the simpler processes seen on the instruments as a whole and the combination of processes seen on this group seem to point to the early evolutionary stages having taken place in the north-east of Ireland. However, at some stage, the manufacture and use of horns spread to the south-west of Ireland. In this area, free from the tradition that had grown up around the Class I horns, the maker was able to develop the instrument both technically and organologically. It is in the Class II instruments, therefore, where the most complex technology is used and where the horns reach their largest size.

Whether the technology originated in Ireland or became established as the result of a low degree of design and technological diffusion — the blowing horn being introduced — it is not possible to say. However, whatever degree of design diffusion took place it did not include the introduction of the side-blow instruments. These remain unique and are thus most probably indigenous developments. This being so, then the simplest/earliest of the side-blows that we see had already resulted from considerable indigenous development. Because of this uniqueness then, any influences from elsewhere must have been of a technical or aesthetic nature only. However, even in what seem to be the simplest of instruments, a manufacturing technology is employed that is very specific to these instruments and unique in this area. No comparable artefacts are known which feature such long, thin-walled hollow vessels in this region. Only the *lurs* are of comparable form but these were all made by the lost-wax process, hence employing a different technology. It would appear then, that a low level of design technological diffusion may have introduced the idea of a blowing horn and metal casting into the island and thereafter, it developed on its own.

Having acquired a base for development, the way was open for the smith to experiment and develop techniques for making better instruments in better ways. Fortunately, these generations of smiths left a record; one that, as yet, remains virtually untapped as a source of information. Nevertheless, to date this has revealed that the smith took casting techniques using a print-supported core and developed chapletting systems capable of supporting a core firmly and accurately. This ability to maintain the core where desired led to the production of finer sectional thicknesses which, in turn, required greater morphological similarity between core and mould. On Dowris 14-O, with measured wall thicknesses of 1.08 ± 0.075 mm and 1.36 ± 0.23 mm, the coarsest of these gives a maximum of 0.46 mm to account for: difference in roundness between core and cope/drag assembly; registration of cope and drag; registration of core relative to cope/drag assembly and movement of the core during casting. The parts that constitute the mould assembly are round in form and it is possibly the use of generation processes that produces inherently round objects that has led to this high degree of uniformity.

In a general sense, the whole area of metrology as applied to both the *lurs* and the Irish horns is awaiting detailed study. Fortunately the Irish horns are accessible for this purpose although, unfortunately, the same cannot be said of the bulk of the *lurs*.

In terms of the manufacturing technology of fabrication using liquid metals the Bronze Age smith was equally active and inventive. From his desire to fix ring mounts, to repair, and to add to tubes he developed a technology that defies description in modern terminology but is closely akin to brazing. Again this experimentation can be seen demonstrated by the successes and failures, along with a lack of the quantum steps in development that one might associate with the input of technology, diffusing from a technologically more advanced area.

The experimentation that can be seen produces its own frustration for the student as no discrete evolutionary sequence can be discerned. Such is the interdigitation of individual sequences, producing mixtures of the simple and complex, that many workshops must have been involved in the developmental process. Just how the process of interaction between these took place, it is hard to say, nevertheless the workshops were at most quasi-independent. Their products yield an intriguing mixture of a steadily developing line punctuated by inputs from other local industries.

On the periphery of late Bronze Age Europe the two great schools of manufacture and performance existed, maintaining a large measure of independence from the European area from which their ideas and technology might be considered to have spread. However, neither culture appears to have needed the constant diffusion of ideas, perhaps the push at the beginning, but after that the developments were mainly autonomous. Perhaps, too, the lack of contact, perhaps the lack of strife allowed these areas to develop their rituals and associated technology untroubled by events in Central Europe. However, at the end of the Bronze Age both traditions of instrumental use died out and, with them, much of the associated manufacturing activity, thus cutting us off from a thousand years or so of active and successful musical technology.

