CHAPTER 4

THE INSTRUMENTS OF SCANDINAVIA[149]

In the area of Northern Germany, Denmark, Sweden and Norway, between 1600 and 500BC, a culture developed which was distinctive and different from those to the south in Europe and to the West in the U.K and Ireland. Bronze was worked there although no indigenous supplies seem to have been available, the source of raw material being either west or central European. Amber was possibly one exchange material as Baltic amber is quite widespread in both West and central Europe. The conventional sub-division of the culture is into Periods I to IV and a rough comparability of these with conventional dates is given below:-

PERIOD	GENERAL DESCRIPTION	APPROX. DATE	
		Radio Carbon	Conventional
I	Early Bronze-Age	1600B.C.	1900B.C.
II	Middle Bronze-Age	1500-1200B.C.	1800–1500B.C.
III			
IV	Late Bronze Age	900–600B.C.	1100–800B.C.
V			
VI	Late Bronze Age/Early Iron Age		300B.C.

The culture of the area was distinctive both in the artefacts it produced and with the ritual recorded on iconographic sources. The latter included engravings on bronze artefacts, and most important of all the numerous rock carvings in the area. Some of these can be interpreted as representations of ritual practices and show, among other things, the use of what appears to be player-voiced instruments of several forms. (See Map 4.1 for location

[149] In recent work, I have described these as of Scandinavian and Baltic origin as the Norwegian instruments such as that from Revheim are found far from the Baltic Sea.

of finds.) Among these instruments, the most distinctive is quite clearly the lur of which 53 specimens or fragments (SD101 to SD154) have been found.

In this study the term "lur" has been reserved exclusively for instruments of the type here designated "standard" lur form. Unfortunately this is not so in Scandinavian usage generally, where all player-voiced instruments are given the title "lur" as in Oldeberg[150] where he consistently refers to non-Scandinavian player-voiced instruments as lurs, in much the same way as Diodorus Siculus writing in the 1st century BC referred to the instruments of the Gauls as "Salpinges" (DR 9). Being the product of a non-literate society the name given to these instruments during their use in the bronze age is not known. However, when cataloguing these instruments at the beginning of the 19th century the term "lur" was used to describe them as the word is mentioned in the Old-Norse literature and this was the period to which they were assigned. In the sagas, the lur is frequently mentioned as the instrument by which the warriors are called to battle[151] and the connection of the name to these instruments must have appeared logical. Although it is now known that the lurs are considerably older than the period of this literature, the name has become attached to the instruments and seems to be as reasonable a title as any other. However, it was applied to these instruments specifically and there seems no reason to apply it to any other with the obvious exception of instruments now shown to belong to the period of the Sagas.

The lur is fairly readily identifiable on several rock carvings and less clearly so on many others. In addition to the recognisable standard form used for the instrument, however, some forms are represented which seem to be clearly identifiable as intermediates between a simple animal-horn instrument and the "standard" lur as represented in the extant specimens.

This "standard" lur, as represented by the 53 finds of instruments and fragments is of a fairly clearly definable form, the major variation from this standard morphology being on the presumed early examples from Gullåkra (SD135), Paårp (SD138) and unprovenanced one in Skåne (SD136). All the lurs are conically-tubed instruments with a tube diameter varying from roughly ten millimetres to between fifty and eighty millimetres. Their lengths vary from 1.46*m* to 2.20*m*, the tip end of this being terminated by a mouthpiece (a mouthsupport in the case of Wismar and Teterow) and the bell end by a decorative bell disc. All the instruments examined have been cast, probably in bronze, and, most probably, using lost-wax technique.

Both tube and bell yards are made up from segments of varying lengths which are joined together either by a "meander" joint in which a protruding portion of one segment interlocks with the next, by use of a ferrule or band or by casting-on directly. See Figure 4.1.

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150 Oldeberg 1947

151 Broholm, 1947, pp. 49-51

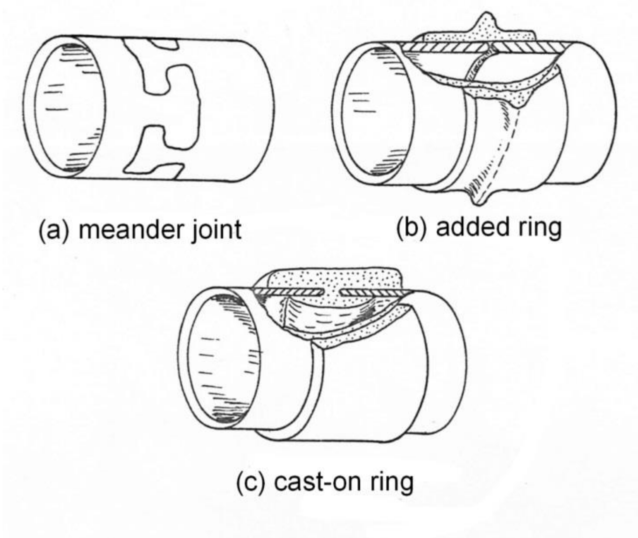


Figure 4.1: Techniques for joining Tube Sections

In some cases, the tube seems to have been cast in sections of one segment at a time in other cases in tube-units made up of several segments.

Visual evidence of the use of chaplets is present on many instruments, from their differential weathering characteristic, their protrusion into the bore of the instrument and from the holes left when these have broken free from the tube material and totally fallen out.

Many instruments have appendages in the form of small (c. 60 mm long) plates attached to various parts of the instrument, mainly on the tube yard and the rear of the bell discs. These rattle or tinkle when the instrument is moved providing a built-in idiophone accompaniment to the music of the instrument itself.

While the early specimens are curved in two planes, somewhat after the fashion of an extended cow horn, the main group of instruments have a very uniform morphology. On these the curvature is almost entirely polarised, that on the tube yard being in a horizontal plane with the bell yard curving in a vertical plane. Some instruments have a transitional segment which curves in both planes while others have a lock which serves to fasten tube to bell yard, where the change from horizontal to vertical planes occurs abruptly. See Figure 4.2.

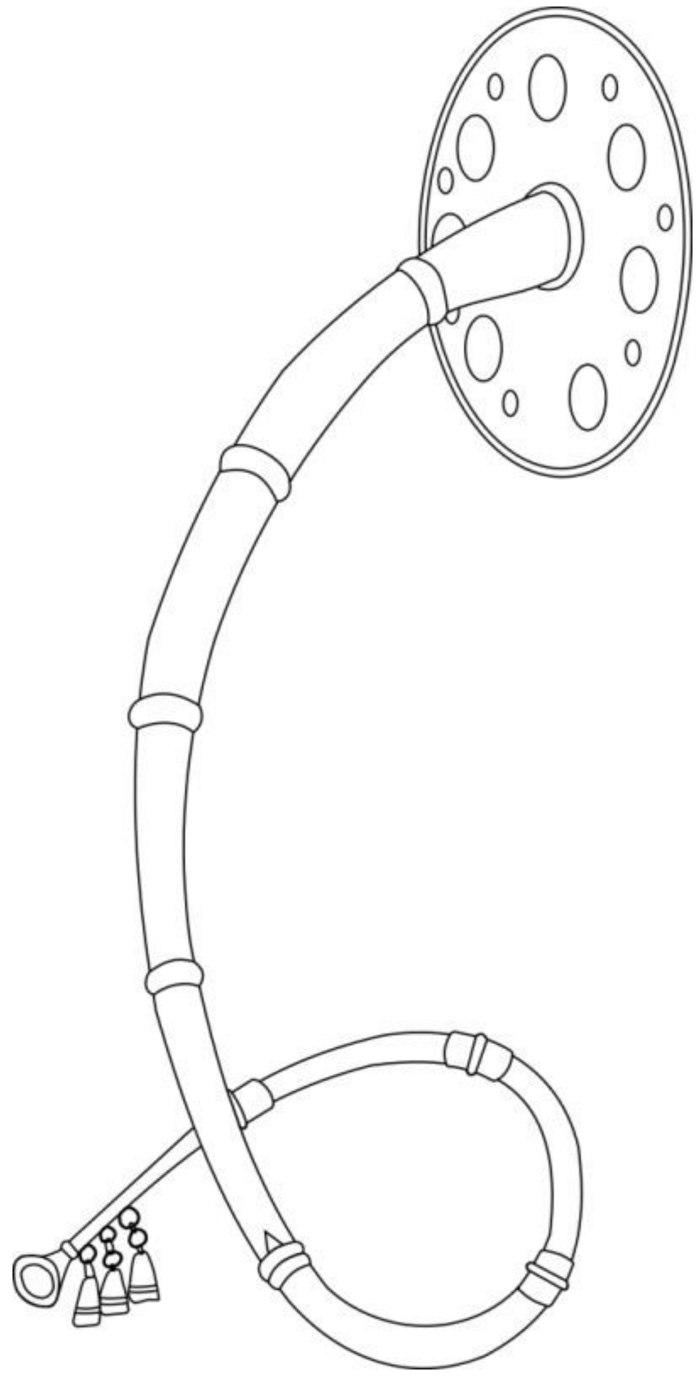


Figure 4.2: A Typical Lur Form

Many instruments have bell discs, and with the exception of the three presumed early instruments, those currently lacking these, have provision for their attachment. Two of the early lurs have an integrally-cast annular disc which meets the bell yard at right angles but the standard bell discs are large annular discs fixed to the bell end so that they fringe the instrument's exit aperture. See Figure 4.3.

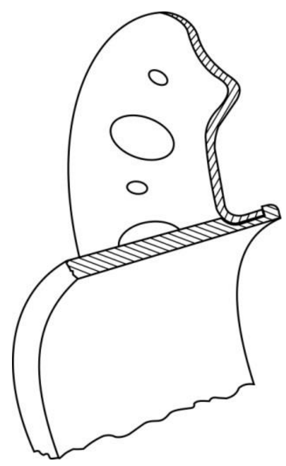


Figure 4.3: Fixing a Bell Disc to a Lur Tube

The lurs generally have been the subject of many papers, their ability to raise interest and spark off controversy perhaps being related to their size and generally spectacular appearance. This has led to considerable speculation and, during the troubled years of the mid-20th century, to their use for purposes of nationalistic propaganda. From the work carried out in the past 200 years, a reasonably stable view of the lurs has emerged, a relative chronology been established and a general picture of the technology involved in the manufacture of these instruments drawn. This study confirms much of the view of the lurs already held but opens up the area of metrology as applied to the lurs in particular and the Bronze Age in general. ln addition it attempts to view the lurs holistically by investigating the evidence of usage and development as presented on the contemporary iconographic material as well as examining the perceptual psychology both of the artists of rock-carvings and the artisan who shaped them.

Three major studies of the lurs have been written previously, by Schmitt[152],Oldeberg[153], and Broholm[154]. Many other references to the lurs are present in earlier literature and these and other specific papers on them are summarised in great detail in Oldeberg[155].

lnexplicably, the iconographic evidence has been largely ignored in previous studies of the lurs. Broholm, discusses two rock carvings briefly on p. 65 of his article and Oldeberg discusses one on p. 81 of his work. This study has located 19 carvings which contain information relevant to the development of the lurs.

THE ESTABLISHMENT OF THE MODERN VIEW OF THE LURS

In works of the early and mid-19th century it had been pointed out that the lurs were cast in several pieces and joined with 'long tenons or rather hooks engaging one segment to the next.' Shortly after this they were generally assigned to the late bronze age. Hammerich[156] discussed the differences between the various lurs and considered that the instruments with integrally cast bell discs were earlier than the others with an added bell disc. He attributed the form of the lur to a development from a prototype cow or ox horn and pointed out that, as with many other instruments, lurs are made, and presumably played, in pairs. By reference to the location of wear on the rattle plates he established that the instruments are played with the bell-disc above the head of the player.

Hammerich's paper was the first to discuss objectively the morphology of the lur in terms of its acoustic performance, coming to the conclusion that the conicity was deliberately designed to achieve a particular acoustic effect.

Writing in criticism of some of Hammerich's ideas, Kroman[157] stated emphatically his belief that the lurs were not played in harmony, being of the opinion that they would have been used as unison pairs.

Curt Sachs[158] considered that the lurs were made by the Etruscans and suggests that the morphology was in some way a derivative of a mammoth tusk form!

A current view that the instruments in the Wismar group of horns were pre-cursers of the lurs was given by Bronsted[159], he suggested a morphological relationship between the

[152] Schmitt 1915.
[153] Oldeberg 1947.
[154] Broholm 1949.
[155] Oldeberg 1947 pp. 1-20
[156] Hammerich 1893.
[157] Kroman 1902.
[158] Curt Sachs 1913.
[159] Bronsted 1938.

Påarp lur and the rock-carvings at Kivik. He continues the old argument that, in lengthening the tubes of the lurs, the manufacturers were trying to attain a diatonic scale, i.e. to break away from the melodic restriction that arises from a "natural" instrument.

Hahne[160] divided the lur material into groups according to age using technological, aesthetic and organological features to establish a gradient of development. Schmidt[161] extended this work and added detailed metallurgical analysis to the tools for research into these instruments.

In his study, Schmidt sub-divides the lurs into Groups A, B and C. Group A, covering the greater part of period III, he considers, includes instruments from Rørlykke (SD119/20), Gullåkra, Påarp and the fragment from Skåne, he characterises them as being of integral construction with several yards joined by meander joints and a bell terminating with an integral flange.

His next group, BI, covering the greater part of the period IV (dated on decoration) are longer instruments made in two parts , the tube and bell yards, these fitting into each other and being held there by the use of eyes cast onto the adjacent tube portions. The instruments he places into this group are: Maltbaek (SD128/9), Lommelev (SD113/114), Lübzin (SD147), Fråap (SD141), and Hindby (SD137).

The next group B2, he characterises as being larger and "more distinctly S-form" i.e. the curvature in the vertical and horizontal planes has become polarised, the former lying mainly in the bell-yard and the latter in the tube yard. These yards are now joined by means of a triangular catch, a protrusion on one yard which fits into a receptacle on the other. The bell discs have cast decorative elements only. He places in this category, the lurs from Folrisdam (SD124/5), Boeslunde (SD111/112) and Radbjerg (SD115/116) and dates them to 'the end of period IV/beginning of period V'.

Group B3 he also dates to the end of period IV/beginning of Period V, assigning the lurs from Tellerup (SD117/118) to this group, these lurs having bell discs with cast bosses and punched decoration.

Group C instruments he dates to period V and characterises as large, "homogeneous" instruments that can always be separated. They are made of segments joined by sleeves and their bell discs are decorated with cast bosses. Their mouthpieces are funnel-shaped with out-turned sides and with an overturned flange. In this group he places instruments from Daberkow (SD144/145), Hof zum Felde (SD146), Brudevaelte (SD101/102, SD103/104, SD105), Långlot (SD142/143) and Broneby (SD139/140)

Oldeberg studied the Swedish, Norwegian and Baltic lurs and published the study of these in his re-interpretation of Schmidt's work in 1947. In this, he re-classified the instruments into groups A, B and C rejecting the earlier sub-division of Schmidt on various grounds.

His criteria for assigning classifications to the various groups are stated as: "the size of the lur; the method of joining the various segments; the connexion between bell and tube and the development of the mouthpiece"[162] .

The group A lurs he characterises as small, cast in four to six segments joined by meander-joints but with yards which are not separable. They generally are of wide bore, have simple

[160] Hahne 1915.
[161] Schmidt 1915.
[162] Oldeberg 1947, p. 45.

flange-like mouthpieces and integrally-cast bell flanges and are decorated by means of cast raised bands.

His group B instruments are larger than the A group. They are separable and each separate yard is generally curved in a single plane. Both yards are made up of segments joined together by casting-on, on occasions a meander joint being utilised. However, some instruments that he considers to be later types were assembled by means of ferrules. The bell discs of this group were somewhat variable, featuring both cast and chased decoration. All instruments in this group have clearly developed mouthpieces and the use of rattle-plates is first seen on the later instruments of this group.

The variability in the B group, which Oldeberg considers to be a typical transitional trait is no longer present in the C group. A further increase in size is seen on the instruments of this group and the curvature has become distinctly polarised. The variability seen in fastening devices in the B group gives way to a uniform use of a triangular tenon and the segments of the tube yards are joined by the use of sleeves. Bell discs on these instruments are the largest seen on any lurs and they are always made separately from the bell yard and secured to this. Their decoration may be punched or cast. The funnel shaped mouthpiece of group B has evolved to a more cup-shaped (trombone-type) mouthpiece with a recurved lip around its edge. Thus, Oldeberg generally retains the classification originally developed by Schmidt, his major change being to group the intermediate instruments together rather than trying to differentiate in finer detail.

Broholm[163], wrote his work after both Schmidt and Oldeberg. ln this work, he dates the lurs by means of their decorative elements and, to a much lesser extent, the techniques employed in their construction. This is necessary as few instruments had been found together with datable material.

The first instruments he considers are those from Lommelev and Maltbaek which have a chased decoration similar to that seen on several objects from.the bronze-age, period III and IV[164] Using these, he dates the Maltbæk lurs to the end of period IV and the Lommelev to the beginning of period V. From these established points, he dates the Nyrup (SD122) fragment by its similarity in tube morphology to Maltbaek and the Dauding (SD123) fragment by its similarity to Nyrup.

Among the earliest lurs, Group A of both Schmidt and Oldeberg had included that from Påarp. However, Broholm discounts this view and assigns this to the end of Period IV on its morphology, decoration and meander-joints. The remainder of this group he assigns to period III on much the same grounds as used by Schmidt and Oldeberg.

On the bell discs of the Folrisdam instruments are two complete circles made up of cast, raised knobs. Broholm dates these by reference to similar decoration on hanging vessels datable to the end of period V and, by means of this date these instruments to the beginning of period VI.

Other instruments too have decorative elements common to other datable material, such as the pips surrounded by raised circles seen on the Brudevaelte (SD103/4, SD105/6) and Daberkow, the spiral lines on the lock of Brudevaelte (SD105/6) and the addition of

[163] Broholm 1949, pp. 51-60
[164] Broholm 1949, Figs. 15 and 16

concentric circles on the large cast bell-disc bosses, Boslunde and Garlstedt (SD148). Again Broholm uses these to date the instruments[165]

The last instruments considered, those from Revheim (SD131/2) in Norway, he dates to period V/V1 and suggests that these are of local manufacture.

ln all, Broholm's survey and dating seem well founded in the dating of comparable archaeological material from this area. Of the three datings discussed here, it accords most nearly with the one derived in this study and has been used for cross-reference to archaeological dates from the Nordic cultural area.

THE PRESENT STUDY

The group of lurs, when studied from archaeological, technological, organological and aesthetic points of view, present spectra of complexity for each of these which do not overlap to provide a simple chronological sequence. However, towards the eastern limit of the cultural area studied, in what is now the DDR[166] three instruments were found (SD221, Wismar, SD222, Teterow, SD227 Bochin). These appear to be very primitive organologically and, consisting as they do of simple fittings for animal horns, could well have had a local source of inspiration for their origin.

Bochin, the earliest of these, dated on its decoration to Bronze Age Early period II by Schmidt[167] is merely a fragment of bronze tube designed to fit over the bell end of an animal horn. It was probably cast by lost-wax technique and, early as it may be, the method of forming wax material over a preformed core which was used on this piece continued to be used on all the lurs examined in this study. The evidence for this is seen on the extant material where the 13 circumferential bands on the bore of the instrument must clearly have been produced by forming over a core while the 20 similar bands on the outside could well have been formed by the removal of wax with a suitable tool. (Figure 4.4).

[165] op. cit., p. 59.
[166] At the time of writing this was the old East Germany, now part of The Federal Republic of Germany.
[167] Schmidt 1915, p. 108.

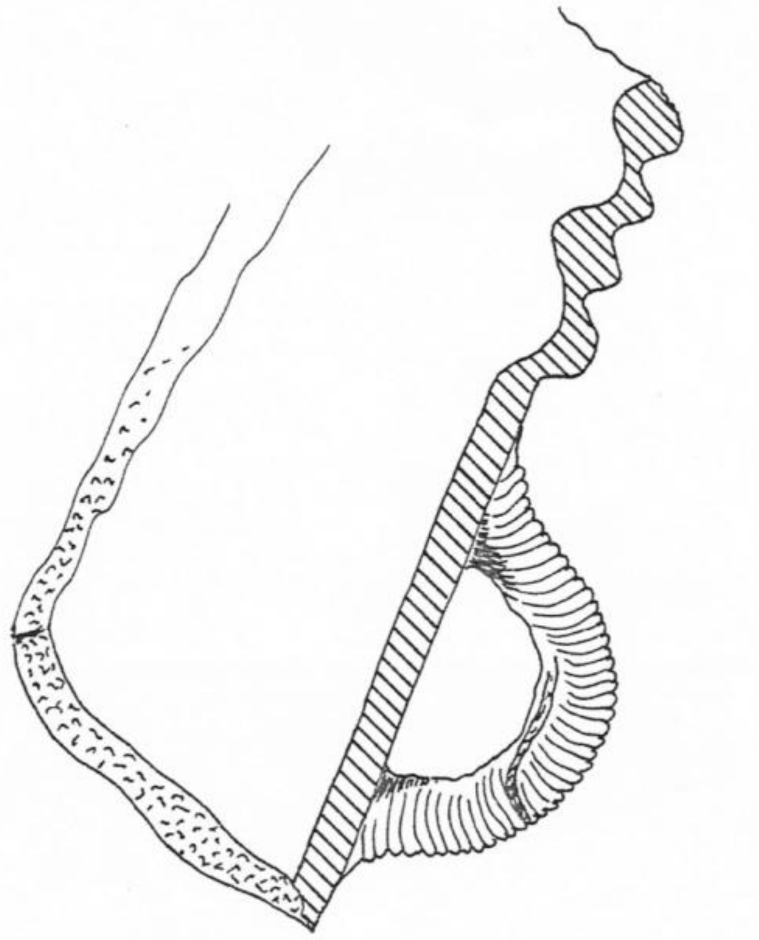


Figure 4.4: The Bochin Fragment

This tube appears to be little more than a simple decorative band, as suggested by the presence of internal decoration. For this to be visible, the bronze tube would need to have been mounted to increase the overall-length of the instrument, thus modifying its organological character.

A similar bell end, along with a central carrying ring and mouth- support tube were found in Wismar.

Prior to Althin's paper in 1945, there was a general agreement as to the dating of this instrument, it being assigned dates to between Periods II and III (Schmidt, 1915) early Period II; Brønsted (1938), Period II; Hahne (1915) Period II - III. However, Althin[168] concludes that much of the decoration of this horn is a forgery carried out, he suggests about 1830. His general conclusion is that the mixture of ornamental elements is inconsistent with that produced in any one object seen until well into Period V. Oldeberg, however, disagrees with this view and cites comparisons for all the decorational elements seen on Wismar that fall in the periods I and II.

From its general construction, Wismar seems quite likely to date from the early periods proposed. Its construction and design in no way resemble the instruments of Period V and, particularly in its provision of a mouthpiece, it lags seriously behind these later instruments. Althin contends that its decoration stems from the 19th century, and Oldeberg contradicts this: There seems little doubt, however, about the body of the instrument itself being from this period. In Period II this, no doubt, represented a considerable technical achievement and the manufacture of such an item in 19th century Prussia would probably still have presented considerable problems. Thus, had it been

[168] Althin 1945, 144.

made as a hoax it would have necessarily involved enough people other than the hoaxer to ensure that the secret did not remain a secret for too long.

The three parts of the instrument together make up the classic trio for an instrument manufactured during the transition from naturally occurring materials to metal.

However, unlike on Bochin, the bell tube is decidedly not round and the wax pattern from which it was made was probably manufactured without a core, again unlike Bochin, ln the bore is a circumferential step of from 1 to 1.5 mm, apparently where one piece of wax was laid over another. Had a core been present prior to forming the wax, the bore of the tube would have taken up the form of this core and this step been smoothed out. (Figure 4.5)

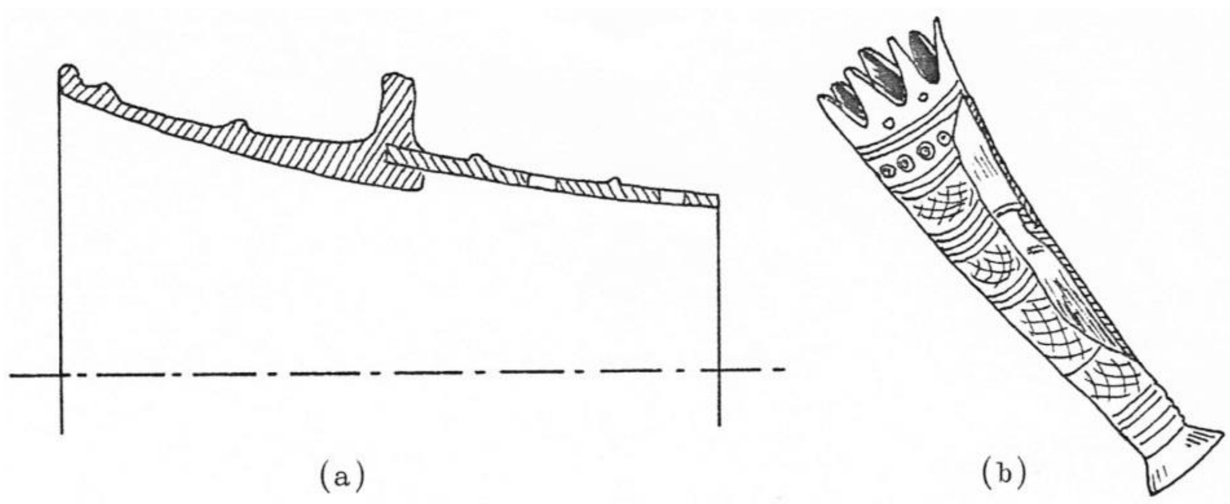


Figure 4.5

Teterow consists of a longer mouthpipe with mouthsupport (0.32mm long), similar in some respects to the Wismar example. On this, however, the central carrying ring is cast integrally; (Plate 4.1 (b).

Plate 4.1(b)

There is little doubt that the three instruments are from the same industrial group, and the decoration on one of these, the Wismar horn, clearly relates the group as a whole to the culture that produced the Scandinavian rock carvings. Several decorative elements present on the Wismar horn are commonly found throughout Scandinavia on the Bronze Age rock carvings.

While it has generally been accepted that these instruments are pre-cursors of the lurs, Broholm[169] suggests that they are simply representatives of a different instrument type from the same culture, He considers that the Gullåkra mouthsupport is inferior to that of Wismar whereas the present study suggests that, organologically speaking, it is identical and indeed, technically- speaking more complex. (Figure 4,6).

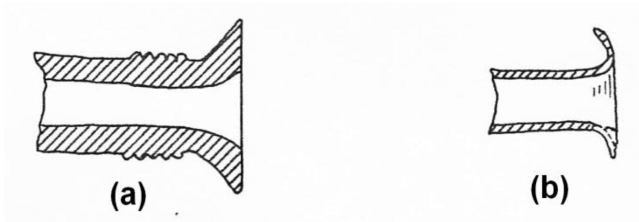


Figure 4.6: (a) Wismar, (b) Gullåkra

The general sectional thickness of the Gullåkra lur is also less than on the Wismar instrument, and the degree of roundness of its tubes higher, both of these features reflecting a higher level of manufacture. Also, as on the rest of the lurs, chaplets were utilised in the casting of the Gullåkra instrument while none are to be seen on any instrument of the Wismar group. Up to a certain length for a given diameter a casting can be made using core-prints to register the core accurately within the mould. However, as the tube length or curvature increases or its diameter decreases either the quality of fit of the core-prints or the diameter of the core itself becomes a limiting factor and chaplets must be employed to retain the core adequately. Significantly, the Wismar group of instruments could all be made without chaplets while the technological step to the Gullåkra (and Påarp) instrument(s) is a quantum step requiring the adoption of chaplets. Thus the critical development that allowed the move to a longer and more curved instrument was probably this technological improvement in the accurate location of the core during the casting operation.

In addition, the evidence from extant instruments and rock carvings provides a fairly complete sequence of morphology from a simple Wismar type of horn to a complex developed lur type.

Ironically, the strongest argument for co-existence of the Wismar type and some developed form of lur comes from the Wismar instrument itself. On this the incised decoration contains a ship motif with passengers one of whom has a feature above his head which is generally interpreted as a lur.

ICONOGRAPHY OF THE LURS: THE ROCK CARVINGS

Throughout the area of the Nordic Bronze-Age many thousands of rock-carvings still exist. In Norway and Sweden these are generally on prominent outcrops of hard metamorphic rock and frequently on the advancing faces of roche moutonnées left by the ice-weathering. In Denmark they are frequently present on much smaller rocks and outcrops (Plate 4.1 (a)).

[169] Broholm 1947, 79-80.

Plate. 4.1 (a)

Carved into these rocks are scenes with groups of people, individuals, ships and a great variety of other symbols. As with any form of pictorial representation which has symbolic meaning the representational style developed traditions which resulted in the use of highly abstract forms. Nevertheless these are frequently intermixed with more conventional feature-by-feature representations.

Interpretation of the message left in the rock, carvings and occasional other pictorial representation is aided by the overlap between the iconography and extant material, notably in the case of this study, of the lurs and their pre-cursors. Probably, the simplest pre-lur illustrated on a rock-carving (type I) is that from Gissleggårde in Sweden (IC171), (Figure 4.7). On this a player blows a short horn which scales about 0.5 m long. Its form is difficult to define but it may well be a variety of fairly simple animal-horn instrument. A clearer animal-horn type instrument (type II) is seen on IC174 (Figure 4.7). On this, a slightly longer instrument is being blown with its bell pointing upwards.

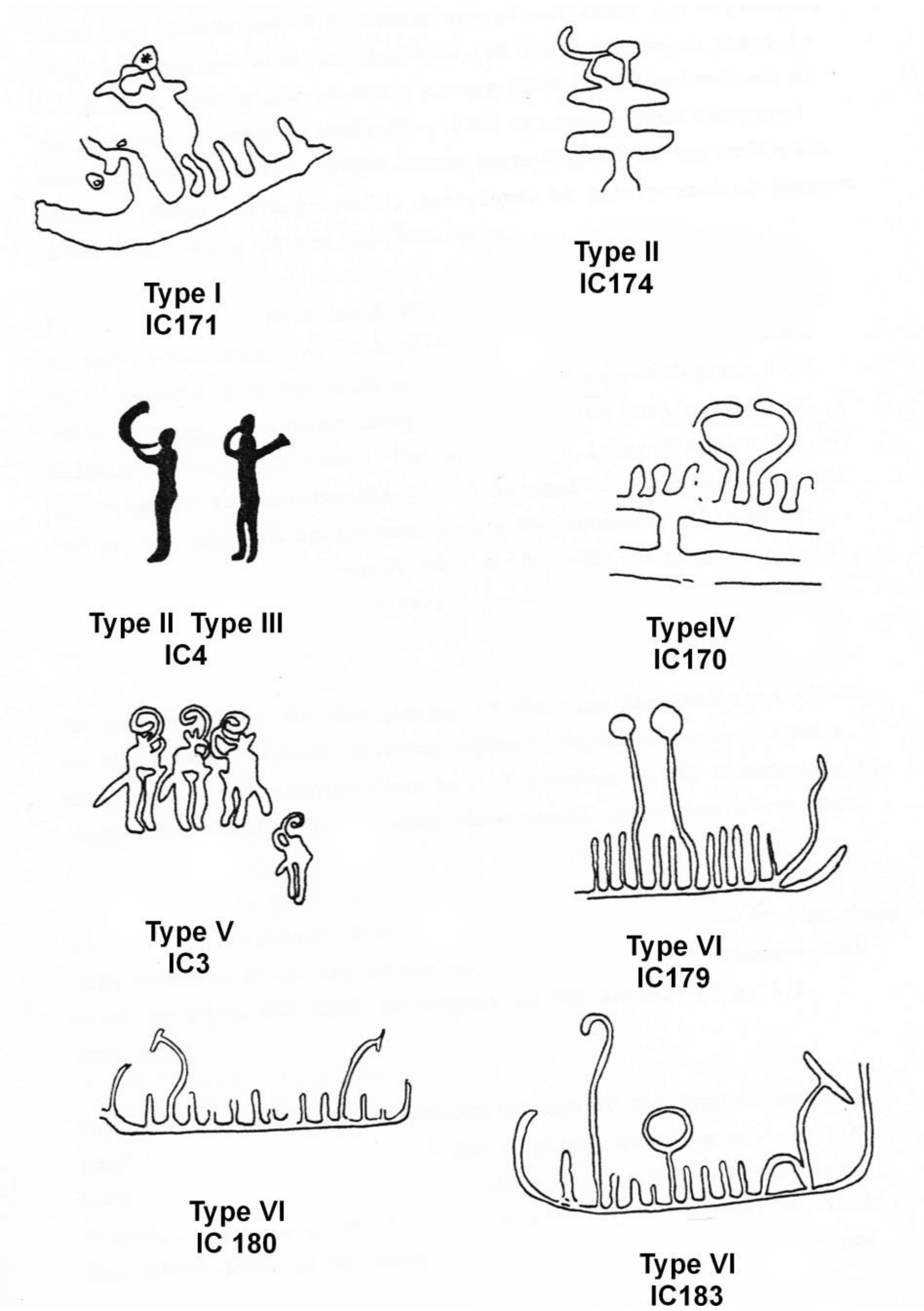


Figure 4.7

A carving from Vitlycke (IC202) shows two players blowing up-curving horns of about 0.9m (scale) length. The size of these must be above that available from animal horn and would point to a metallic instrument being used. Hence, by this period either an organological or aesthetic pressure had led to the increase in length and the technology of manufacture had presumably been able to cope with this demand. Alternatively, the possibility of applying this to lur manufacture have been appreciated and, hence, the longer instrument made. The metrological work carried out on these instruments which is detailed below would tend to favour the former view i.e. organological/aesthetic pressure.

A further example of this type is seen on a carving from Blåholt, Broholm, (IC184). On this, the player appears to be holding a similar single curved horn but on this occasion is standing on a ship

The oft-published carvings from the Bronze Age at Kivik contain an illustration of two players blowing lurs (IC 4 on Figure 4.7). These instruments are very highly curved and about 1.4 m (scaled) long, and compare with the Gullåkra (SD135) instrument which is 1.3 m long. lt is not possible to say from the illustrations of the carvings currently available, (the originals were destroyed some time ago) to what extent these horns curved in two different planes. These carvings could, therefore, be interpreted as players using instruments of the Gullåkra type.

It is interesting that the Kivik carving shows instruments being played in two ways i.e. in both vertical and horizontal planes. This suggests that the problems involved in supporting the lurs while playing were occasioning experimentation into methods of holding them at this time. The weight of a large diameter lur of 1.3 m.length is considerable (2 to 5 kg) and an experiment carried out on the Gullåkra instrument during the course of this study revealed that it was, indeed, most comfortable to play when held as in the right player on Kivik, i.e. in the modern French-horn style.

Unfortunately for the lur players of the time the aesthetic effect of having the lur bell pointing skywards must have been judged a more important criterion than ease of playing as all future developments took place on instruments whose sound source was above the player.

All the illustrations of this next group of instruments are on ships with players, generally in twos, holding curved instruments that stick up above the other passengers on the ships. (Figure 4.7, type IV)

One carving, IC186, shows one instrument of the type described above but in front of it is a lur player standing up. In his hand this man is holding what could be a lur with a double curve. According to Glob[170],the design of the boat on which they stand dates to the transition between Periods II and III and would, thus, point to the presence of the double curvature instrument by this date.

As the lur had increased in length and its playing position had become standardised as vertically above the head of the player, any increase of tube length had tended to increase its visual impact. Thus, when further lengthening of the tube necessitated curving this more acutely in a second plane, the additional curvature was placed where it could be seen, at the top of the bell. At the same time as accommodating additional tube length, this development also allowed the bell exit to be twisted so as to project forward. Such developments are seen on IC 3 and IC187 where 3 and 4 players respectively are depicted. On IC178,the lurs scale at 2.48, 1.81 and 1.78 metres long. (Figure 4.7, type V)

However, the evidence from extant instruments seems to suggest that they were held with the tube yard horizontal and the bell yard curving in a vertical plane. It could be, therefore, that these instruments were played in this way, the current rules of perspective at that time not allowing the differences in plane to be readily depicted.

While the organological significance of accommodating an increase in tube length to about 2m was considerable, so too was the aesthetic effect, Since it is only on representations where this type of instrument is used, that the horned helmet is seen, the visual effect of vertically oriented lurs was obviously held to be significant. The combination of the two features would also suggest that a degree of standardisation of usage had developed i.e. using vertically oriented lurs.

[170] Glob 1969, Fig. 37.

By the time lurs of 2m length were being made, considerable technical developments must have taken place. Not only do the sections of instruments need to be fastened together adequately, but they also need to be manufactured with a wall thickness that would keep their weight down to an acceptable level. It is possible, therefore, that the two remaining stages of development required only organological and aesthetic innovation the necessary level of technology having been developed previously.

In view of the obvious aesthetic impact of the large bell discs of the developed lurs, it is surprising that so few rock carvings depict instruments which have these. This points to the former existence of a whole period of lur history of which nothing is known other than what these rocks tell. When illustrations do occur that carry bell discs they do so over a very limited area of Zeeland and Bohuslan, in much the same area as that occupied by the Zeeland group of instruments. The carvings themselves are quite clear, however, and show an awareness of the problems of depicting such complex three dimensional objects in the two dimensions of a rock surface. These illustrations all show lurs used in pairs suggesting that, by this time, this had become the standard pattern of use.

The straight, frontal depiction of the bell disc is seen on IC179 (Figure 4.7) where two instruments project above the heads of the players on the ship. With the bell disc in this plane, the bell yard is seen as a vertical line and the tube yard as a slight curve in one case to the right and in the other to the left. Any more realistic depiction would have run the line of the tube yard into the next passenger on the ship, thus confusing the whole scene. On IC183 and 187, the whole lur is shortened to a straight line with the former having a relatively large bell disc.

Side views of lurs are shown on IC180 (Figure 4.7) where the curvature of the bell yard is very apparent and the bell disc seen only in profile. A more elaborate representation is seen on IC183 (Plate 4.1 (a) , above) which contains lurs seen both in side and end view. With the side view depiction, the curvature of the bell yard and profile of the bell disc are seen but the artist has also attempted to depict the tube yard. This he has done by showing a humped line which connects with the bell yard and, in order to fit this in, he has omitted several of the ship's passengers. In all this is a very credible representation of the dual polarity instrument in two dimensions. In this review of the rock carvings the evidence cited has been relatively sparce and much more evidence must remain to be described. However, no previous work has recognised either the type I, type IV or many of the type III instruments as lurs and no body of published work exists on these. No doubt, the acceptance of the view expressed here as to their identification will allow many more such illustrations to be brought to light.

METROLOGICAL ANALYSIS OF THE LURS

In addition to general observations on the manufacturing techniques employed in the production of the lurs, a fairly detailed metrological examination was made of those lurs that were both suitable and available for this.

Dimensions were obtained from the axial features of the lurs - ("x" values) by measuring the length of each segment and each decorative band or ferrule. An accurate tape measure was used for this where the curvature of the instrument necessitated it, the straight or relatively short features being measured by means of vernier calipers. The respective outer diameters ("y" values) were measured at the beginning and end of each segment by means of either a vernier caliper or micrometer, depending on the specific nature of the measuring point.

Figures for x were obtained by the accumulation of values of 'x' for individual segments and ferrules/joining bands, and the errors in these are thus likely to increase as the station distance from the tip increases. However, where a group of segments is analysed separately the accumulation of errors prior to the lowest x value utilised is not significant.

The reading of the tape measure is considered to be subject to an error of ±0.3 mm and that of the vernier calipers to ±0.03 mm. Thus each segment length being made up of a length of plain tube plus a ferrule is subject to an error of ±0.33 mm and the cumulative length x for the end of segment n to an error of ±0.33n mm. Values for y, the diameter of the instrument tube at a given point were obtained by use of the vernier calipers. The possibility of an unquantifiable error existing from the skew of the calipers across the tube cannot be ruled out, the problem being greater on the larger diameters of the tube, However, repeat checks, where carried out, showed this error to be of negligible magnitude.

The most striking features of the lurs which has been discussed in practically every paper ever written on these instruments is the similarity between right and left-hand instruments.

It is clearly an important factor as, not only are the pairs of instruments found to be superficially similar; they have the same number of segments, of the same diameter, virtually identical bell discs and appendages, but the detailed metrological work carried out in this study failed to find significant differences between the individuals of a pair. The absolute values to which this statement is true are discussed later in this chapter. While the manufacturer clearly produced instruments that are found as identical right and left hand pairs, it seems quite possible that these have resulted from the policy of making instruments to a given fixed standard but of different windings. Thus, the pairs found probably represent right and left-hand output made to this standard rather than deliberately matched instrument pairs. One dimensionally similar pair of instruments are of the same winding, those from Rørlykke which are both right-wound, their dimensional similarity being discussed below.

It is difficult to express the degree to which instruments resemble each other in a clear mathematical way and, as this similarity between pairs may also be expressed as the result of each instrument in the pair being similar to a theoretical (abstract or concrete) model, discussion of the feature of pairing is integrated into the general study of morphology.

In the pre-lur stage of the Wismar group of instruments, bronze tubes were formed which increased the length of the instrument, both at its tip and bell ends. The shape of these additions extended the form of the material to which they were attached and could, broadly speaking, be described as "round" with their enclosed air-space varying from "cylindrical" (parallel tube) to "conical" (tapering tube). Early varieties of this type of instrument would probably have the bronze extension pieces tailored to suit the individual shape of the horn for which they were made and these pieces would presumably be shaped to blend in with this horn in an aesthetically pleasing way. Thus, the requirement for dimensional accuracy arose from the need of the bronze addition to fit the horn and to look reasonable, i.e., it was only a moderate requirement. However, as the length of the horn increased in later, all-metal, instruments, the tendency to extend by continuing the horn taper in both directions would result in a very small diameter at the tip and an excessively large one at the bell.

On the Gullåkra instrument, for instance, the development of an excessively small mouthsupport is avoided by providing the instrument with an almost parallel mouthpipe (semi-vertical angle = 7.3 mrad) whose smallest diameter is only 2.6 mm smaller than the centre section entry diameter. (Figure 4.8, p. 129).