I am grateful for all the assistance and advice given during my studies of the Irish horns to Dr. Joseph Raftery and the staff of the National Museum of Ireland, Dublin, Laurence Flanagan and the staff of the Ulster Museum, Belfast and Dr. Ian Longworth and the staff of the British Museum. Also, in addition to his 1963 paper which formed the basis of my study, Dr. John Coles has given constant helpful guidance and advice throughout the course of my study. Financial assistance from Middlesex Polytechnic has made my frequent visits to Dublin possible.

BIBLIOGRAPHY

VON HORNBOSTEL E. M. and SACHS, K., 1914, "Systematik der Musikinstrumente", *Zeitschrift fur Ethnologie* 46, pp. 553-590. An English translation of this in *Galpin Society Journal,* no. 14, 1961, p. 3 ff.

DAY, R., 1875, "Irish Bronze War Trumpets," *Journ. Royal Soc. Antiq. Ireland* 13, 422.

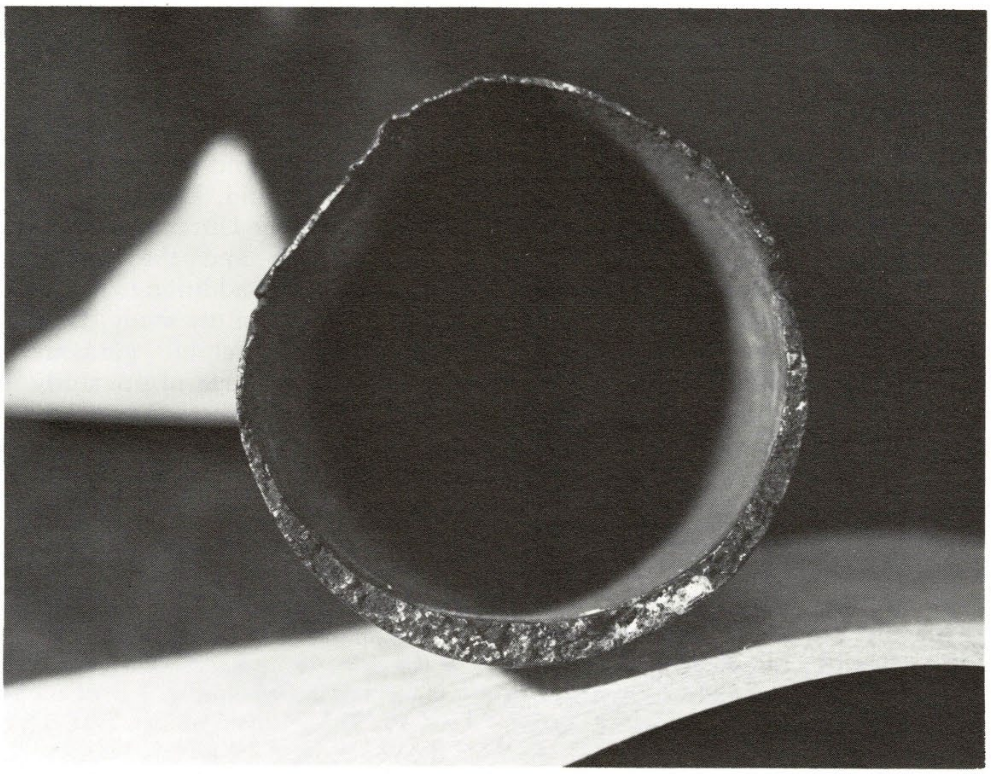
EVANS, J., 1881, *Ancient Bronze Implements,* 357.

COFFEY, G., 1913, *The Bronze Age in Ireland,* 85.