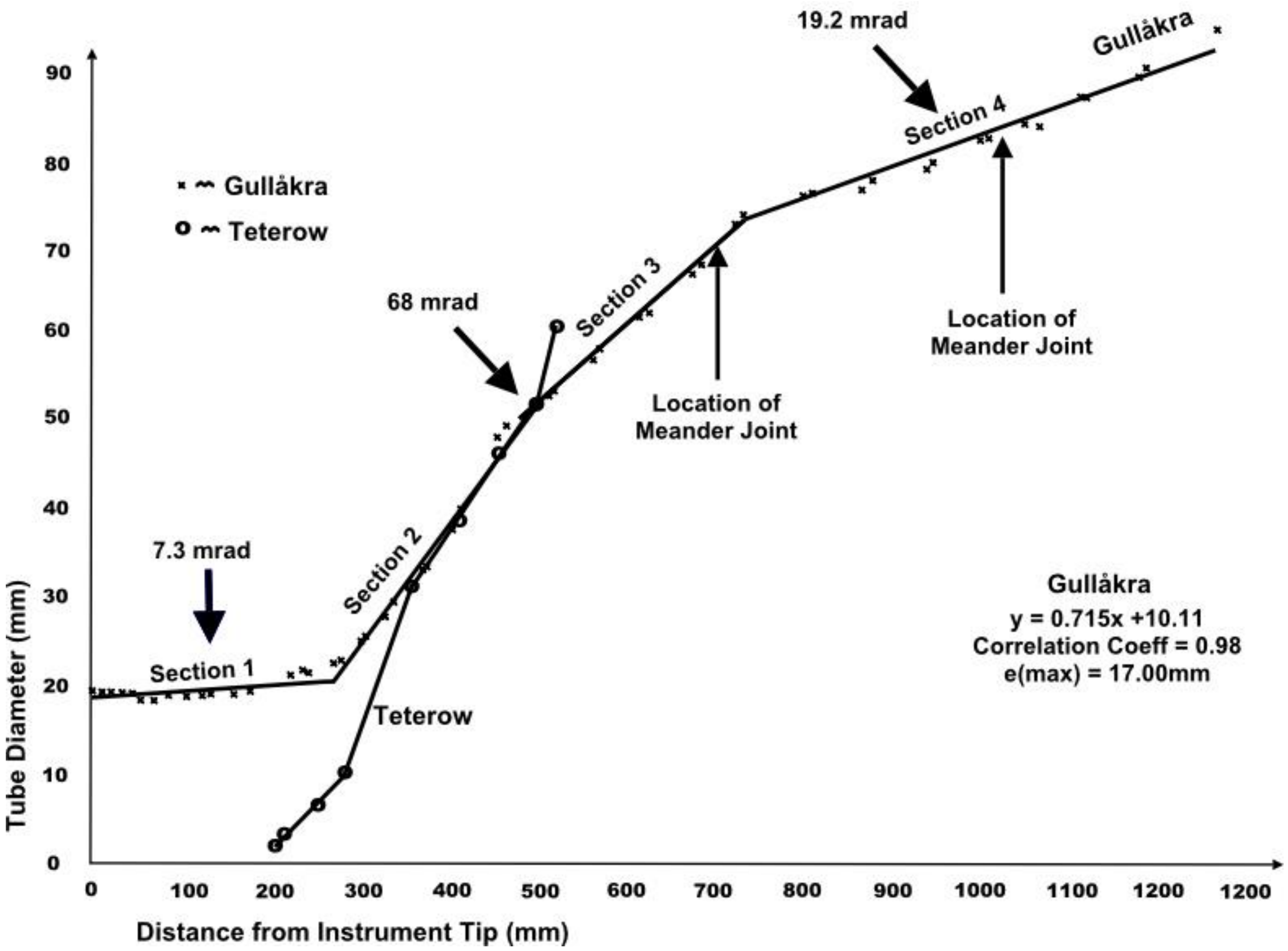


Figure 4.8: The Tube Dimensions of the Teterow Horn and the Gullåkra Lur

Similarly at the bell end, the bell yard expands but at a much slower rate than this centre section (α = 19.2 mrad compared with 68 mrad) thus avoiding the development of an excessively large bell diameter.

This instrument, thus gives the appearance of having originated from a central section similar in form to the Teterow instrument. (Section 2 on Figure 4.8) Two other sections were then added,(1 and 3 on Figure 4.8) and finally, the addition of section 4, the longest yard with the gentlest slope, created an instrument of 1.3m length.

From the data obtained by measuring these instruments, the nature of the relationship between the tube diameter (y) and the distance of the measuring point from the instrument tip (X) can be determined. (See Appendix II for details of the statistical analysis applied). In the case of the Gullåkra instrument the relationship between the x and y measurements (taken as a whole) is $y = 0.0715x + 0.11524$ with r = 0.9800 and E (max.): the maximum deviation from the "best" straight-line = 17.0mm.

However, the second yard of this instrument, from $x = 0.27$ m to $x = 0.464$m has slope approximately twice as steep as the overall figure at $\alpha = 68mrad$, this being roughly comparable with the $\alpha = 81mrad$ of the mouthpipe on Teterow. 1

While most other instruments retain the 4-yard structure that the Gullåkra instrument displays, they tend to have a more uniform overall slope and the E (max.) for these overall figures is generally much less. Put in more general terms, the instruments tend towards the development of a uniform slope from tip to bell such that the relationship $y = mx + c$ holds very closely throughout the whole length of the instrument.

On Maltbaek for instance, although the correlation coefficient for the overall instrument form is less than for the Gullåkra $r = 0.9534$ cf. 0.9800, the value E (max.) is reduced to 8.*6mm*. Moreover, as a pair of instruments were found at Maltbaek, the difference in morphology between these can be determined. From the plot of these dimensions, (Figure 4.9) this difference can be seen to be very small, its maximum value of 2 mm occurring at the junction of the tube and bell yards while, overall the four slope construction is retained on this instrument.

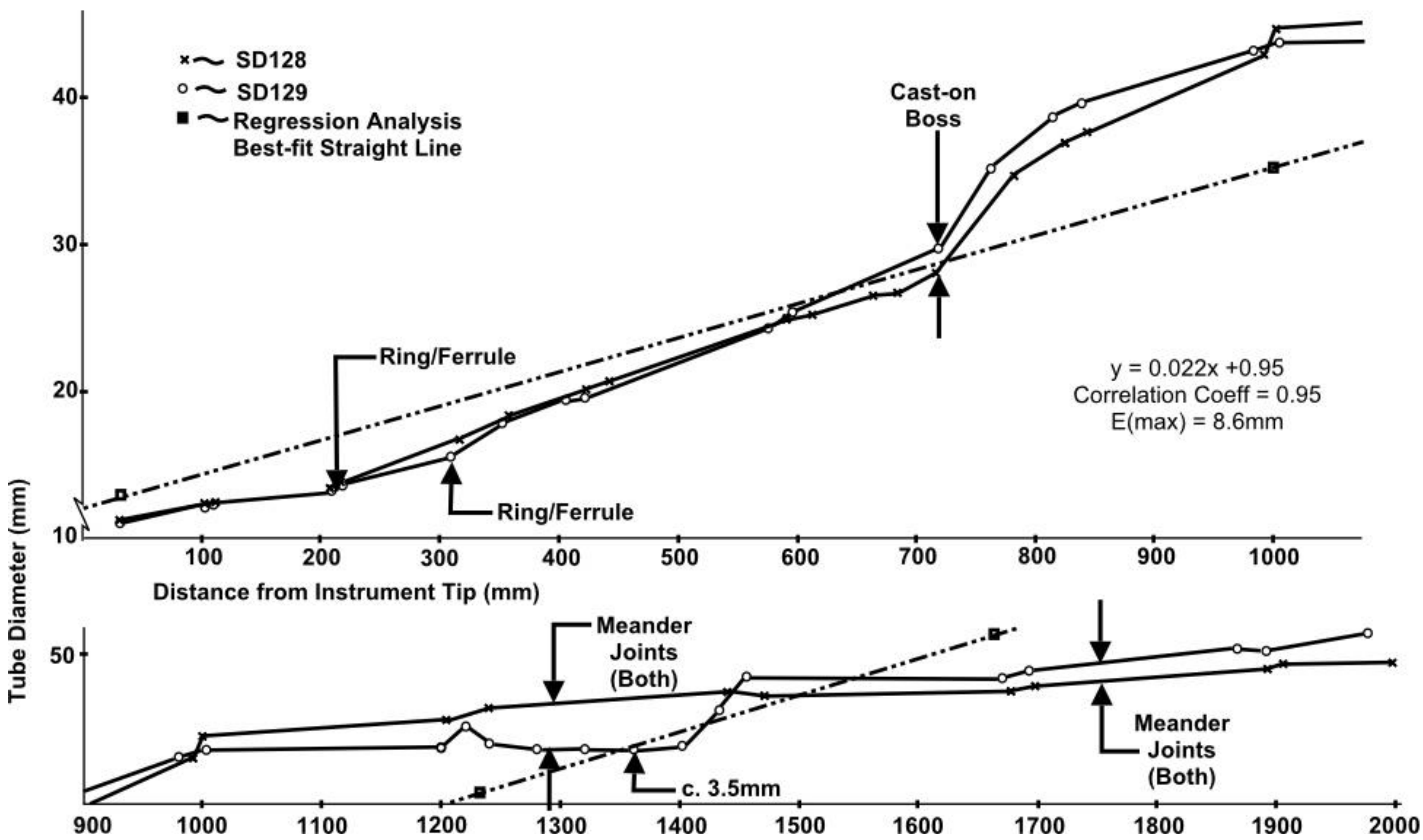


Figure 4.9: The Tube Dimensions of the Maltbaek Lurs

Another group of instruments from Brudevaelte consists of 6 lurs made up of 3 pairs. on the second pair of these, SD103/4, the structure of the slopes has been virtually reduced to a 3-unit pattern, (Figure 4.10). However, the units of slope differ very little from the best straight line equation for the dimensions as a whole r = 0.9951. The maximum "error" from this line is about 2.5 mm and values very close to this exist at both intersections of slopes and at the bell exit diameter. This suggests that this instrument is built to a design; i.e. a set slope of the order of this best line slope. Figure 4.10 also shows the remarkable similarity in dimensions of these two instruments, the largest difference at any point being of the order of 1 mm, while the average difference is almost zero! As a group, the Brudevaelte instruments are generally very similar and this can be seen on Figure 4.10, where the dimensions of the five instruments that were studied are plotted.

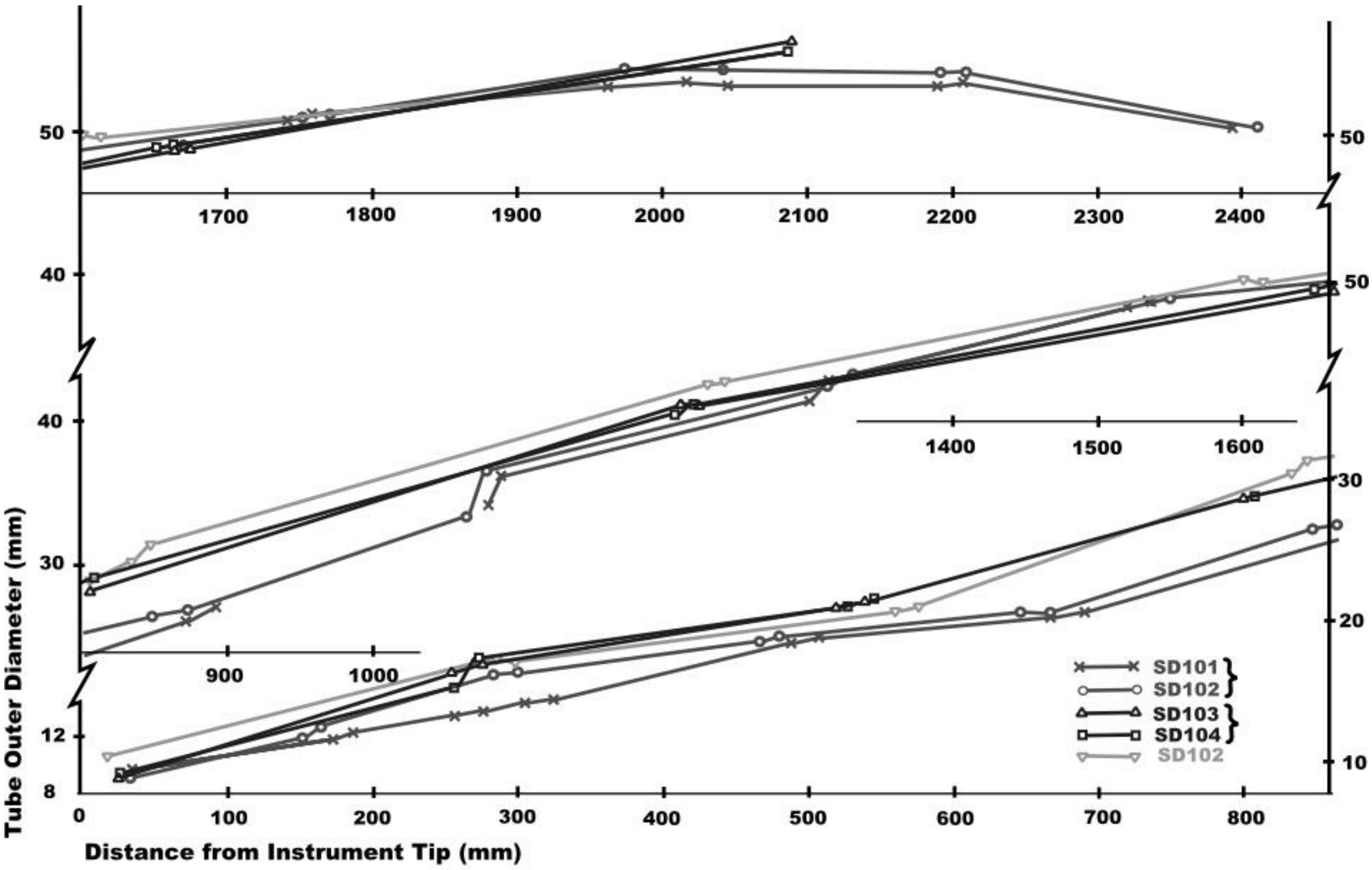


Figure 4.10: The Tube Dimensions of the Brudevaelte Lurs

In its most highly developed form, the uniformity of tube slope is seen on the Folrisdam instruments where the relationship between x and y is described by the equations:

Instrument 1: $y = 0.0275\,x + 6.964,\ r\,(1) = 0.9930,\ Syx = 1.327mm$

Instrument 2: $y = 0.0277\,x + 6.653\ r\,(2) = 0.9943,\ Syx = 1.411mm$

These figures show a very close approximation to a straight-line relationship between *x* and *y*. However, the crude expression of error in terms of *Syx* values hides the fact that the error is very systematic, and that even on this instrument the (x, y) relationship is best described by three separate equations with standard errors of:

Instrument 1 $S_{yx} = 0.277, 0.332, 0.245$ *(mm)*

Instrument 2 $S_{yx} = 0.700, 0.332, 0.200$ *(mm)*

However, the nature of the variation of these equations from the overall equations, (Figure 4.11) is quite different from that on earlier instruments, in that the slopes of all three intermediate lines are similar and lack the clear steeper central section of the earlier examples. This suggests that an overall concept of the complete instrument had emerged and that the maker was succeeding in matching the three segments to an overall specification very accurately.

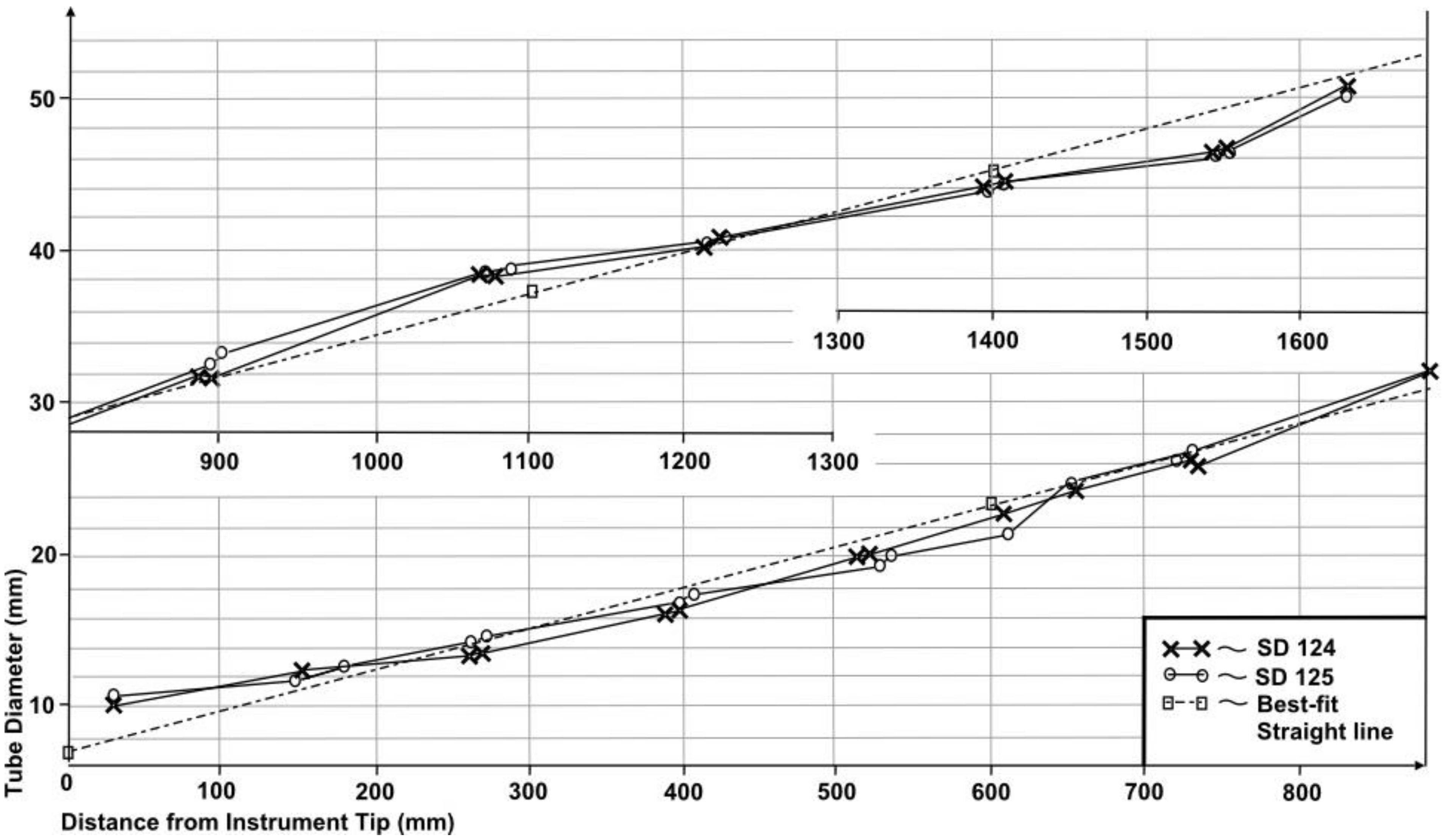


Figure 4.11: The Tube Dimensions of the Folrisdam Lurs

Not only are the diameters of instruments as a whole related by a straight-line relationship but the tube units too follow such a relationship closely. In the case of the Folrisdam instruments, the section from the tip to $x = 0.61m$ is manufactured with standard errors of 0.*2mm*/0.*6mm*. Thus, were the 610 mm of this instrument to be straightened out to produce a straight conical tube, then it would open out uniformly, with a slope of 0.27 in such a way that the diameters at all points are within 0.3/0.9 mm (actual values) of the best straight line values.

Even on these instruments whose overall form is less uniform than the Folrisdam ones, the individual segments are manufactured in such a way that their own slope conforms very closely to a straight-line relationship. On Gullåkra, for instance, although E(max.) is high at 17*mm*, its third unit of slope has a straight-line correlation coefficient of $r = 0.9947$. (13 values) On Maltbaek, slope 2 has a value of $r = 0.9976$ with a mean tube diameter variation from the best-fit line of 0.26 mm.

Only one tube was available for detailed analysis of the tube diameters at 10*mm* stations, this being the Rossum bell yard fragment (SD133). This was measured over 230*mm* of tube, the plot of these figures being on Figure 4.12. From the figures, a regression line was calculated giving a correlation coefficient r = 0.9958, this line is shown on Figure 4.12. Measured values show a maximum deviation from this straight line of about 0.35 mm with this error having a periodic reversal of 60 to 90 mm. Such a variation suggests the use of form of a paring tool to remove the material, with a cutting surface length of 50 or so millimetres.

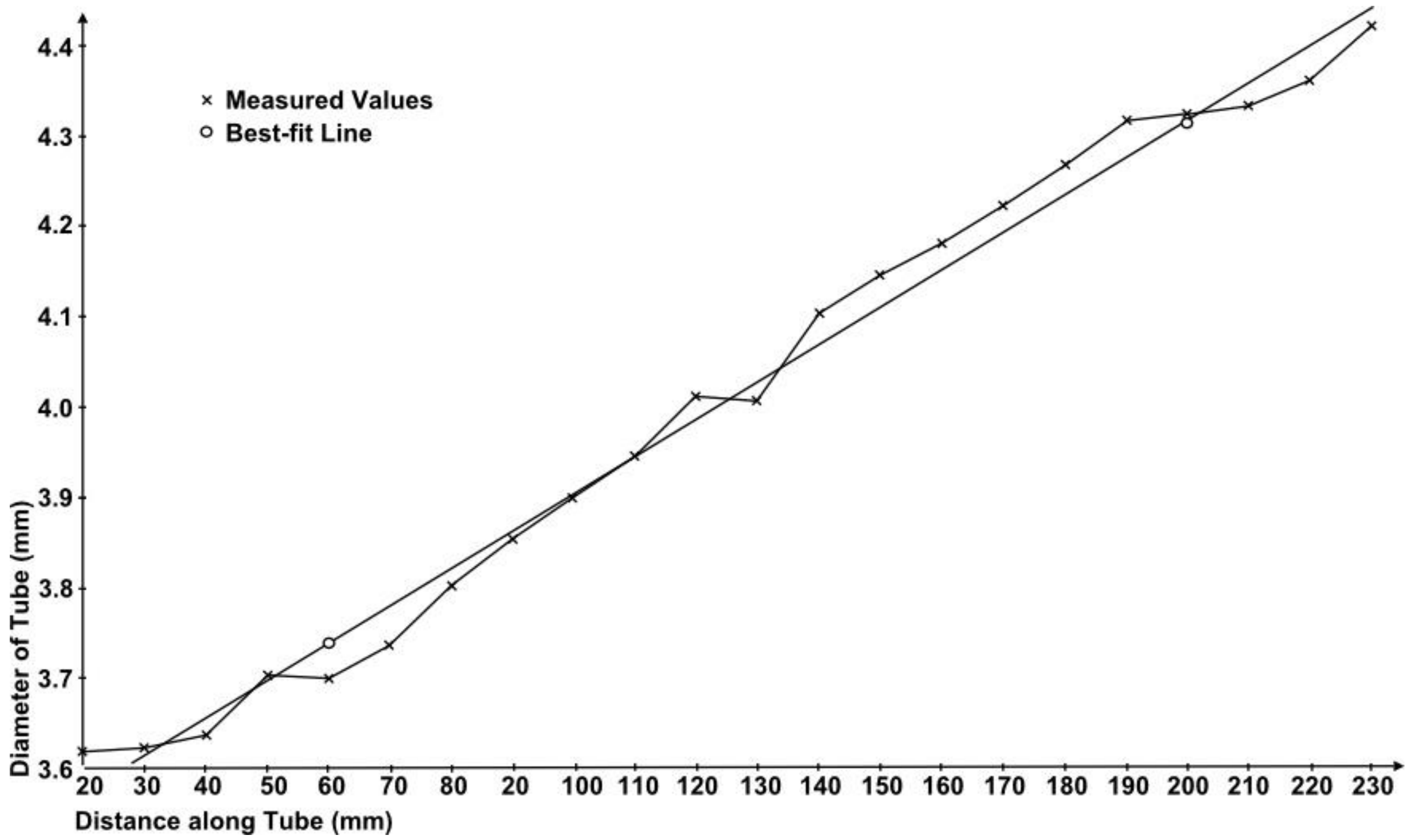


Figure 4.12: The Rossum Lur Tube Fragment Dimensions

THE ROUNDNESS OF TUBES

Along with increasing ability to control conicity of the tube the maker had also developed techniques for producing round cross-sections. The earliest instruments from this area are quite clearly not very round at all. This is most noticeable on the Wismar instrument, the bell part of which is a rather complicated "roundish" shape. Unfortunately measurements were not taken at the time of examination of this so its roundness cannot be expressed with the accuracy that can be applied to instruments studied later, the other instruments having been specifically measured to obtain a "roundness" value.

Unfortunately, many instruments have suffered damage since manufacture and hence, where deformed, the tube can give no indication of the level of accuracy to which it was originally manufactured. Where damage is obvious these areas have been avoided when taking measurements but more superficial damage may not be detected as such, and readings taken at this point. Hence, where several sections of tube are found of a high roundness, this is taken as an indication of a generalised ability to manufacture round material.

The Gullåkra instrument is considerably more round than the Wismar group but its out-of roundness can still be detected both by eye and by feel. Running along the axis of this instrument can be felt decidedly flatter areas, suggesting the cross-section to be a form of polygonally deformed circle. (See appendix III). From the five stations measured, a mean roundness of 1.32*mm* was found. Two stations of the five were round to within 0.90*mm* although, even here the out-of-roundness was visibly detectable.

While human perception includes the generalised conception of roundness, various factors, both tactile and visual limit an individual's ability to discriminate between objects varying only slightly in their level of roundness. Thus for a given individual, a minimum increment of roundness, or at least a range of values of this, may be defined, above which differences can be detected and below which the individual perceives the object as "round". Having developed the technique or skill to manufacture objects to this maximum degree of roundness that can perceived, no improvement on roundness can be expected unless the manufacturing technique adopted, itself produces inherently round objects.

The roundness values (based on OD's) of the other instruments, along with the number of stations measured are listed below (in mm) in order of increasing roundness.

Instrument		Roundness (mm)	No. of Stations
Name	Reference		
Rørlykke	SD120	2.3	4
Rørlykke	SD119	1.9	4
Gullåkra	SD135	1.32	4
Brudevaelte	SD102	0.74	4
Maltbaek	SD128	0.65	8
Brudevaelte	SD101	0.62	24
Brudevaelte	SD104	0.61	11
Revheim	SD131	0.59	13
Revheim	SD132	0.54	15
Rossum	SD133	0.47	7
Brudevaelte	103	0.38	6
Maltbaek	129	0.36	7
Folrisdam	125	0.28	5
Garlstedt	148	0.24	10
Folrisdam	124	0.10	4

This list shows a wide range of values for roundness and, from the close grouping of the pairs of instruments in this list, it appears that the sequence listed above gives some crude ranking in terms of level of manufacturing technology. Whether or not instruments in the above list are manufactured by a technique which produces round objects, it is not possible to state categorically, lacking experimental data on this subject. The only data that seems to be available is an old engineering rule-of-thumb which says that the smallest detectable difference in measurement using what nature provides is $^{1}/_{64}$" i.e. 0.015" or 0.397*mm*. However, a large gap is seen on the above list between the 1.32 and 0.74*mm* figures and may suggest a point of difference between manufacturing processes. Certainly when considering the 0.10*mm* roundness figure for Folrisdam (SD124), it seems perfectly safe to state that this was manufactured by a process that produced inherently round objects.

If the assertion is true that the roundness error on several instruments is less than the human eye can perceive, then the cross-sectional form must have been produced by a generating process, i.e. the tube or its pattern was rotated on a form of bearing while a tool, point or flat surface, was worked onto the rotating element to generate the circular object. In such an operation the bearings would have to constrain the motion to within 0.10*mm* to attain the degree of roundness found on these instruments.

Even to the limit of 0.10*mm* it is not adequate to state baldly that the tube is out-of-round to this degree, it being necessary to define much more accurately the actual morphology of the cross-section if more detailed comments are to be made on this subject. Such measurements, however, were outside the scope of this study as more sophisticated measuring instruments would be needed along with much greater access to the instruments than is currently available.

THE DESIGN OF THE LURS

The high degree of similarity of pairs of instruments provides no guide as to whether these instruments are similar to each other or to a common standard. Another type of information must be sought, therefore, and this seems to be provided by the group of six instruments found at Brudevaelte and the two instruments from Rørlykke.

These latter instruments are not a pair, being both right-wound, but are clearly from the same workshop. Their overall form is very similar, (Figure 4.13) the shape and type of the decoration bands is identical and the level of technology displayed in the casting of each instrument is clearly similar.

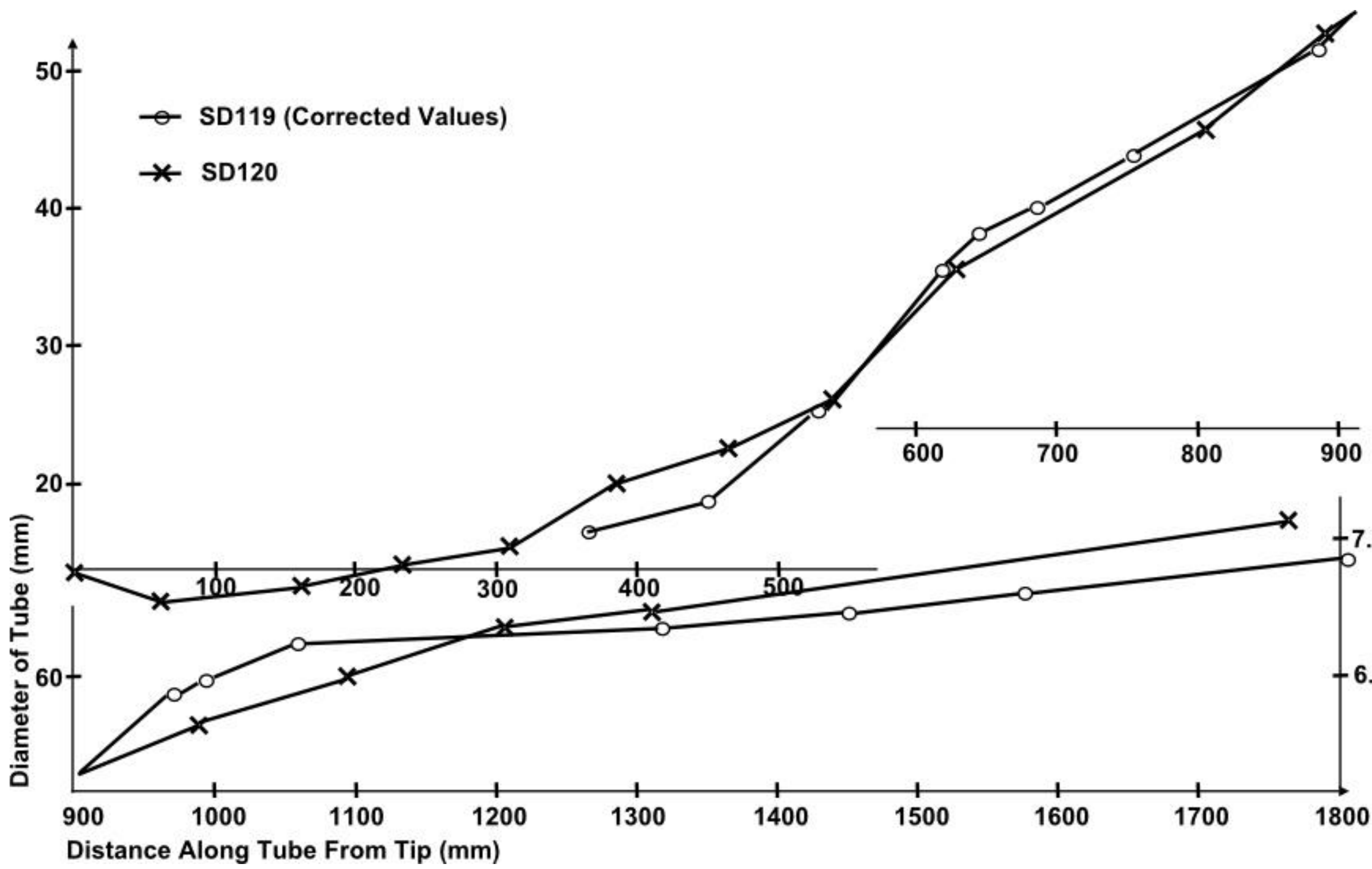


Figure 4.13

One of these instruments was in several pieces when found and has been reconstructed but appears to lack about 29.6 cm of mouthpipe. This figure is estimated from the x-shift necessary on Figure 4.13 to allow the maximum coincidence of the two *x-y* plots. Such a move appears to be justified by the very close coincidence of the two lines when this correction has been applied. Over much of their length they are within a millimetre or so of the same diameter and at the points of maximum divergence differ by under *4mm*. What is striking is the close similarity throughout the instrument. Indeed, over the section between $x = 525$ and $x = 880mm$, the tubes are virtually identical. Although the tube's morphology does diverge over certain sections it still seems to be produced to an overall design, such that the divergence is "corrected" and the tube dimensions again coincide down- stream.

The decoration applied to the tubes of these instruments is made up of a series of parallel circumferential bands and it is the number of individual bands in these that suggest strongly that the instruments were not made at the same time. Nowhere on the two instruments do the number of bands coincide and on SD119, the average number of bands per group is 11 compared with 9 on SD120. In addition, the segment lengths demarcated by these bands are also quite different and the meander-joints between adjacent yards are in different places on the tube. (Figure 4.14) Such a divergence between instruments of a "pair" is unique among the lurs, there generally being an extremely close similarity between the individual elements of such instruments. Thus although Figure 4.13 suggests that the instruments are to the same design/pattern, these differences in individual elements suggests that one instrument was made without direct reference to the other but to some form of overall design.

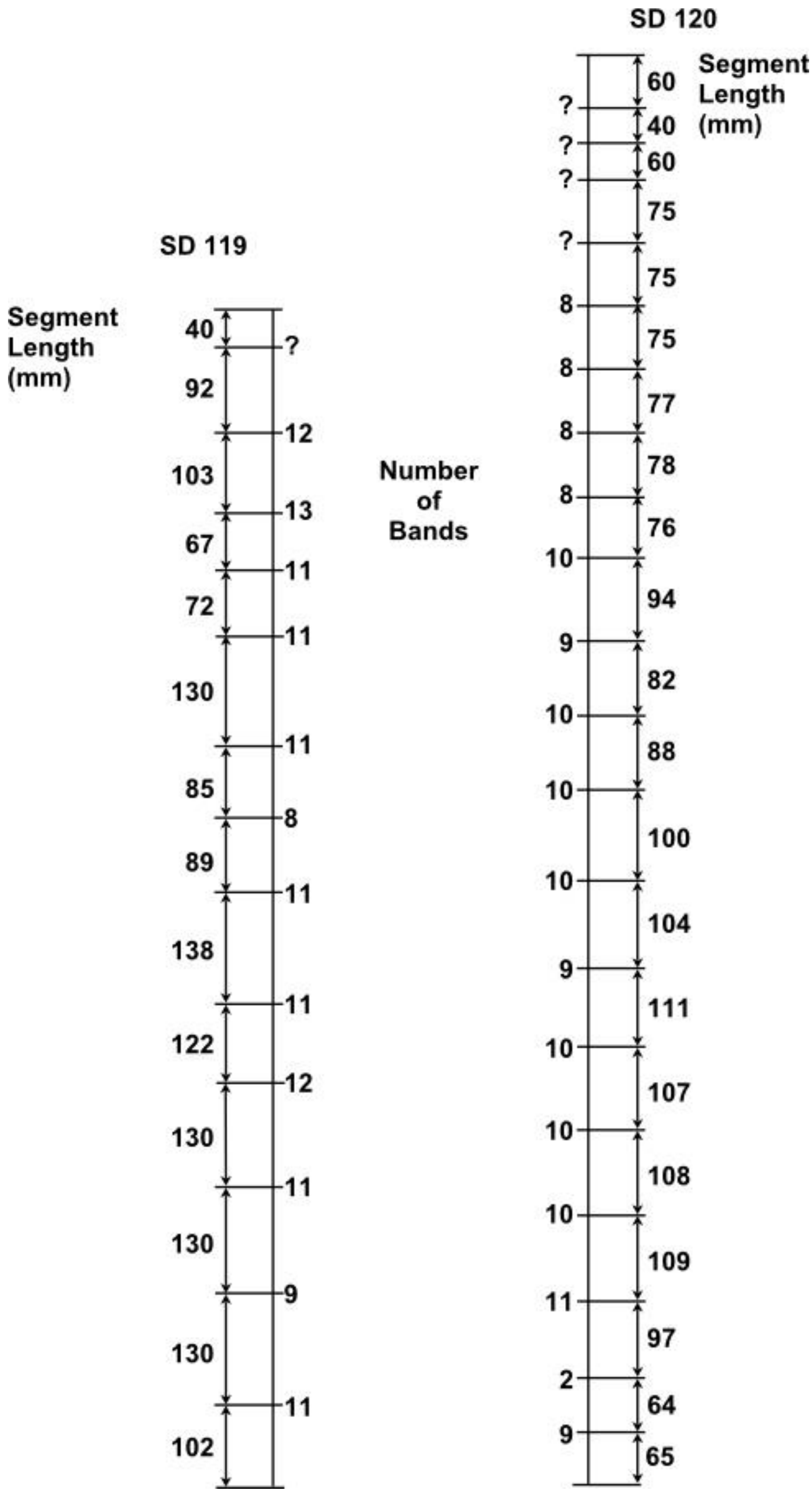


Figure 4.14: Segment and Decoration Details on the Rørlykke Lur Pair

The other group of instruments is that from Brudevaelte where three pairs of instruments (SD101/2, SD103/4, SD105/6) were found. One of these, SD106, was not currently available for study.

Like the Rørlykke instruments, the Brudevaelte group are all clearly from the same school of manufacture, having similar tube morphology, all instruments being of roughly the same roundness and having similar bell discs. However, one pair, SD101/2, is sufficiently different from the two other pairs to suggest that it was either manufactured earlier than the other instruments or was made by a less accomplished craftsman. The features which illustrate this difference are:-

Segment length: the mean lengths for instruments SD101/2 are 180.2/180.8 mm while those for the other instruments are

SD103/104 332.7/331.9*mm*

SD105 526.5*mm*

Conicity: The x/y data for instruments SD103/4 and SD105 follows a straight line relationship with

E (max.) = 3*mm* (103/4)
E (max.) = 4.5*mm* (105)

while that for instrument SD101/102, although following a very similar relationship shows a much greater variation from this, *E (max.)* : 6.6 mm

Mouthpipe Morphology: The mouthpipes on SD101/102 are roughly semi-circular as on the majority of other lurs while those on SD103/104 and SD105 have a straight portion immediately downstream of the mouthpiece. (Figure 4.15)

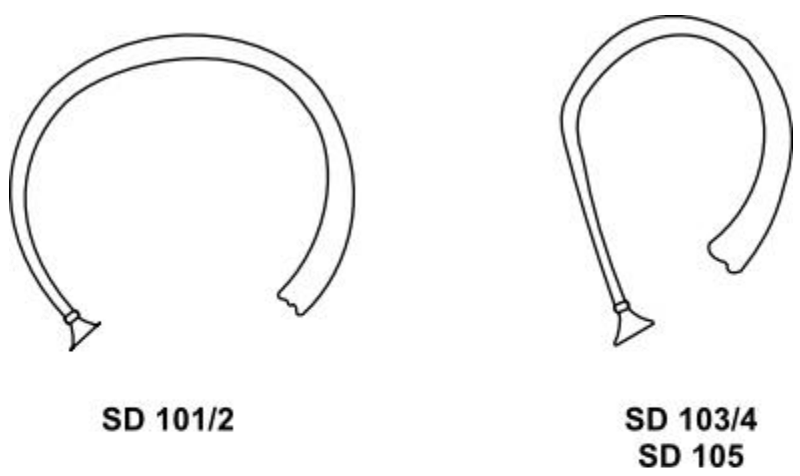


Figure 4.15: Brudevaelte Mouthpipe Morphology

Bell-disc Design: The bell discs of SD103/104 and 105 are larger and contain a greater number of decorative elements than SD101/102 for, while these latter instruments are decorated with six bosses and six equally-spaced sets of concentric circles the other instruments have both a completely circular set of these circles and other patterns made up from them. (Figure 4.31)

Junction Pieces: The bell yards of SD103/4 are cast with only a thin band, possibly as on Rossum while SD101/2 have a much thicker feature here.

Although these instruments were probably made at different times the overall tube morphology is very similar (Figure 4.10) Their overall slopes are 0.022/0.021, 0.024/0,025 and 0.026 and at a point 1.67 m from their tips, all 5 (6?) are within one millimetre of the same diameter. Thus, if these instruments were made at different times but to a similar design, the information to define this design must have been stored in some way.

THE DESIGN AND MANUFACTURING PHILOSOPHY OF THE LURS

The Folrisdam instruments, SD124/125, are the ones whose design appears to be most deliberate. As shown above, the entire instrument can be defined by a straight-line equation to within about 3 mm, i.e. at all points along the 1.7 m of the instrument's length, the diameter is within 3 mm of that predicted by the appropriate straight-line equation.

Two possible patterns of manufacture could be suggested for the instrument as a whole

i) progressive development of the instrument form, either from the tip-end to the bell-end or vice-versa, or
ii) consecutive construction of the three yard sections, starting each yard at its tip or bell-end and building that up progressively.

It could be argued that the presence of a large cast-on boss at the end of the mouthpipe yard suggests that at least the first and second yards were subsequently joined together. However, as the change in polarity of curvature occurs at the junction of these two yards, it could similarly be argued that the material added here serves only to strengthen the instrument tube at this highly stressed point.

Assuming that the instrument/yard manufacture was started at the mouthpiece end of the mouthpipe yard, the maker produced a tube of increasing diameter from about 10*mm* to about 22*mm*. (Figures from SD125). Then, 610 mm from the instrument tip, having manufactured a length of tube that opened out with a slope of 0.0208 to within about 0.4*mm* of the best-fit straight-line value at each point, he increased the slope on yard 2 to 0.0350. Again this yard was manufactured closely to this slope the mean variation from it being 0.2*mm*. Thus, at this point 610*mm* from the instrument tip, he was clearly aware of the change in slope, i.e. he had made it deliberately. It seems likely therefore that he was clearing the cumulative error that had built up at that point, where, presumably it had reached a detectable value. His change of slope produced a second yard that crossed back over the "best-fit" line, correcting this "error."

As a further indication of the degree of fit of the data to a presumed theoretical model, the equations of the two best-fit straight lines may be treated as simultaneous equations. Their solution gives an intersection of (689.0, 22.59) which compares well with the actual measured intersection of (606.9, 22.6)

Yard 2 was then manufactured with a consistent slope up to 1.075 m from the tip where the slope was changed from 0.0350 to 0.0181, On yard 3 this slope was again closely followed, the mean error here being 0.17 mm. In yard 2, as with yard 1, a variation from the overall best-fit line appears to have accumulated during its manufacture, being at its greatest value of 2*mm* at the intersection of yards 1 and 2. However, these yards do run smoothly into each other suggesting that the variation from the overall best-fit line that now exists was designed into the specification and was not a measuring error.