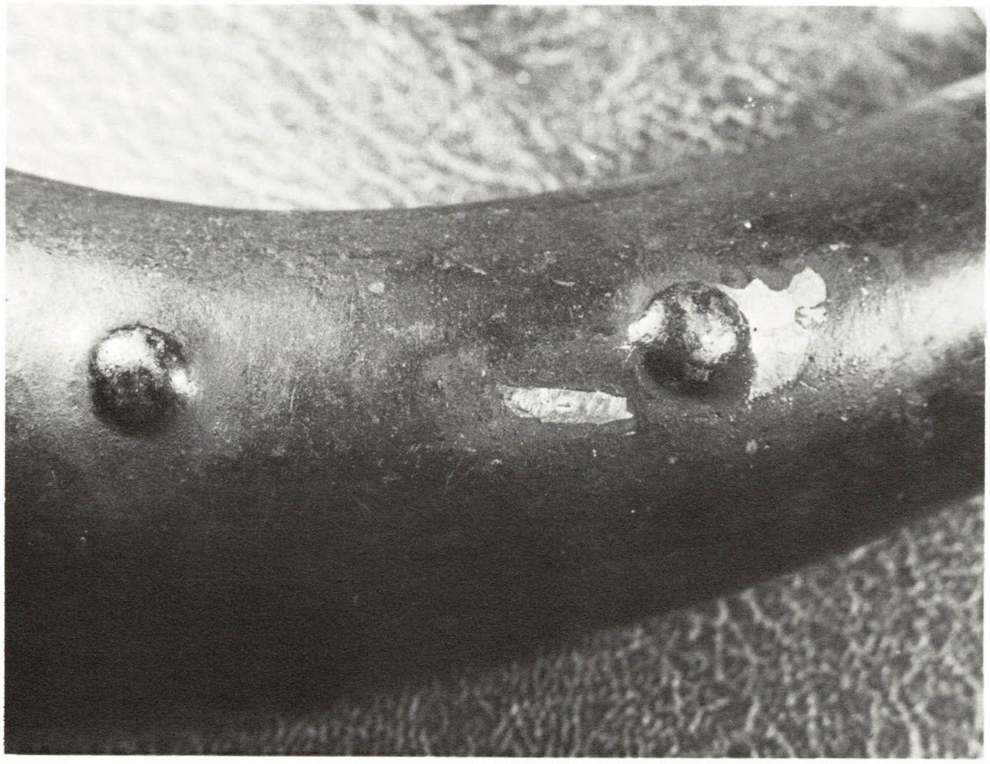
MACWHITE, E., 1945, "Irish Bronze Age Trumpets", *Journ. Royal Soc. Antiq Ireland* 75, 85.

COLES, J. M., 1963, "Irish Bronze Age Horns and their Relations with Northern Europe," *Proc. Prehist. Soc.* Vol. 29, p. 326 ff.

JONES, T. A., 1957, "Arnhem Land Music," *Oceania* 28 (1) 1-30.



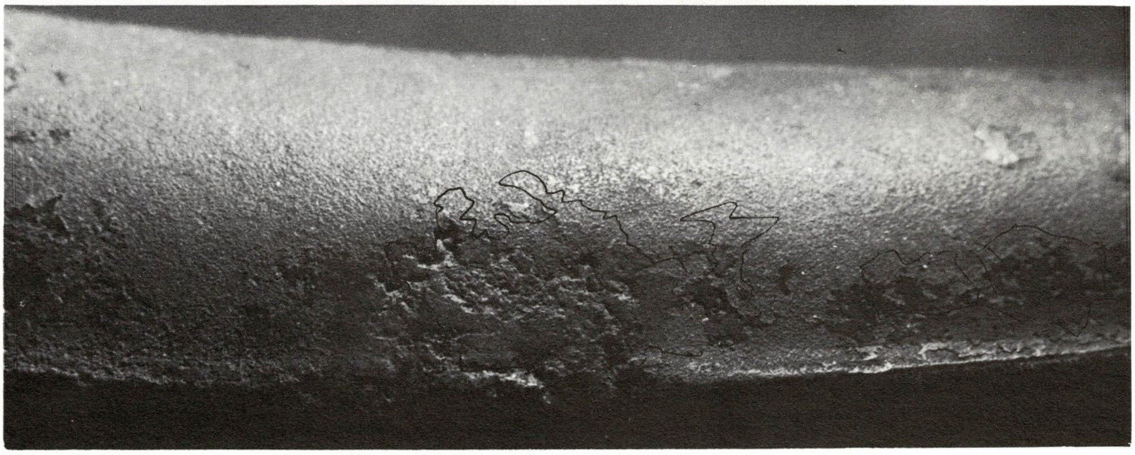
Pl. 1 — Irregular tube cross-section resulting from core movement during casting.