Considering the possible manufacturing process where the whole instrument was made in one piece, a break in slope could similarly be interpreted as indicating that, at the intersection point, an error of detectable size had built up and that the slope of the next yard was adjusted in order to compensate for this.

ln the case where the instrument is made in individual yards, the dimensional requirement to enable adjacent yards to fit accurately is that the exit diameter of yard 1 would match the entry diameter of yard 2. This places a tight requirement for accuracy on the manufacturer particularly when manufacturing adjacent yards simultaneously, as the required exit diameter for a particular yard is established as soon as the entry diameter to the next yard is made.

The clear implication arising from the Rørlykke and Brudevaelte data is that these instruments were made to a defined design. Obviously this had to be stored in some way but, resulting as they do from the activities of a pre-literate society which has left no definite evidence of the mode of storage of data, the lurs themselves are the sole source of data on overall design philosophy.

IMPLICATIONS OF DIMENSIONAL ANALYSIS ON PRODUCTION

There seems little reason to doubt the generally-held belief that the lurs were made by casting using lost-wax technique. The material used for forming the pattern was, most probably, beeswax, which given the conditions believed to have existed during the bronze age, may well have been readily available within the Nordic cultural area. To produce a 3.3*kg* instrument (a typical instrument weight) about 0.4*kg* of wax would be required, this being the amount produced in association with about 3*kg* of honey.

At an ambient temperature of 20°C, beeswax is moderately hard but, when warmed only 10°C or so above this, is malleable and readily formed by the hands or with simple tools. However, when making tubes of 60 to 80*mm* diameter with wall thicknesses of only a millimetre or so it would be difficult to obtain a reasonably round object and to maintain its roundness using wax alone. Added to this difficulty, is that of obtaining a well-fitting core as the shrinkage of clay is generally about 10%. This would mean that a clay core moulded green inside a 60*mm* diameter wax pattern would shrink some 6*mm* on drying. When reduced in this way, it would give rise to a tube of considerable wall-thickness, i.e. always at least 5% of the tube bore and chaplets, put in while wet, would be pulled loose by the differential movement between the wax and the core,

None of the Wismar group of instruments have wall thicknesses which approach this figure, 1 to 2% being a more common figure. Were a clay of much lower shrinkage to be used such as a fire clay with an admixture of sand or grog (previously fired clay) the overall shrinkage figure might be brought down to around a 1 to 2% figure. This would still give an overall wall thickness in excess of that seen on these instruments possibly twice the value, and raises doubts about its practicability as a viable technique.

However, the bore of the Wismar horn clearly shows a step, (Fig.4.5) and such a feature would clearly not be deliberately constructed on a core prior to forming wax over it. The manufacturing process then, must have followed the sequence: wax pattern - infill and this infill material would need to have a negligible shrinkage rate upon drying. It is possible that this area provided a suitable material such as a fine-grained sand with a 1 - 2% clay admixture. The clay would be sufficient to bind the sand while wet and, on drying the overall shrinkage of the core would be negligible. Although the dry green core would not be particularly strong, it would be sufficiently so to hold together during handling of the pattern and core together. Of the suitability of this material as a core there is no question as it is used to this day as a core and mould material in small-scale casting operations. For its appearance, the technique depends upon the existence of deposits of suitable argillaceous sands, or knowledge of the technique of mixing the two materials. Other than on this Wismar instrument, however, there is little suggestion of its use. elsewhere. Other tubes of lurs are too long to have had sufficient structural integrity when made in wax alone and remain too round to have been handled while in that condition.

Chaplets are present on the later lurs and their use, while necessitated by the increasing length of tubes used, probably coincides with the introduction of cores as the basic generator of instrument shape. Used in this way, a clay core provides, while dry and green, an ideal form which is dimensionally stable, strong, and yet can be worked by the use of stone or metal tools. It is probably the development of the core that is the key to the high level of dimensional uniformity of the lurs. If the core is round and of the required form, then the overlaying of a uniform thickness of wax over this will produce a round pattern to that form.

Moulding of clay materials by hand has been carried out since the Neolithic and would have been nothing new to the maker of the early lurs and their pre-cursors. When moulded green and wet and finished abrasively when green and dry, close dimensional control can be exercised over the form produced. However, when breaking away from the morphological constraints imposed by animal horns i.e. a lack of uniformity both in their cross-section and their conicity the maker began to construct instruments to a model, abstract or otherwise that was rounder and more uniformly conical than natural material.

THE GENERATION OF ROUND CORES

Early instruments are recognisably round in form but have visible variation from perfect circularity, the Gullåkra instrument, for instance having clearly definable flattish areas along its length. The degree of roundness, 1.32 mm, is, thus, clearly of an order that could be formed by hand using a generalised concept of roundness to judge when the required degree had been attained. This is not so with other instruments, one of these having a roundness of 0.10 mm. This is more round than could be achieved by hand-forming and suggests that a generating process was used.

Processes for producing round objects are known from the Mediterranean and the Middle East where the earliest depictions of about 600BC on Greek pottery shows the potter seated at a large turntable which he himself or a helper turned by hand. Two Egyptian reliefs from about 300BC show the use of more sophisticated rotating machinery. One of these depicts the god Khum using a potters kick-wheel and the other shows two workmen using a lathe. On this latter machine one provides the power by pulling a band across the work-piece. The general literature of this period assigns the invention of the lathe to Theodorus of Samos, the truth perhaps being that he refined some equipment of the day to take the whole credit for the invention.

In North-West Europe, however, no documentary or iconographic evidence exists for the use of the lathe although in Mordant et Prampart[171], it is demonstrated that a lathe was used in Late Bronze Age II N. Burgundy to polish up the heads of bronze pins (Fig, 4.16).

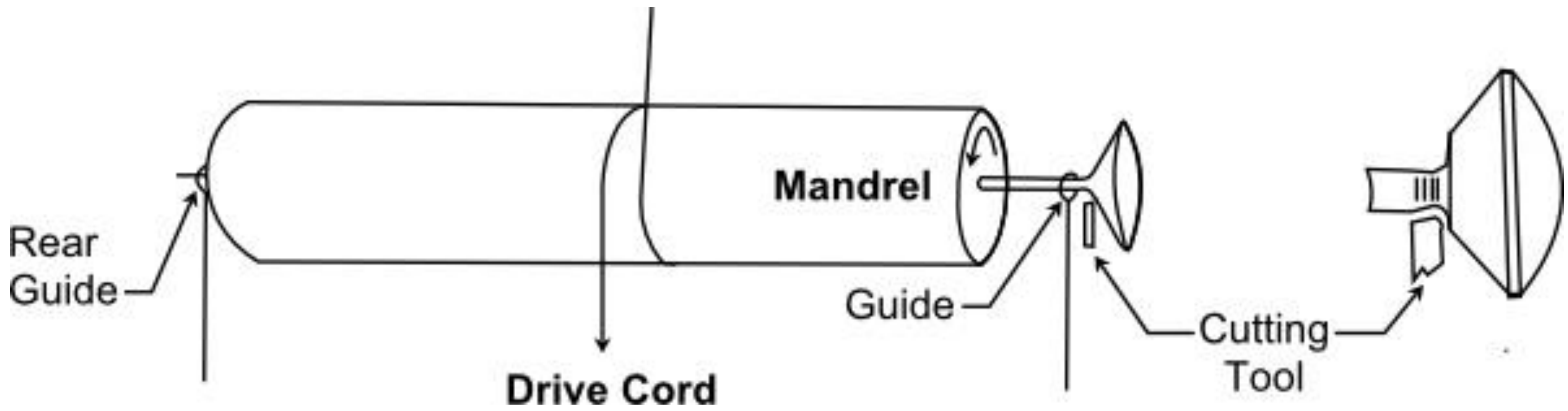


Figure 4.16: Decorating Bronze Pin Heads

However, irrespective of how these instruments were made in terms of the detailed production sequence a rotary generating process was clearly used, i.e. a lathe-type device.

While a lur may be round and of conical form, its axis curves in two planes, (Plate 4.2 (b), Plate 4.3 (a)) It would not, thus, be possible to generate a finished instrument between centres as the generating process involves rotation about a straight line connecting the effective centres. Thus the roundness of the lurs must have been produced on the core before it was curved i.e. while its axis was still straight. For such an operation to have been possible, the core must have been malleable, i.e. in a green and wet state. However, a core in this state lacks the strength to support itself between centres for the turning operation to be carried out. Part of it would have to act as a pulley, to allow the rotational energy to be fed into the system, while the bulk of the core would need to be strong enough to transmit the torque necessary to overcome bearing friction and the load applied by the cutting surface.

[171] Mordant et Prampart, 1976, 139, fig. 126

Plate 4.2 (b): One of the Folrisdam Lurs

One possible manufacturing sequence could be: rough manufacture of the core in a green/wet condition; drying of the core; turning to achieve the round conical form; re-wetting the core; bending the core to the required curvature; insertion of the chaplets; final drying of the core prior to forming the pattern over it. The difficulty in this proposal lies in the re-wetting of the core as the major core shrinkage occurs during the green core drying process. As this process is slow and continuous, the clay is capable of shrinking in three dimensions at this rate without cracking. It is not easy to re-wet the core at this rate and when the outer surface is wet too rapidly it expands and breaks away at the sharp wet/dry interface. However, it seems reasonable to assume that the Bronze-Age worker, as has the present-day potter, had several techniques that enable him to re-wet a piece of clay which has dried before he has I finished working on it. In the present-day application of this technique the dry clay is wrapped in newspaper and then placed in a sealed polythene bag which is packed with wet newspaper. This is then left overnight or, if necessary longer until the moisture soaks throughout the clay. Presumably, during the Bronze-Age the same effect could be achieved by wrapping the clay in a piece of cloth and then covering this with wet leaves and, if necessary, pouring water over this.

A further solution might be found by the provision of a temporary support during the turning operation. To do this a piece of wood could be fed through the centre of the core which was then turned in the green/wet state. If the wood could then be removed without deforming the core, the requisite curvature could be generated and the core allowed to dry. In order to maintain the dimensional regularity seen on these instruments, the wooden insert would need to be reasonably round, straight and smooth to facilitate its removal from the wet core. This process of stiffening moulds with wood is known from mould fragments found in Northern Ireland where a longitudinal hole down the length of sword moulds attests to the use of wood or other such material as a central backbone to support the mould in its green state. Hodges[172] considers that the supporting stick was generally left in the mould right throughout the casting process and cites a mould fragment from Lough Eskragh which still contained a charred fragment of wood when found.

It is, of course, possible that a technique other than lost-wax had been utilised to produce the instruments or the patterns from which they were derived. As with the Irish Bronze-Age material, some stage of the manufacture could have utilised a two part mould the most likely piece to have been made like this being the core. However, the two-part mould technique suffers from a limitation in dimensional stability across the mould joint-faces. Thus, cores made by such a process, while reproducing the curvature of the mould form over much of their circumference, tend to show a greater divergence from the presumed design dimension when measured across the normal to the joint-line, i.e. tend to be oval. (Figure 4.17) Further evidence of the use of two-part moulds is generally provided by the presence of joint line evidence, where the two parts of the mould fail to fit together tightly and allow material to flow into the space provided. (Figure 4.18)

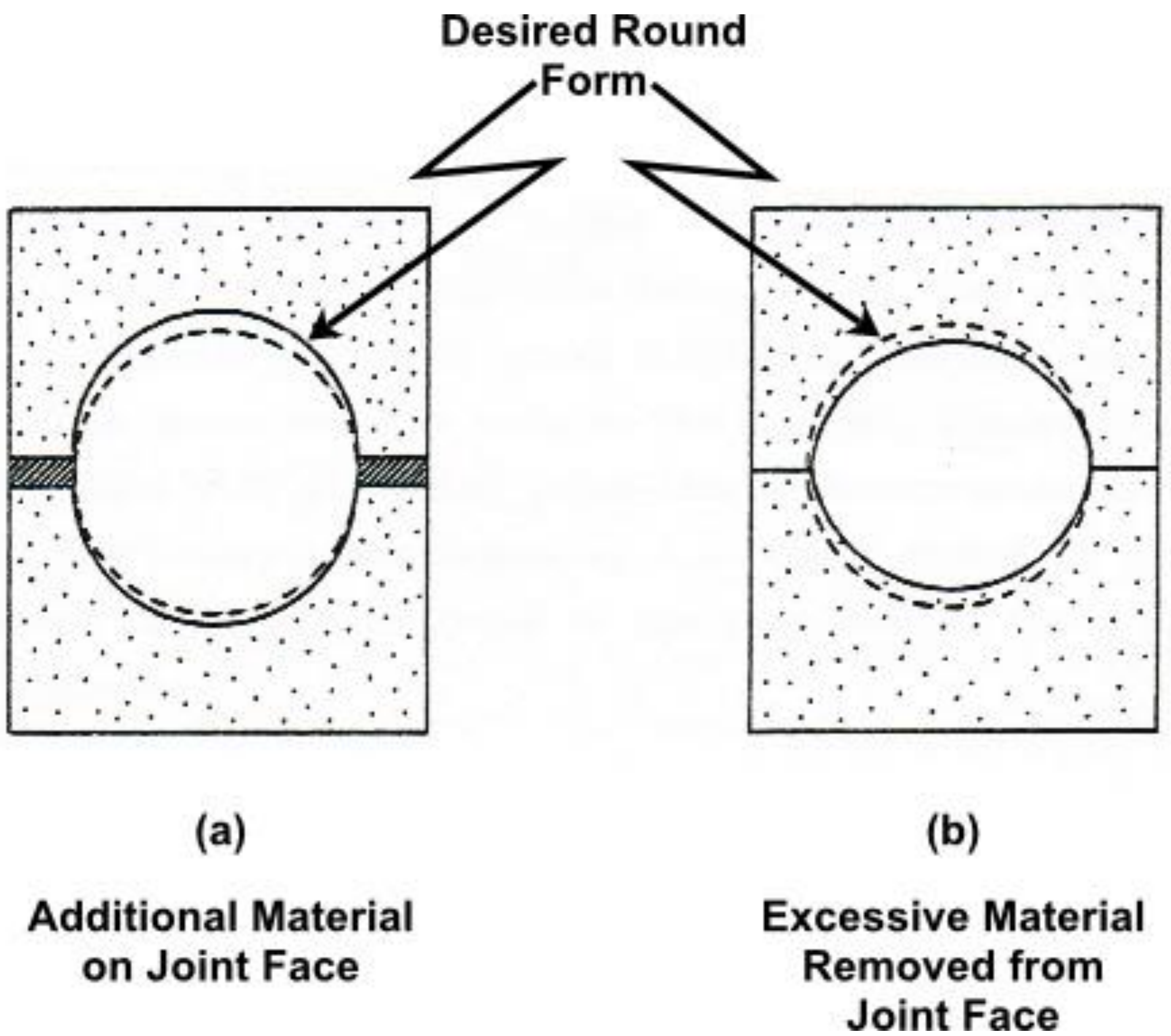


Figure 4.17: Problems arising from the Use of Two-part Moulds

[172] Hodges 1954, 64.

No instrument bores show any evidence of joint-lines, although these could have been fairly readily removed. (Some core markings are present on Gullåkra's bore but these are not joint-line evidence and probably result from the build-up of the core using sheets of clay.)

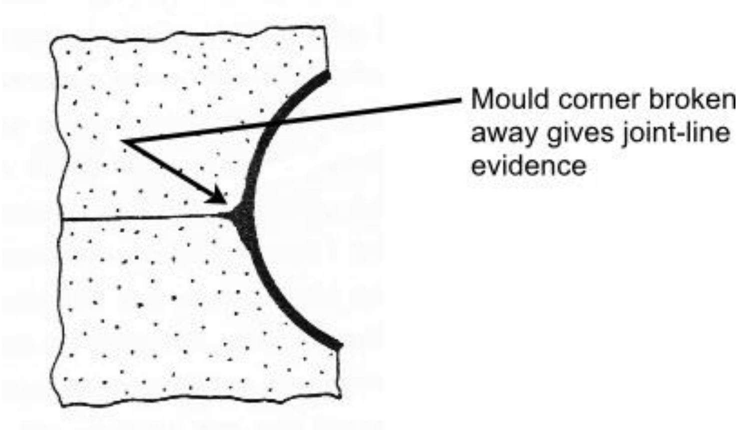


Figure 4.18: Flash Lines from Two-Part Moulds

While all the lurs have curvature of their axes in two planes, this became markedly more polarised in the later instruments. (Plate 4.2 (b), above) In these one segment only remains curved in both the horizontal and vertical planes whereas the dual curvature is seen in several segments in earlier instruments. The split mould technique is able to handle an item with a non-planar joint-line only with great difficulty and it seems unlikely that cores could be made to the accuracy observed using a split-mould with a complex joint-line. Measurements of roundness of the transitional segments, i.e. those curved in two planes show these to be just as round as the remainder of the single-plane segments. Thus, overall, the evidence outlined suggests that these instruments or their cores were not made by forming in a split mould.

THE MANUFACTURE OF PATTERNS

So far the discussion has centred on the manufacture of the instrument core, but the pattern wax must be laid over the clay core, allowing the chaplets in the core to penetrate it. The thickness of the sheet of wax is, therefore, a further determinant of the final dimension of the tube outer diameter. Hence, it is also tightly constrained to be uniform if manufacture is to a be carried out to within the limits measured. To examine one particular case, the Folrisdam instruments are considered, their mean figure for roundness being 0.19*mm*. Assume that, as a first step, a core was formed and that this was manufactured perfectly round i.e., say, to within 0.001*mm*. Thus, in order, to manufacture the overall pattern to within ±0.095*mm* of this figure the wax sheet would need to·be made uniform to within 0.095mm (say 0.1mm). Sheet could be made to such a constant thickness by rolling the material with two distance pieces to set the working gap and hence the thickness. (Figure 4.19)

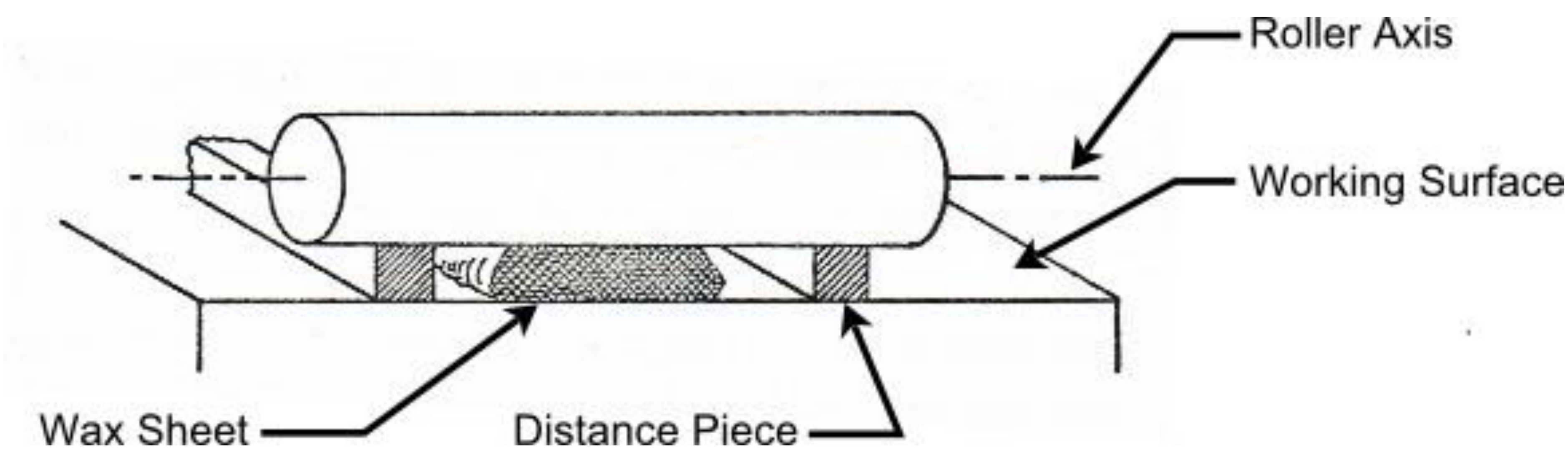


Figure 4.19: Creating Wax Sheet

However, the figure of 0.1*mm* for maximum permitted thickness error would be made up from cumulative errors in: the thickness difference between the two distance pieces; the planeness of the working surface and the trueness of the axis of the roller.

As the thickness of the wax sheet used in manufacture is replicated in the tube material itself, measurement of the instrument wall thickness would give an indication of the degree of uniformity of the sheet used in manufacture. However, it was not possible to do this during this present study as suitable instruments did not exist. Several are under development at the time of writing and the possibility of their use in a further study is discussed in Chapter 5.

THE ASSEMBLY OF COMPLETE INSTRUMENTS

Not only was considerable attention paid to dimensions such as diameters and lengths but the production of curvature on these and their assembly into complete instruments was also carried out very carefully. Figs. 4.20 and 4.21 show the dimensions of instruments SD101/2 and SD103/4, illustrating dimensions formed both by the curvature of individual tube units and by their assembly together.