Pl. 2 — Cast-in features replacing apertures left by core-supports.

Pl. 3 — Typical loose surface-chaplet.

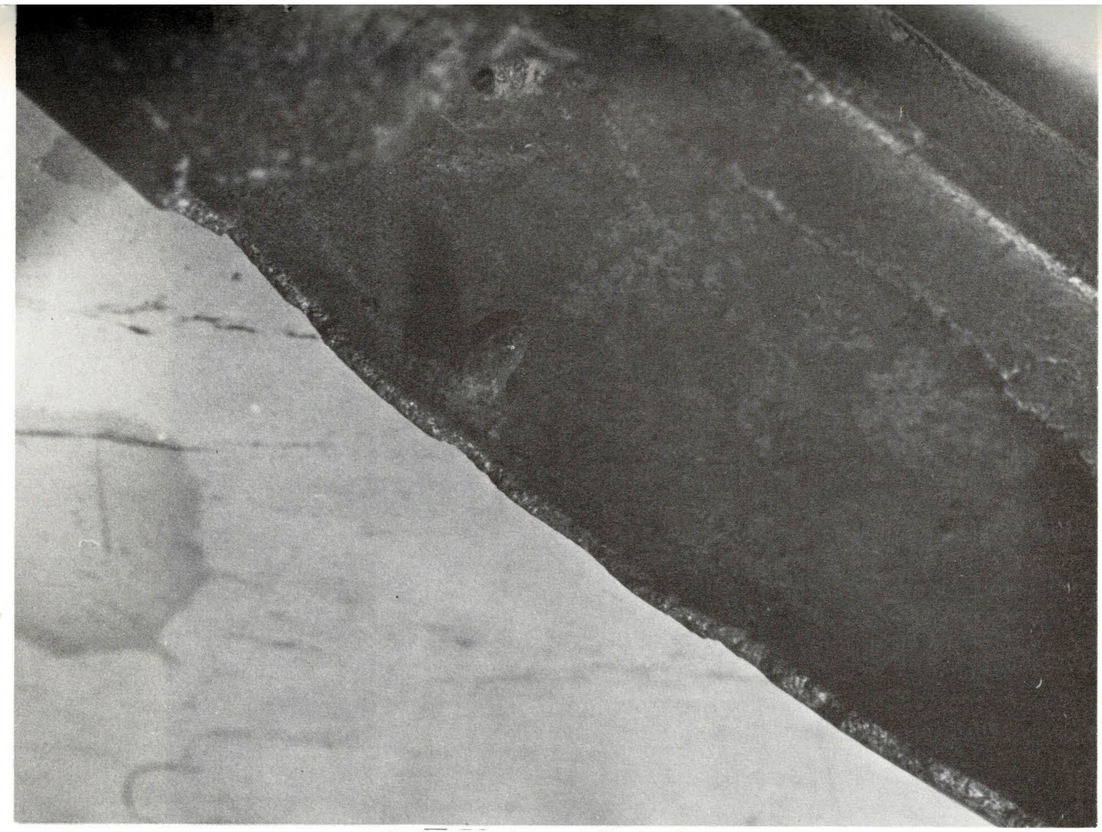
Pl. 4 — Two surface chaplets, one having moved during casting.



Pl. 5 — Chaplet on tube joint-line.