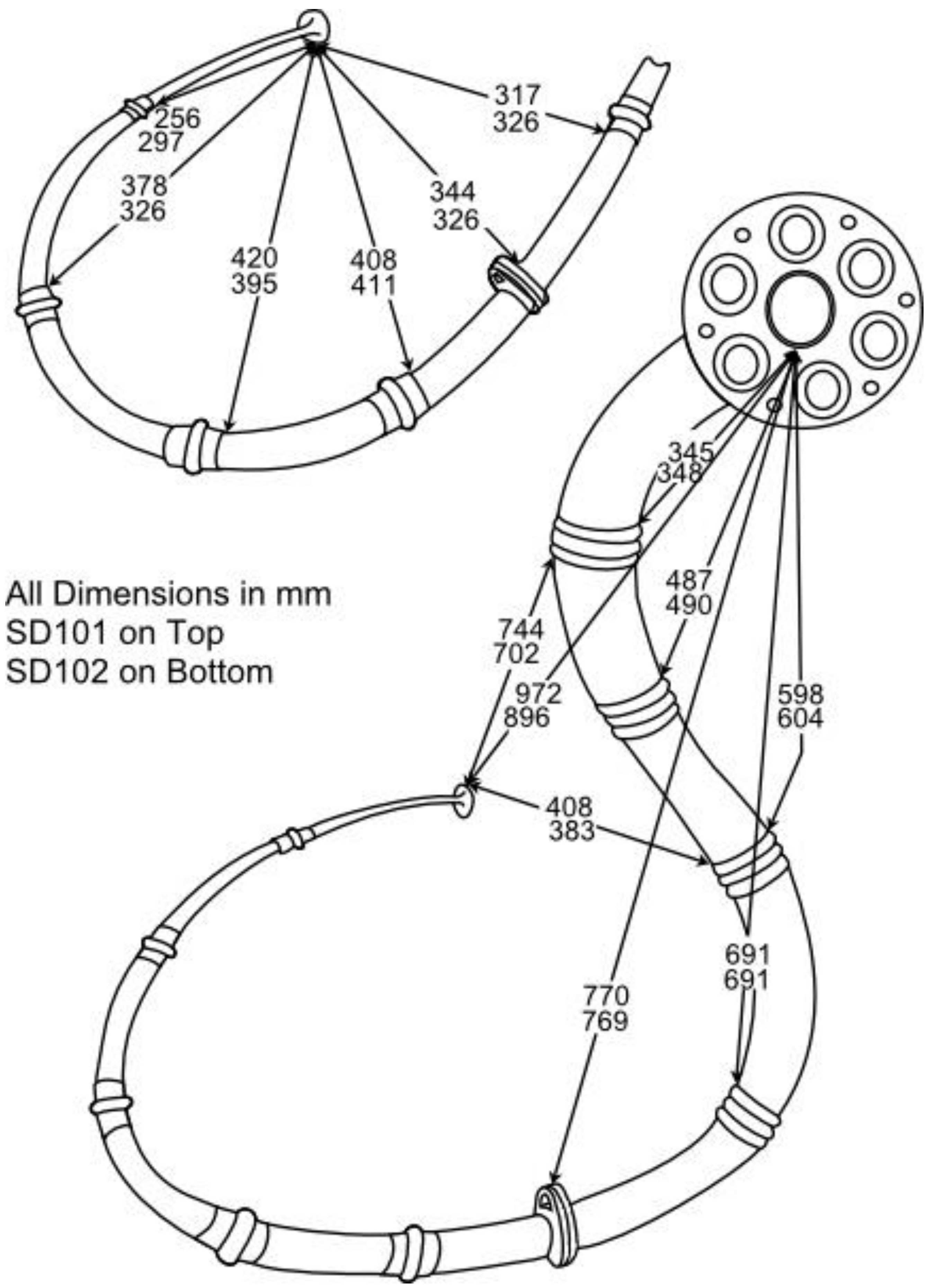


Figure 4.20: Assembled Dimensions of the Brudevaelte SD101/2Lur Pair

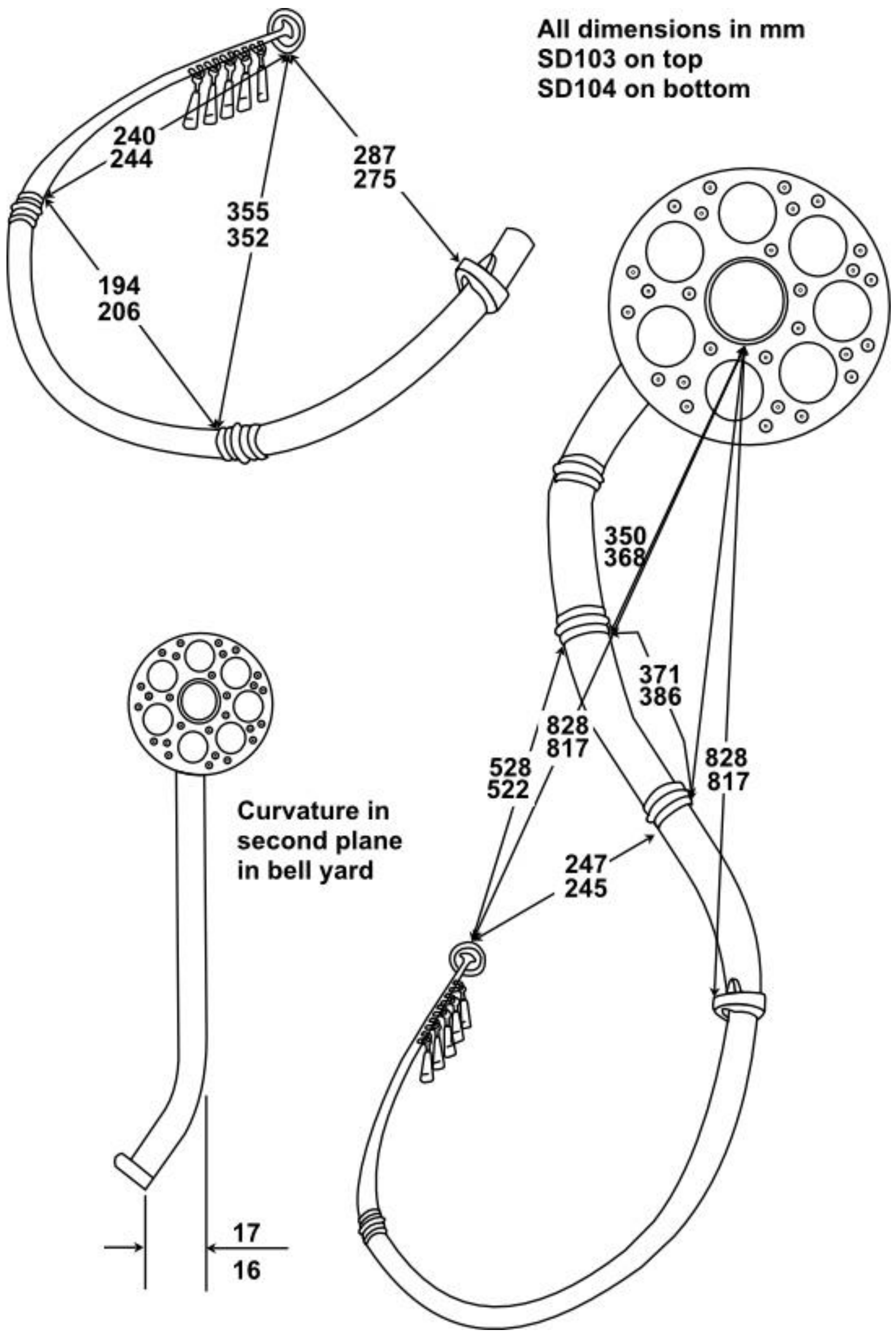


Figure 4.20: Assembled Dimensions of the Brudevaelte SD103/4Lur Pair

On Figure 4.21, for instance, the difference between the four tube yard dimensions are 12, 12, 4 and 3*mm*. In the case of the closest of these dimensions, 355/352mm, this is derived from two individual curvatures of tube units and one joint, between the mouthpipe and the second tube unit. It is clearly a closer fit than can be achieved by visual assessment alone, suggesting that some form of measure was used in its construction.

This effect is even more noticeable on the bell yard of SD101/2, (Figure 4.20). on this, the dimensions from the tip of the bell mouth to the segment bands are:

SD101	SD102	Difference	
		Percent	Absolute (mm)
345	348	3	0.86
487	490	3	0.61
598	604	6	0.99
770	769	1	0.13

These are most impressive figures for repeatability between items and the uniformity of this repeatability over the four readings leaves no doubt as to the deliberateness of the dimensions. Their achievement must derive from careful assembly of the segments when casting these together. Undoubtedly, the chords measured here were used as check measures on assembly, presumably to achieve identical forms on instrument pairs.

The amount of work of a metrological nature such as that above, is strictly limited by the fact that these instruments are now mounted on display as permanent fixtures. Thus, in order to obtain the dimensions shown on figs. 4.20 and 4.21 it was necessary to work inside the display case and accept such limitations as this imposed.

THE GENERATION OF CONES

When turning the cones that subsequently form the core, the maker could either use a single point tool traversed across the cutting surface or a straight-edge to pare off material across the whole edge. In the former case the locus of the tool determines the straightness of the line cut. Thus, the maker has to manipulate the tool to traverse in a straight line against the tendency of the hand to traverse a radius defined by the length of the forearm. This can be overcome to some extent by use of a guide to work the tool against but any irregularity in this guide is reproduced on the finished item. Using a straight-edge to generate the form also requires an accurately made edge as any irregularity on this will again be reproduced on the finished work, albeit to a slightly lesser extent. Hence, in the case of an instrument with a yard manufactured to within 1 *mm* of a defined straight form, the straight-edge would similarly have to be straight within about 1 *mm*. The manufacture of an edge straight to this limit is a considerable technical feat involving a certain amount of motor skill and, more importantly, a good conceptual grasp of the idea of a straight-edge.

CONCEPTUAL GRASP OF THE PROCESS OF MANUFACTURE

Perhaps the most difficult of all aspects of the lur manufacture to evaluate is that of the level of conceptualisation of the manufacturing process. On the one hand, it could be argued that manufacture was to a previously developed pattern that was copied, while on the other, the design could have been stored in some way to be retrieved when making another instrument.

If a physical standard were used, to which new instruments were made then the limit of reproducibility is defined by the ability to copy a dimension or form from this standard.

Thus, if perception alone is used to carry out this process, the limit of reproducibility is defined by the perceptual ability of the maker, the possibility of arriving at some figure for reproducibility using perception alone being discussed in Appendix III.

However, the figure calculated for the minimum perceptual increment is by no means the absolute figure to which matched diameters can be produced. Clearly the tube seen as larger than the standard will need to be modified and in doing this both the skill of the maker and the actual technical process involved are significant. Generally speaking, the simpler technical processes are less controllable, for example the use of a coarse abrasive material to reduce a core diameter. (If a finer abrasive is used this readily clogs and thereafter fails to cut until cleaned.) With this coarse material, by the time contact with the workpiece is established, a considerable amount of material would already have been removed. Following this initial contact, the amount removed would be dependent both on the pressure applied and the length of time for which this was applied. It is in judging the time of application where the skill lies as, when progressively working down a dimension to a requisite value, the tendency is, after several attempts to match, to overdwell with the tool and to remove excessive material. Thus, not only is the minimum perceptual increment a determinant of repeatability but to this must be added the minimum quantity that can be removed in one machining pass.

Development of instrument form under these conditions could arise either from deliberate design or by dimensional drift, as the dimensions of the standard form are likely to vary by up to the minimum perceptual increment each time this standard is replaced. This drift although almost imperceptible would, nevertheless, be consistently towards a more aesthetically-pleasing design.

Several different types of physical patterns could be used to store dimensional information and in increasingly abstract order these are:

l. An actual instrument (or a pair) kept as a copy

2. The yards of a dismembered instrument (i.e. following prime manufacture)

3. The cores of an instrument for use as generators of form

4. The cores of an instrument in the form of a straight cone

5. Station markers or gauges storing dimensional information specific to set locations on the tube

6, Dimensional data stored in the form of units by some means. In the case of 1 to 5, all these techniques could be used in association with information transfer using;

a) perception alone

b) gauging of some form

No physical evidence exists for the use of any of the techniques above and one must rely on interpreting the instruments themselves for a guide to the practices employed.

If perception alone cannot account for the uniformity between instruments in a pair or group, the second level of abstraction (b), that of gauging may have been employed. This would enable a dimension on the instrument being made to be matched to one on a standard, the gauge allowing a close assessment of size to be made.

The concept of taper in a tube or bar is fairly readily understood but the expression of taper as a uniform incremental change in diameter per unit length is more restricted in usage to mathematical work. The use of gauging in the production of a taper may be seen as a first stage in the abstraction of the concept, allowing the user to note that equal increments in length of tube require equal increases in diameter to achieve true conicity. There is, of course, no reason to connect the size of the two units, that of length and that of diameter quite possibly being seen as totally different types of things. Given time for development, they might well be conceptually united to give rise to a unified system of measurement. Thus a diameter gauge could be used with provision for inserting spacers to step down its aperture progressively, producing intermediate points on the taper. Such spacers could, of course, eventually become the new minor units of the total aperture gap or units of measure.

Suggestion 6, the use of dimensions, the most abstract form of storing and transferring dimensional information would free the maker from restrictions imposed by physical models and their imperfections and leave the problem of defining the unit of measurement as the major problem. It could also lead the maker towards a geometrical analysis of his product, significantly different from that of earlier instrument makers who simply copied a shape.

THE USE OF STANDARD UNITS OF MEASURE

Although this cultural region provides no evidence of the use of units of length, much evidence exists from other areas for the use of units from much earlier periods. In Egypt and Mesopotamia, for example, as early as 3000BC, standard lengths were used, being kept in temples and royal palaces[173].However, such units as are known have the finger-width as the major sub-division and, being defined on a very variable anthropometric feature, such a unit would appear to be far too coarse for use in defining the tube morphology of a lur.

One caveat that must be entered here when speaking of dimensions is that, as the major medium for recording and interpreting the morphology of the lurs, in this study, has been dimensional it is .easy to begin to think of this entirely in terms of values of 'x' and 'y' and their mathematical inter-relationships. This obviously influences the view taken and is in danger of precluding the holistic view that needs to be taken, encompassing organology, perception and production processes. The key feature of the results that allow or deny

[173] Hodges, 1970, 110, Wilder, 1973, 94.

mathematical analysis as a valid procedure is that of the uniformity of the dimensional information and its repeatability from one instrument to another. From the data already mentioned it seems clear that the dimensional information is quite valid and, indeed, would justify even more rigorous analysis of these instruments in a further study.

Evidence of a finer unit of measure was reported in 1970 by Butler and Sarfarij. This was in the form of a dimensional analysis of a ceremonial bronze sword deposited as a votive offering in Jutphaas in the province of Utrecht. No dating was possible with this find but, the authors believe, it can be related stratigraphically to three finds in this area that are dated to the Middle Bronze Age. (Here about 1200 - 1000BC, based on C14). Table 4.2 below shows their analysis of the dimensions and appears to confirm their view that a unit of 26.5 mm was used to construct this sword - a unit that they entitled the Jutphaas inch or J-inch.

	Jutphaas			Ommerschans			Factor
	measured mm	constr. mm	J-in	measured mm	Constr. mm	J-in	Increase
length	423	424	16	685		25.85	1.62
max. thickness	7		c.¼	9			
height hilt-plate	48	48			62.2		1.31
blade length (minus hilt-pl)·	375	376			622.8		1.66
radius of constr. circle		106	4	113	171.25	6+	1.62
chord across butt	77.8	80.2	3	113		4¼+	1.42
length side hilt-pl.		48.3			64.4		
width	129	131	5	186	187 to189	7¼	1.41
height trapeze		40	½		52.4	2	1.33
angle of side hilt-plate	57¾°			55°			
angle enclosing butt	45°			39°			
weight	0.705kg						

TABLE 4.2: Comparative Dimensions of the Jutphaas and Ommerschans Swords

All the lurs available for study have been measured as accurately as possible using hand methods of measurement and this data has been extensively analysed in order to find what dimensional standards might lie buried in it. The key to such standards as the smith may have used, however, lies not in mathematical analysis alone but primarily in the understanding of the processes by which the smith designed and made his product.

The basic unit of construction of a tube appears to be a segment, whether on the tube yard, assembled by means of ferrules or on a bell yard, assembled by means of meander joints, cast-on bands or whatever. Thus, the ends of these units are covered over to deny access for assessing both true segment lengths and their terminal diameters and these dimensions must be reconstructed. (Figure 4.22)

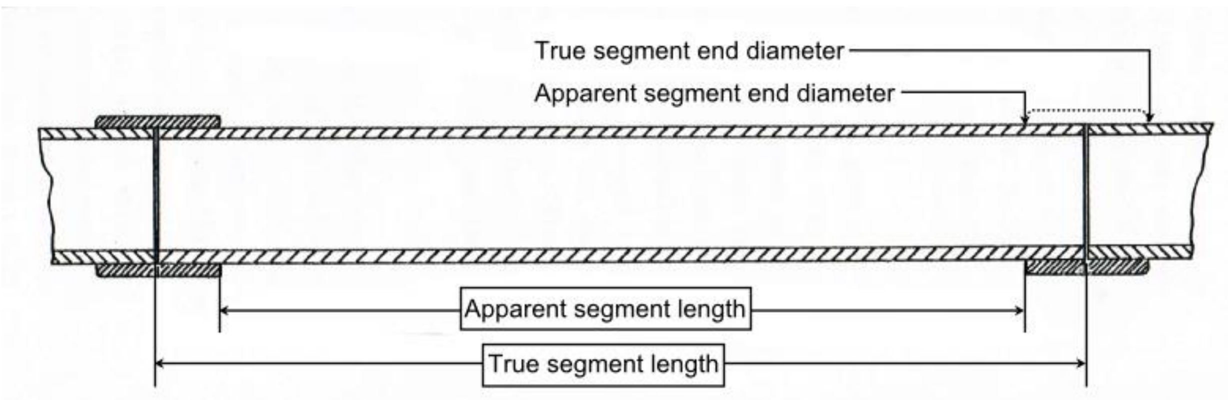


Figure 4.22: Establishing the Smith's Segment Length

True segment lengths and end diameters were calculated for Brudevaelte, SD102, as a fairly complete set of data was available for this instrument. Segment end-diameters were estimated by taking the mean of the tube diameters either side of the joining piece, i.e. assuming that the slope between these diameters was uniform and that the segment ended in the middle of the band or ferrule. The first of these assumptions appears to be justified by the detailed analysis of Rossum which showed a close approximation to a straight-line within the segment itself, although Schmidt's butchery of a cast-on ferrule on Daberkow[174] shown on Plate 4.3 (b), p. 167) suggests that the second assumption may be only approximate.

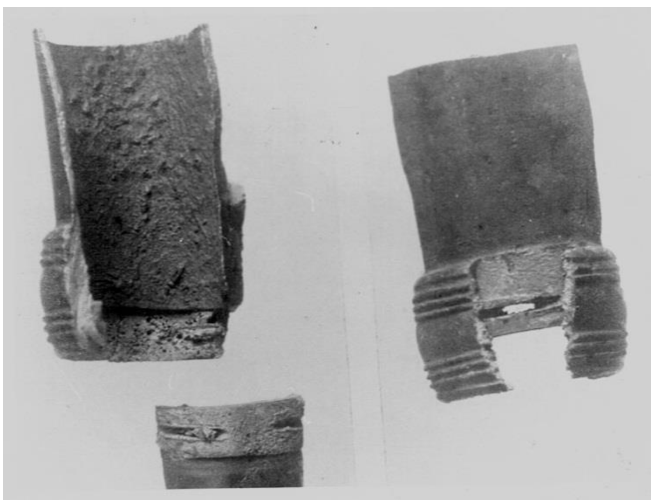


Plate 4.3(b): A Section through a Ferrule of the Daberkow Lur

On Brudevaelte (102) a unit of 4.5 mm was found to give a series of multiples which coincided quite accurately with the calculated segment end diameters these being shown on Table 4.3. For purpose of shorthand notation this unit is referred to as a (Bronze-Age inch) or "brin" in the case of Brudevaelte (102) the value of 4.5 mm being a Brudevaelte

[174] Schmidt, 1905, 99, Abb. 5, 39 and Taf. 8.

brin. Table 4,3 expresses the nearness of the measured lengths to multiples of brins in two ways: Column 1 shows the number of brins needed to generate the measured value while Column 4 shows the value obtained from an integer number of brins and Column 5 the difference between the integer number and the actual measured value.

Column 5 on Table 4.3 seems to substantiate the view that 4.5 mm is a relevant unit of measure as most of the difference values are very low. In addition, each of the 2nd to 5th segments seems to be one brin longer than the preceding one while the diameters of segments 7, 8 and 9 increase at only half that rate. This may account for the large variation from an integral number of brins seen on line 7 of Table 4.3 as this may result from the desire to increase the tube diameter more slowly. Were the application of a unit of measure to these figures false, then a range of error values from 0 to ±2.25 would be obtained with a numerical mean of 1.125. The mean error of the figures in Table 4.3 is 0.85, counting the two large figures and 0.55 omitting these.

No. of brins to obtain corrected value	corrected value of tube dia. (mm)	nearest integer no. of brins	value of integer number (mm)	difference columns 2 and 3(mm)
2.02	9.1	2	9.0	-0.1
3.16	14.2	3	13.5	-0.7
4.16	18.7	4	18.0	-0.7
4.53	20.4	5	22.5	+2.1
5.89	26.5	6	27.0	+0.5
10.78	48.5	11	49.5	+1.0
11.44	51.5	11	49.5	-2.0
12.07	54.3	12	54.0	-0.3
12.02	54.1	12	54.0	-0.1
11.24	50.6	11	49.5	-1.1

Table 4.3: Estimation of Standard Measurement Units for Brudevaelte 102

The fourth of these listed values, 20.4*mm* (Table 4.3) which occurs 666.5*mm* from the tip, could equally well be approximated by 4*brins* (18.0*mm*) or 5*brins*, (22.5*mm*) and thus does not conform well to the theory. However, if the "theoretical" value of tube diameter is calculated by extrapolating the best-fit line obtained from the tip to 479.5*mm* then a value of 22.96*mm* diameter is obtained. It could be, then that this was the diameter that the smith had determined would terminate yard 1 but, in order to make this mate with yard 2, he had to reduce this by some 2*mm* . When compared with the other lurs from Brudevaelte (Figure 4.10) the shape of SD101 and SD102 is decidedly hollow at this point,

and this feature could also represent a stage in the evolution of the overall straight line form as is seen in SD102, 103 and 105.

Segment lengths, being of larger dimension that tube diameters would probably have been dealt with in a different way from tube diameters. However, there is no doubt that in many cases, the dimensions of segment lengths were conserved and frequently used in the multiple form. This suggests that, at the very least, the concept of length and its use was understood.

Tests were carried out on the segment length data to check for uniformity based on the brin defined above and in the case of the corrected segment lengths of Brudevaelte (102), using a brin of 4.5*mm* ,gave a mean error of 0.88*mm* which seems significant in terms of the random error value of 1.25*mm*. However, 4.5*mm* is a very small unit for measuring lengths of segments which vary from 1530 to 210*mm* and it would be possible to reduce this "error" to any desired level, simply by choosing a small enough unit!

In view of the size of segment lengths several tests were carried out using multiples of 4.5*mm* as it seems likely that if the brin were used then it would have been in multiple form for measuring x lengths of 100*mm* or so. When using a value of 10*brin*, the mean numerical error from integer values on SD102 (i.e. as column 5 on Table 4.3) is 7.75*mm* or c. 17% of the multiple, this compares with the random error of 11.25*mm* (25%). A further test was carried out using the J-inch (which approximates to 6*brins*, i.e. 27.0 *mm* cf 26.5) and with this a mean numerical error value is 4.96*mm* (19%).

In neither of the cases does the evidence appear overwhelmingly positive but neither is it clearly negative and much the same can be said for the results of much work carried out on other instruments. In nearly all of these some degree of uniformity can be seen in the dimensions but the key to this has not yet been found. The approach taken here may be too simplistic and the data points used not be coincident with those taken as references by the maker. On Brudevaelte, SD105, for instance, the first three measured segment lengths of 263, 261 and 259 mm are all very close to a value of 10 *J-inches* (265 mm) whereas the "corrected" values of these segment lengths are 281, 278 and 270mm which are nearer to 10.5, 10.5 and 10.0 *J-inches* respectively. On the Maltbaek instrument tube diameters measured at certain segment ends coincide very closely with integer *brin* values but, as the taper of the tube itself is slow, the possibility of this being a chance occurrence is clearly in need of investigation.

Much more work would need to be carried out on a range of instruments before a sample large enough to be statistically valid could be assembled. In addition, a number of re-iterative programmes would need to run to establish values for the "best-fit" lowest common factors and the overall summed errors when using these. Unfortunately such programmes could not be run on the calculator available during this study as it lacked a conditional step. Future work could better be run on a computer but would require as a firm prerequisite, a solid statistical base. However, the major problem would still remain that of gaining reasonable access to the lurs themselves.

Whenever standards are stored in a concrete form, some dimensional drift is inevitable when transferring these and using them in manufacture. Hence, units in use that are separated both in time and distance can be expected to show the level of variation outlined above. It is no more than remotely possible that some connection between these units and that of Butler and Sarfatij[175] exists. Their value of 26.5*mm* for the J-inch could be

[175] Butler and Sarfatij 1970.

interpreted as a coarser unit than that seen on the lurs, being made up of 6 units of 4.42 mm length.

Obviously much more valuable information is locked away in the lurs themselves. It is unfortunate that at this moment it is also locked away behind glass in Copenhagen!

THE DEVELOPMENTAL SEQUENCE OF THE LUR

In his work in 1915, Schmidt developed sequences of lurs, grouping these in groups A, B1, B2, B3, and C, this being varied somewhat by Oldeberg in 1947 when he eliminated the sub-division of the 'B' group. Later, in 1949 Broholm re-classified the instruments in terms of standard dating sub-divisions of the Nordic Bronze-Age, i.e. periods I - VI. (See above).

Two separate stages have been applied to the problem in this study firstly that of defining the sequence of the instruments using whatever information is available and secondly inter-relating this where possible with established archaeological periods.

Several general trends in design and manufacture can be distinguished which, given a culture with increasing technological capability could define a chronological series of instruments. Such trends are expressed in a positive direction in the following sequences:

A. TECHNOLOGICAL

i) Increasing lengths of segment. This sequence is difficult to express as all lurs have segments of different lengths. Thus, this sequence is sub-divided into

a) Increasing value of mean segment length

b) Increasing value of maximum segment length

ii) Tendency to separate prime manufacture from final assembly.

iii) Increasing roundness of tube diameters

B. ORGANOLOGICAL

i. Increasing sophistication of mouthpiece design
ii. Increasing conicity of instrument tubes
iii. Change in tube morphology to facilitate handling
iv. Increasing sophistication in lock provision

C. AESTHETIC

i. Increasing complexity of tube decoration
ii. Increasing complexity of bell-disc decoration
iii. Increasing complexity of chain decoration

iv. Decrease in number of segments
v. Increasing polarity of tube curvatures
vi. Morphological development of mouthpipe

However, this analysis fails to produce a single sequence, this failure leading to the conclusion that the sample of instruments available for study is only a minute fraction of those that have existed, and that developments took place at several localities producing a whole series of individual sequences, the various features typical of these becoming mixed through trade. Nevertheless, groups of features do produce clusters that have a definable geographic spread.

THE SCANIA GROUP

The first of these groups - here called the Scania group - are the presumed early instruments. These, although presumed early are nevertheless, variable in form and individual instruments display some of the following features: integrally cast bell discs of undecorated annuli; (Plate 4.10 (a)) integrally-cast tube structure; individual elements being joined by means of meander joints, (Plate 4.4 (b), below) highly conical tube morphology and an overall shape roughly like an enlarged animal horn.

Plate 4.10(a): The Gulåkra Bell Disc

Plate 4.4(b): A typical Meander Joint

Some features which are, or could have been, common to all the instruments are simple mouth-supports of the Gullåkra type (Figure 4.6(b)) and decorative elements made up of groups of raised bands. Broholm dates the instruments of this group from Scania on the basis of the simple band ornamentation which is also seen on wide arm-rings datable to period III. However, there are technical differences in manufacture between the two sets of bands, that on the arm rings being partially pressed through from inside while the Gullåkra bands are produced by addition to the existing band. Nevertheless this dating allows what appears to be a reasonable relationship between both earlier and later material.

One of the instruments of the group, that from Påarp, has a markedly less conical tube than the other group members, its semi-vertical angle being 10.8 mrad compared with 35.2 for the Gullåkra instrument. It thus appears to be a later indigenous development on Scania towards a less conical form. A further feature on this instrument is the decoration of linking concentric circles on the bell yard[176] which has counterparts on the Maltbaek instruments and other material that dates it to the close of the 4th period.

The most advanced members of this group, the instruments from Rørlykke, share many of the group characteristics but have an overall morphology which is clearly polarised, with the tube-yard horizontal and the bell vertical. This polarisation is then seen on almost all later instruments. It is possible, therefore, that these instruments developed from the Scania type, probably on the island of Langeland. From here the industry that produced them appears to have formed the basis of industries that developed to the North-East and North-West.

The bell discs of the Rørlykke instruments are integrally cast but differ slightly from the rest of the group. Around their exit diameters are portions of cast metal which turn at right angles to the tube axis and serve to anchor the bell-discs. It is thus possible that the bell disc was cast separately and moulded onto the bell-yard or that it was made in wax and thence moulded onto the bell yard prior to investment.

One other instrument, that from Lübzin in Northern Germany, seems to have a close

affinity with the Scania group. While this instrument is of the general animal horn-form and has a simple four-ring decoration, it has a two-piece construction with a simple lock.

[176] Oldeberg, 1947, Fig. 29 and Schmidt, 1915, Abb. 7.

This suggests a derivation direct from Scania indicating that at least two lines of development were present, one leading to this instrument and one to the Rørlykke types. Schmidt dates this Lübzin instrument to period IV, mainly on account of its bell decoration. This dating allows the presumed close affinity to the Scania group to appear reasonable.

POLARISATION OF TUBE AND BELL YARDS

All the Scania group instruments are of integral construction i.e. the instruments are in one piece, all joints between segments are of the same form, and several segments are curved in two planes. However, all later instruments have a joint which separates the bell yard from the tube yard and is either in the form of a large cast boss or a lock. The development of such a feature became necessary when the two instrument yards became polarised to such a degree that the torque on the instrument tube resulting from the mass of the bell yard overloaded this, causing potential failure in torsion. This is illustrated in Figure 4.23 where C is the effective centre of mass, through which the mass M of the tube yard acts, at a distance of d, from the critical cross-section.

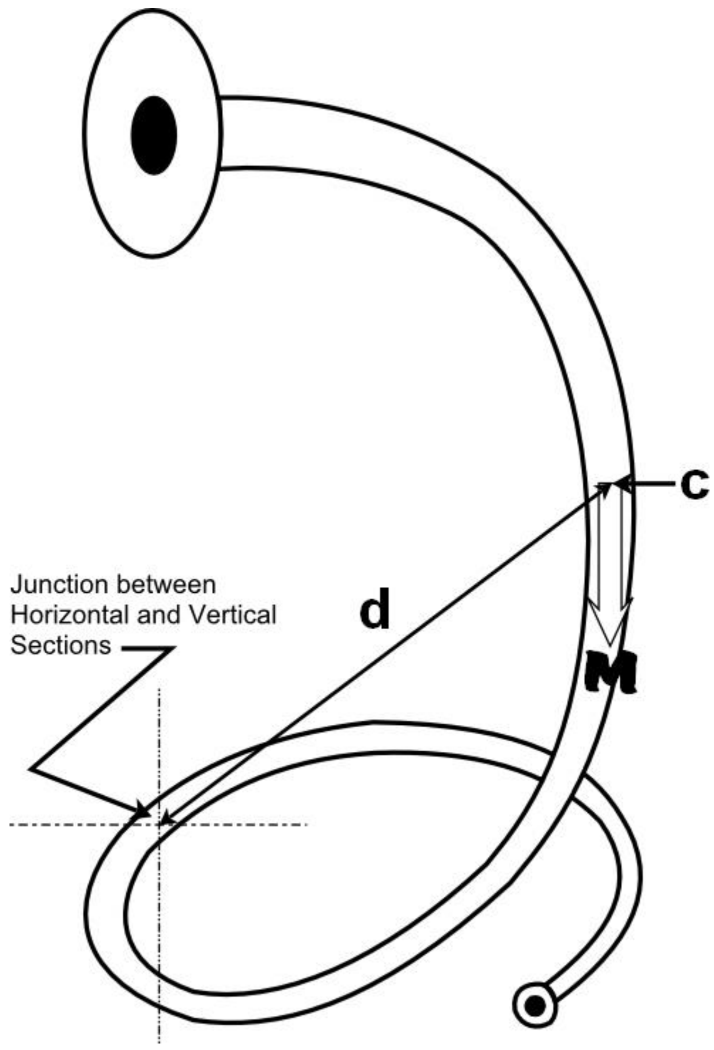


Figure 4.23: The Torque on the Junction piece between the Horizontal and Vertical Lur Elements

In a homogeneous tube of uniform cross-section, the torsional failure would occur at a predictable point. However, when the tube is made up by means of meander joints it would be most likely to fail at one of these. Thus the problem would come to be seen as one of providing a suitable strong joint rather than one of designing a strong enough tube.

Even on instruments of only moderate polarisation such as that from Froarp, the centre joint was obviously a problem as on this instrument the central meander joint differs from the rest (Plate 4,5 (a)) On this holes had been drilled in the tube wall and were then infilled with molten bronze. These, being connected internally to a thick annular band around the bore, serve to anchor together the two tubes. As failure was most likely to occur at meander joints a further solution, that of casting-on a heavy boss, probably over a meander-joint, in order to hold the two parts together, developed. This is seen on instruments such as that from Maltbaek where the boss was clearly cast-on onto the existing tube.

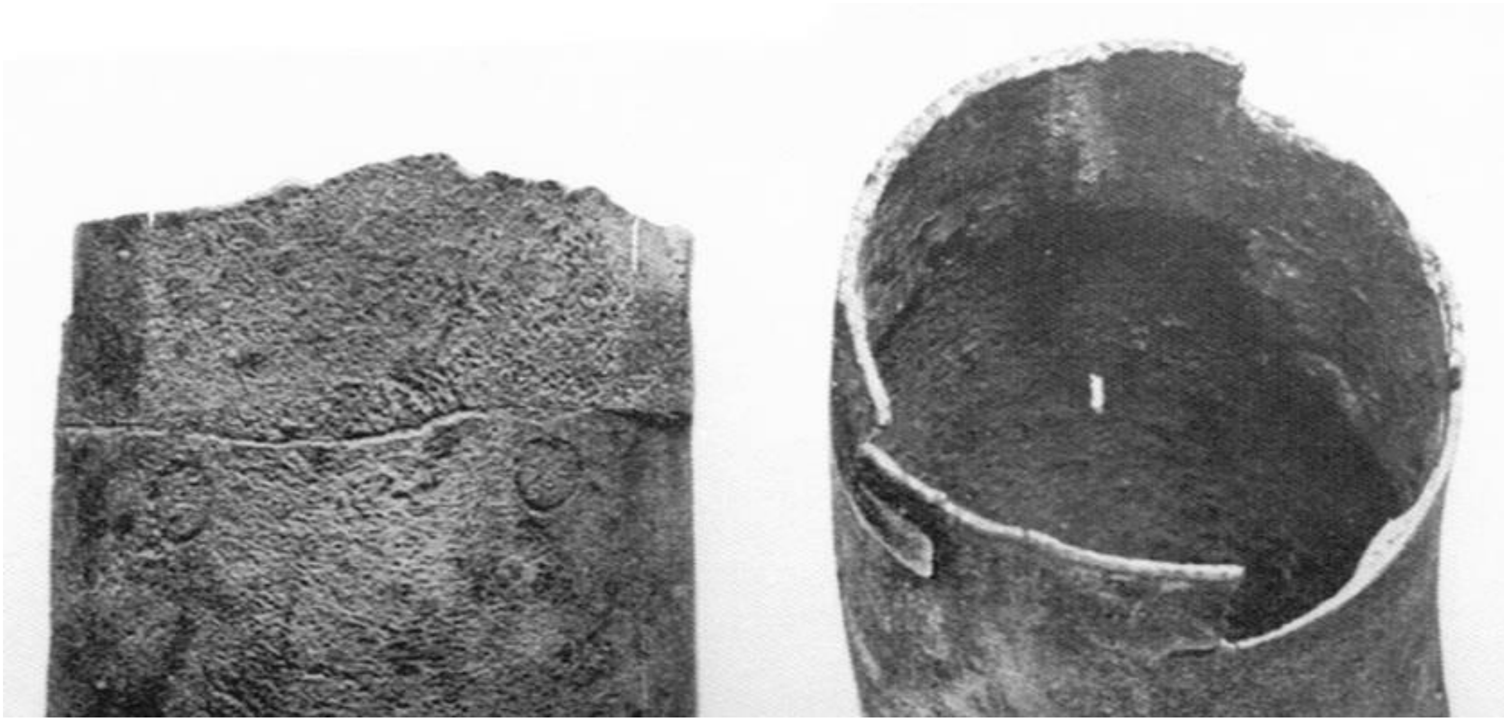


Figure 4.5(a): The Centre Joint on the Froarp Lur

DEVELOPMENT OF THE LOCK

The other solution adopted, was to provide a joint which could be disassembled - the lock - although it was quite likely that this joint was, in fact seen as a semi-permanent feature that was only rarely taken to pieces. Such a lock had to fulfil the basic requirements of providing a male/female junction that was tight enough to hold together, remained air-tight, and was capable of preventing rotation of the bell yard on the tube. The Lübzin instrument achieves this by means of a simple male/female junction and a pair of eyes, normal to the tube axis, (Figure 4.24) through which a peg could be inserted for purposes of location or to hold the two yards together. At the present time one link of the instruments chain is threaded through this ring.

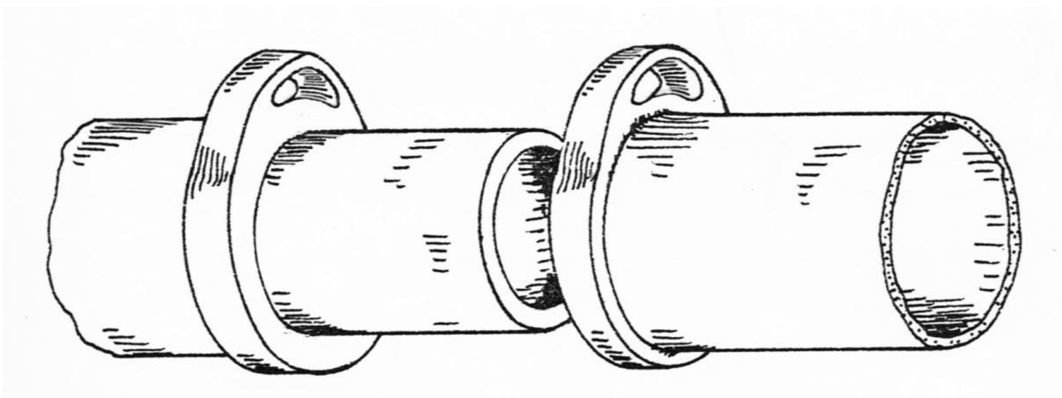


Figure 4.24: The Lübzin Lur Lock

This device clearly represents an early attempt to provide a locking mechanism between the two yards and is undoubtedly effective as a tie between the two yards when either a cord or wire is used to hold the two eyes together. However, it is less effective as an anti-rotation device and an instrument having only this simple two ring lock would still suffer from rotation of the bell. In seeing this as a remaining problem, therefore, attempts made to solve it would be quite likely to accept the eyes as a stop to lateral movement and to provide a totally separate anti-rotation feature. This is, indeed seen on the Lommelev instrument where the lock provision consists of a pair of eyes at 180° to a triangular tongue which penetrated from the tube yard into the bell yard. (Figure 4.25).

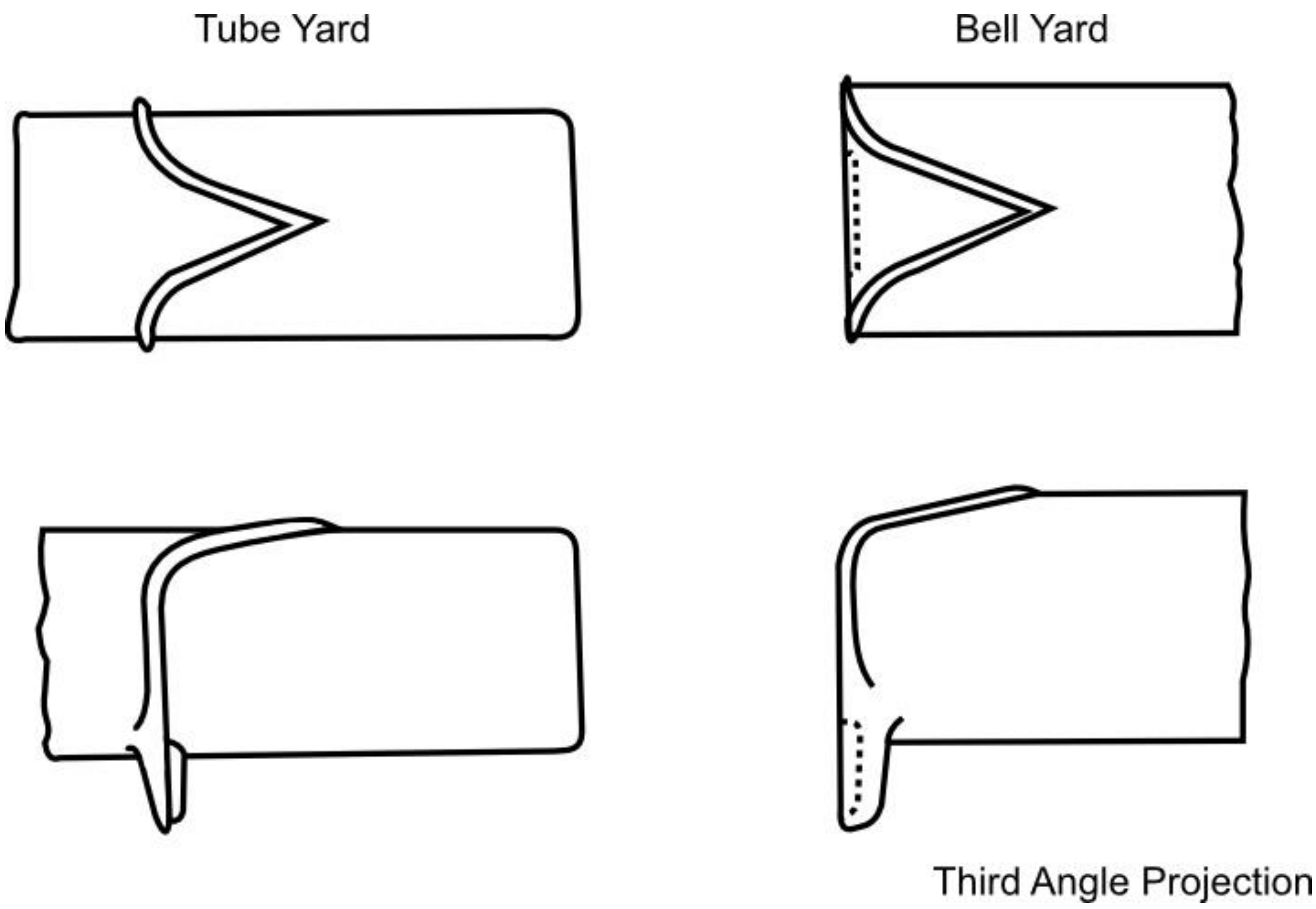


Figure 4.25: the Lommelev Lock

The tubes of these instruments are decorated by pairs of double bands which delineate the individual segments and, in many ways, resemble the bands on the Gullåkra instrument. As with the rest of the Scania group, the instruments are assembled by means of meander-joints but are generally not so well cast as these.