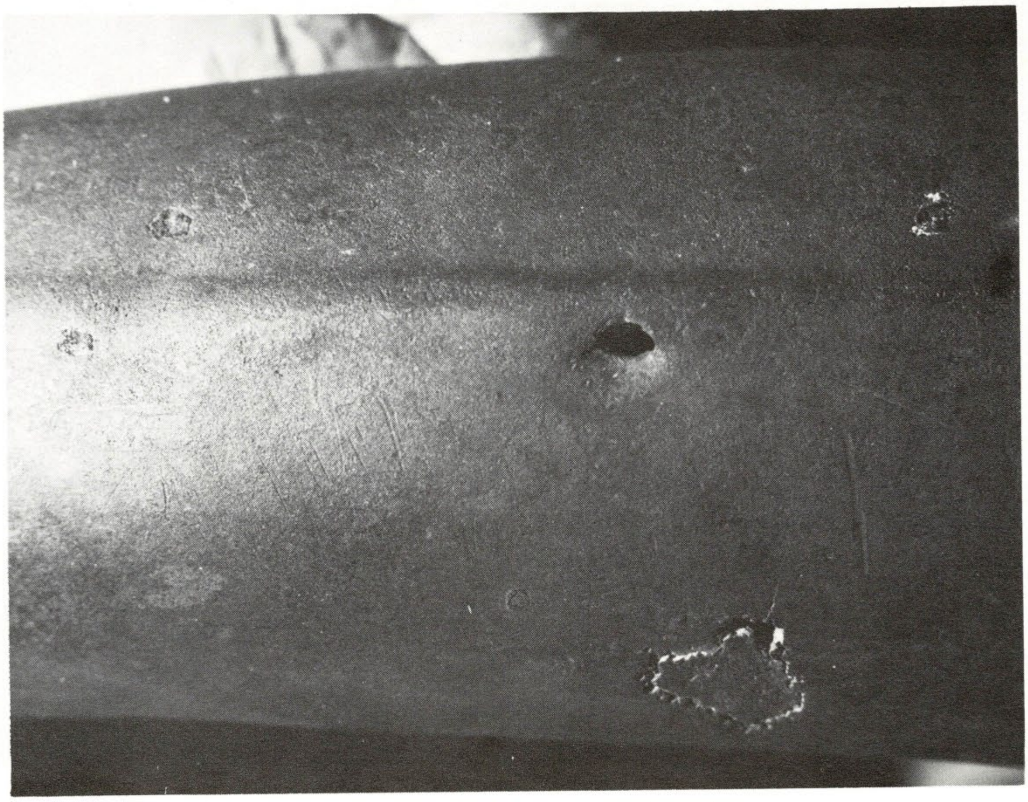
Pl. 6 — Keyed surface-chaplet, showing protrusion into bore.

Pl. 7 — Large spiked-chaplet in tip of side-blown horn.



PL. 8 — Chaplet protruding into bore.

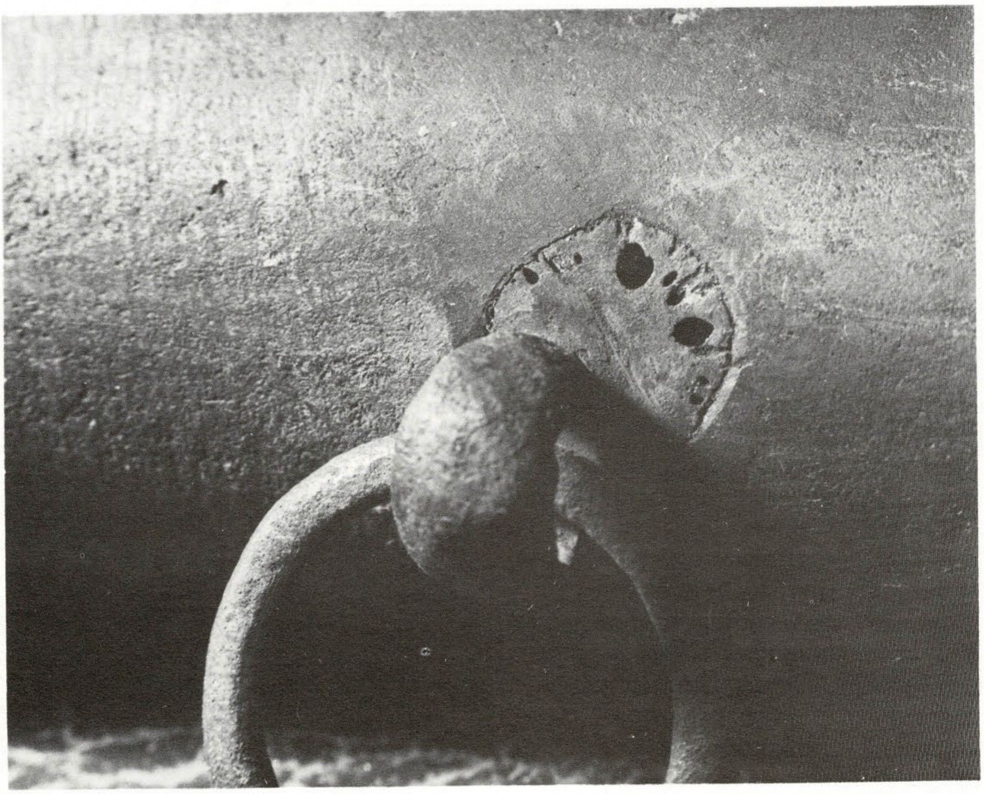
PL. 9 — Tanged-chaplet protruding into bore.



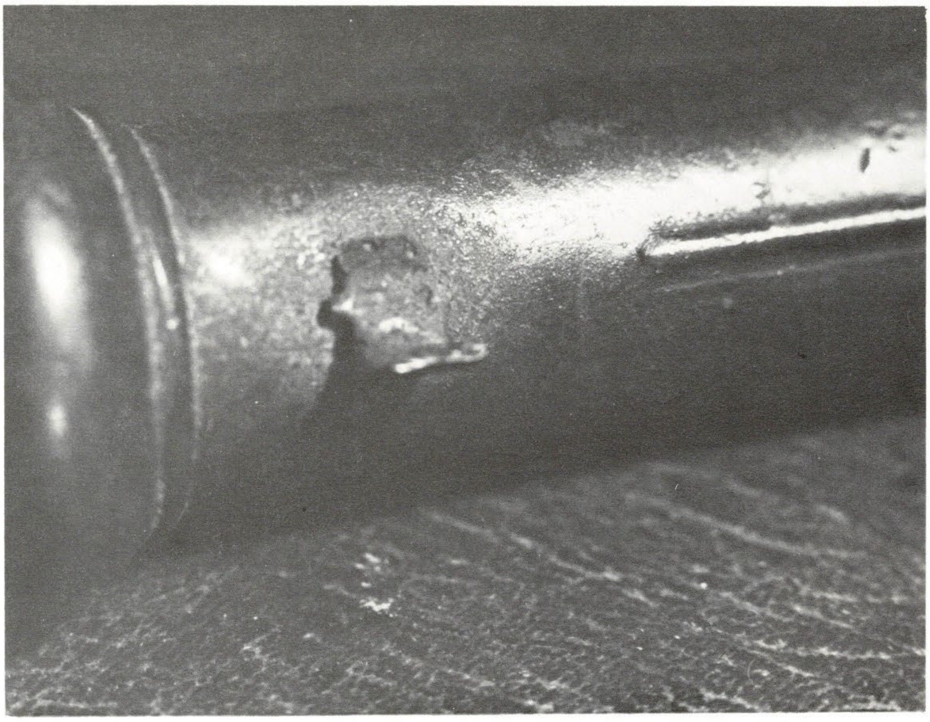
Pl. 10 — Surface of tube showing two different chaplet types.

Pl. 11 — Tube-loop showing drilled-out hole.

Pl. 12 — Tip-mount showing wear from movement of mount.



Pl. 13 — Tube ring and mount set into tube wall.



Pl. 14 — Tube-mount, placed in position following removal of joint-line.

Pl. 15 — Ring-mount with cored-out aperture.