With the development of polarised instruments of greater length and with almost semi-circular tube yards, the weight of the instrument came to be supported more by this tube yard than the case on earlier instruments. (Figure 4,26).

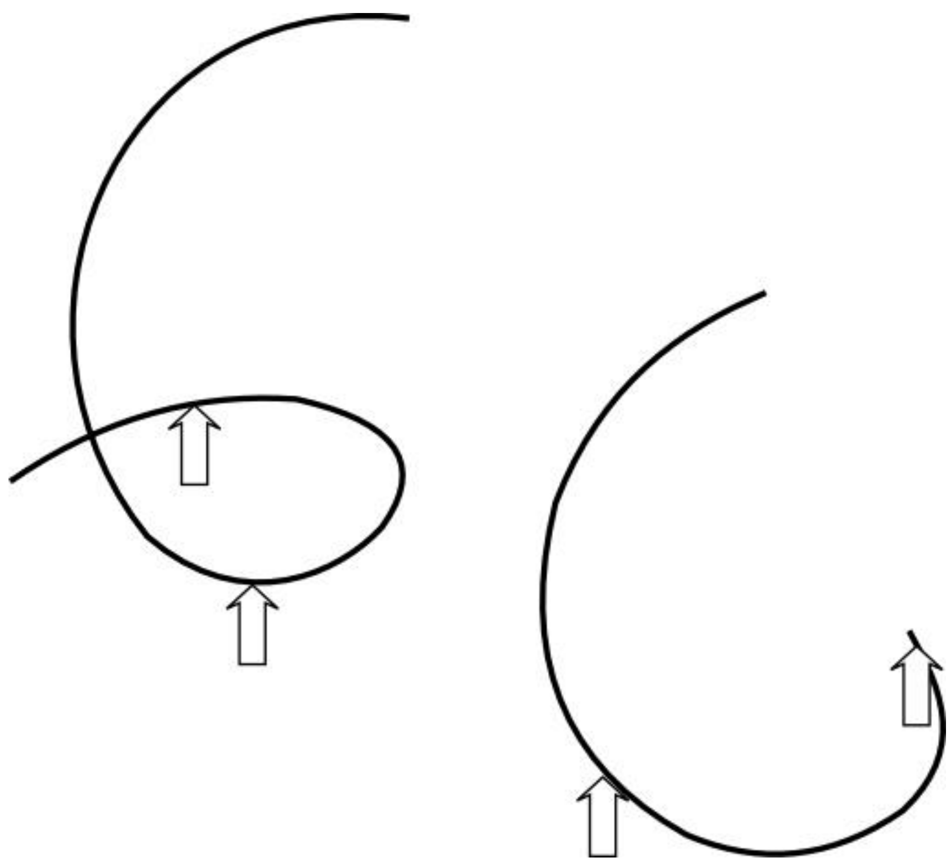


Figure 4.26: Lur Support Points

This increased loading on the tube yard undoubtedly led to failure of this on many occasions as witnessed by the many repairs that are seen on the extant specimens. On both the Lommelev instruments, for instance, cast-on ferrules are present that are clearly added after the instrument was complete and are in different places on each instrument. It is probable that these cast-on sections led to the generally accepted practice on all later instruments, of providing a ferrule, either cast separately or cast-on integrally, to join together the segments of the mouth-pipe and tube yard.

Thus, this instrument pair seems to be closely related to the Scania group but to have developed slightly more advanced features than the other instruments in the group. If this rather sparce evidence is truly representative of what actually took place, it would suggest that at this stage of development, probably during period lV the main area of manufacture and development had moved from Scania to the Danish Islands of Langeland and Falster and possibly Northern Germany.

No other instruments show the separation of the two lock functions in the way that the Lommelev locks do. It would appear, therefore, that the development of the lock that had a triangular tenon passing through the eye developed rapidly from a Lommelev-type prototype to become an accepted standard. The only notable variation on this - an aesthetic development - was the provision of scrolls on the tube yard bell, adjacent to the thickened band at the tube edge.[177]

[177] .Broholm, 1949, fig. 13.

The Cast Boss

The alternative joining technique to the lock which was used on a large number of instruments was the cast boss. This is a rather heavy, prominent boss which breaks up the line of the instrument and frequently carries an integral mounting ring. (Maltbaek, Folrisdam). There seems no reason to believe that this is an earlier design than the demountable lock as Larsson suggests[178] It is, more likely, a different solution to the problem and one moreover that appears to have been quite successful as all but one of the instruments that have the large bosses are still intact. Thus, lacking suitable X-ray photographs, nothing can be said of their internal construction.

The one example that is available for study is the bell of a lur from Høng (SD109). It is broken at its upstream end, presumably where it met the tube yard and failed through the cast-on portion. This addition to the tube consisted of a band, cast-on around the two tube ends. The joint appears to have failed through the cast-on section and, according to Broholm, is in the form of a "thick clumsy ring."

The Development of Bell Discs

Developing from the Scania group, which had integrally cast bells was a series of instruments with permanently attached but separately-manufactured bells. As a result, partly of the decrease in diameter of the bell itself and partly of an increase in the disc diameter, the area of the disc increased. Thus, unlike on the smaller annuli of the Scania group, this bell disc was decorated.

On the Lommelev, Maltbaek and Lübzin instruments, this decoration was applied using the standard techniques of the period that were used on other bronze work. The patterns used also mirrored those used on bronze work of the period and were used by Schmidt[179] for dating this material.

As with all metalwork of this period, the first stage in its manufacture was the casting of the disc. This, however, was cast to a semi-finished state with a corded circular rim around the circumference of its rear surface. This decoration must have been built up in wax on the wax plate prior to investment. (Plate 4.5 (b), (c))

[178] Broholm, 1949, 45.
[179] Schmidt, 1915, 132.

Plate 4.5(b): Rear of a Bell Disc

The clay investment was pressed onto this rear face in several pieces, as is witnessed by the raised line formed where these pieces failed to meet, leaving voids in the mould. Following casting, the front face of the disc was cleaned up abrasively and the pattern marked on. This pattern was then punched in using a series of punches from a dotting one to a triangular forming punch. While punching in the arcuate decoration on the central part of the disc, the disc itself was placed on a hard surface resulting in bruising of the metal below. However, when putting in the circumferential wedge-shaped decoration the circular rim on the underside of the disc must have been supported on a material which took up its shape while still giving support as no sign of bruising is present on this. A modern smith would use pitch or perhaps lead to give this support but it is possible that a soft wood could have been used on this occasion. The finishing touches to this arcuate petal-like decoration was then carried out using a graver which effectively cleaned out and smoothed the profile of the punched decoration. (Plate 5.5 (b)

Plate 4.5(c): A Bell-Disc Decoration

A similar decoration is seen on the bell of the Lübzin instrument although this lacks the circumferential bands around the disc. On the Lommelev instrument the decoration is made up of many more, smaller arcs, each having a hook-like feature at the end of the arc. Schmidt[180] dates this as period IV by analogy with dated decorative discs which carry this decoration.

In contrast to this form of bell-disc was a type that was essentially complete after casting. It is seen at its peak in the Zeeland group (see below) but several simpler forms are seen earlier than these. These instruments are decorated with bosses but of a much more simple form than those of the Zeeland instruments where the bosses are generally large and very round.

On the Folrisdam instrument, for instance, the decoration on the disc consists of two concentric rows of dimples pressed through from behind. (Plate 4.6 (a),(b)).

Figure 4.6(a): The Front Face of the Folrisdam Bell Disc

180 Schmidt, 1915, 133.

These were formed in wax prior to investment and in the cases where the section failed, this is made good by a repair patch. Repairs such as these were obviously carried out at the stage when the disc was in wax as their material is now integral with that of the disc. A peculiar feature of this pair of instruments is the difference in number of these dimples on the disc; instrument SD124 has 15 dimples on the inner circle and 20 on the outer while SD125 has 17 and 20 respectively, this being a unique occurrence on a pair of lurs. Around the periphery of the disc is a poorly-formed rim, created by adding wax to that of the disc proper during manufacture. Altogether, these bell discs are crudely made and contrast starkly with the remainder of the instruments to which they are attached. These instruments are the most uniform in conicity and size of the whole group and it is hard to believe that a manufacturer who carefully and deliberately constructed such precise tubes would clumsily dash off a pair of discs like these. Unless that is, the precision of the tubes was either an end in itself or was designed to achieve a particular acoustic effect. In this case, the aesthetic impact of the bell disc would be largely ignored, care being taken to ensure that, metrologically speaking, the instrument's air-column was correct.

Manufacture of the Bell Yard

As the lurs were by this time, being held by the tube yard or quite low down on the bell yard this had become a highly stressed part of the instrument so the tendency to use a cast-on ferrule to join segments of the tube had become fairly general. This was not so, however, with the bell yard and the meander joint continued as a constructional feature in some areas. In others, however, attempts were made to replace it and the use of a large cast-on ferrule was, most likely, rejected because of the effect of additional weight high up on the instrument rendering it less manageable and creating a greater visual impact when held above the head of the player. Instead a thinner, narrower ring was cast-on around the two tube ends and, as a joint on the bell yard only carries the weight of that tube above it, appears to have been successful. That the technology was available for exploitation in those areas where the meander-joint continued to be used cannot be doubted as one instrument from Radbjerg (SD116) has both joining techniques present on the bell. No doubt, the cast-on band represents a repair, on this instrument, but it is, nevertheless, both extremely well formed and well cast and such a successful repair could well give impetus to the use of this technique generally. However, in this area of southern Denmark the meander-joint continued to be used, while in the island of Zeeland the use of the cast-on band seems to have been more generally adopted. With this new technique, the distinction between decorative and functional usage of the segment junction disappeared. Such instruments as use this technique, therefore, have bands which are both decorative and serve to link together segments, whereas the band on the Radbjerg instrument simply replaces one of the double band-space-double band decorative elements, the meander-joints remaining between these.

When adopted initially, this cast-on band appears to have been a fairly simple added ring such as is present on the Garlstedt instrument. Among this very fragmentary material is a cast-on boss with the ends of the two adjacent tubes. On the inside of the tube is material that has flowed into the tube, possibly unintentionally, nevertheless helping to key in the cast-on part. (Figure 4.27)

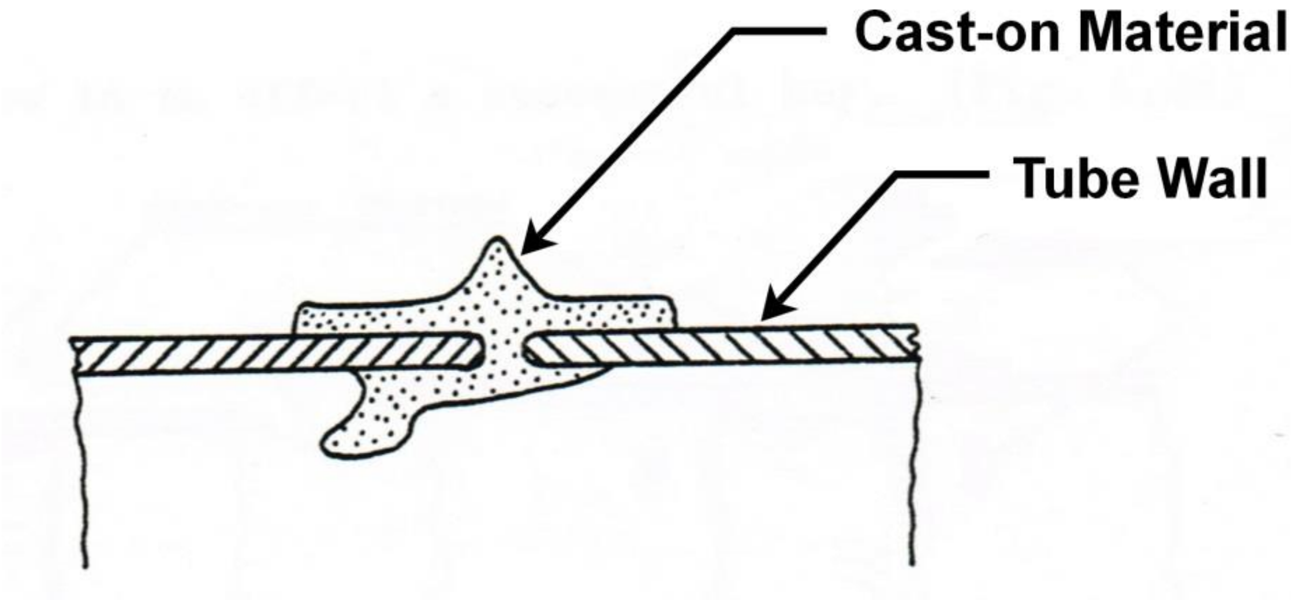


Figure 4.27: A Cast-on Joint on the Garlstedt Lur

A further instrument fragment from Northern Germany, a piece of bell yard from Hof zum Felde, has two cast-on bands. One of these is in the form of a simple fairly thick band, simply decorated by means of circumferential double scribed lines. At one point around the circumference, a portion of this tube is missing and the edge formed at this point has been decorated by means of notches at about 1*mm* pitch. However, as these notches are normal to the outer surface of the tube, they could not have been cut into the finished bronze ring without marking the tube's surface. It seems probable, therefore, that they were cut into the wax formed around the tube as a pattern. At this stage the maker, presuming he had a supply of wax, could, equally well, have built up the rest of band to correct this error. A further rather crude piece of workmanship is seen on the other band. This is apparently a repair and much abrasive working can be seen adjacent to it. The band itself was formed from a profiled strip of wax that was wrapped around the tube, presumably at the break or desired junction. However, no attempt was made to butt the two ends of the band neatly and the excess length of strip was simply wrapped over, Thus, over a portion of the circumference two thicknesses of strip together form the band. From the shape of the overlapping portion it appears that the strip had been pre-formed into a suitable cross-section, prior to wrapping around the tube.

In addition on the Garlstedt instrument is a peculiar joint, unique among the lurs, where a 4*mm* axial length of tube was cast-on, being held in by an internal annulus of material in the bore. It is clear from this that the maker did have a measure of control of the core dimensions to leave the space for metal to flow in to effect a successful key. (Figure 4.28)

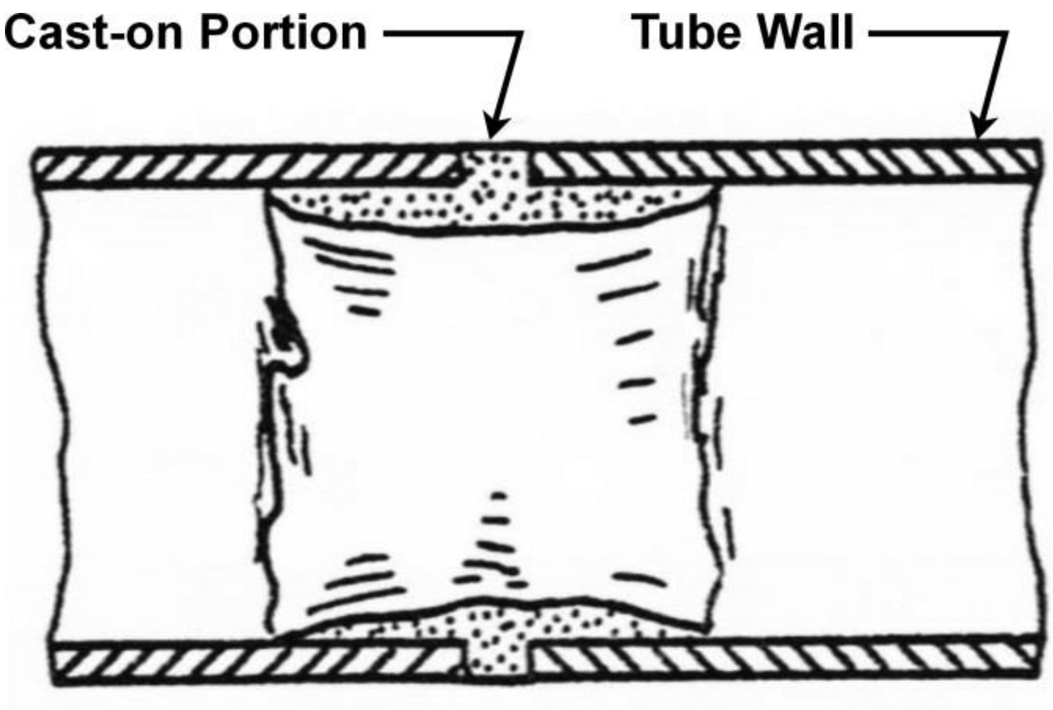


Figure 4.28: A Cast-on Portion of Tube on the Garlstedt Lur

A slightly more-elaborate version was found by Schmidt on the Daberkow instrument.[181] On cutting through the tube of this he found the cross-section as shown on Figure 4.29 and Plate 4.3(b)). Schmidt considered that the casting-on process had utilised the flowing bronze to heat up the tube ends to their melting point and hence attain a welded-joint structure.[182] In addition, slots had been made around the circumference of the tube, Schmidt claims by chiselling, and these produced depressions into the bore normal to the axis of the tube. (Figure 4.29) Similar features are present on both the Borgeby and Langlots Norregård instruments but on these, the slots are more numerous and in one case can clearly be seen to have been filed in[183] although Oldeberg, too, says these were "punched in." (Op. cit. 72)

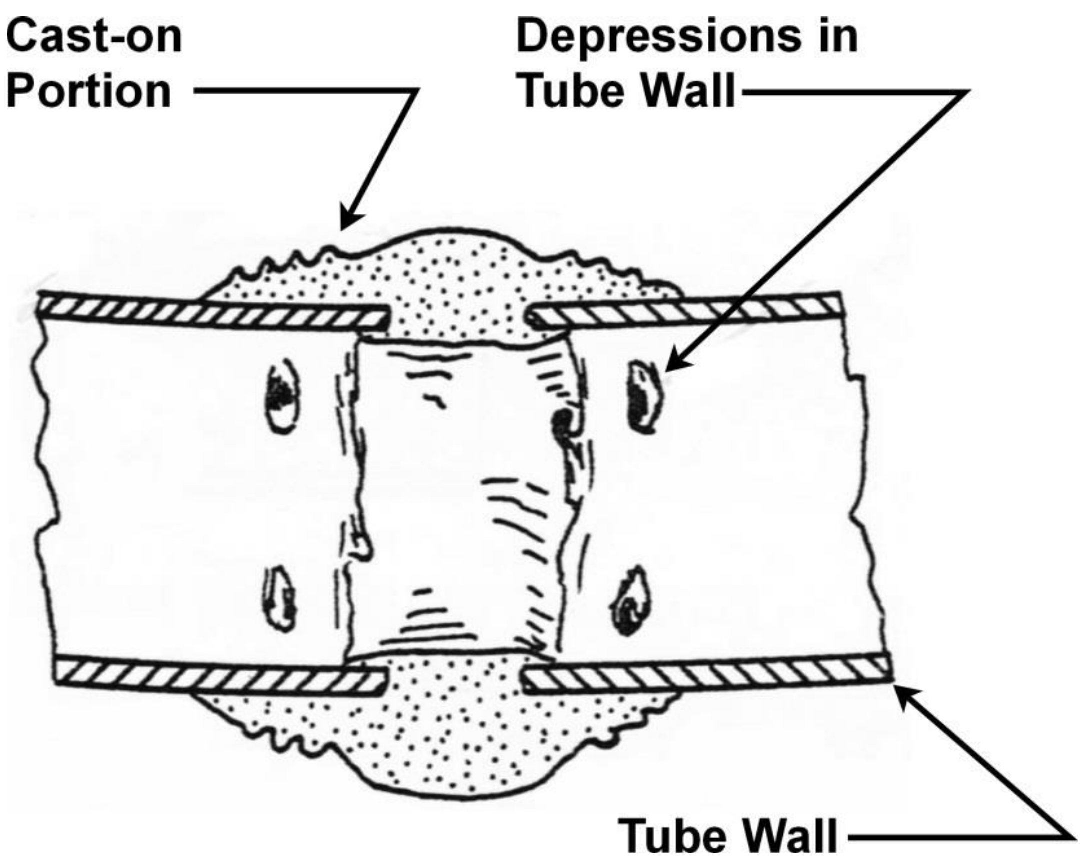


Figure 4.29: A Cast-on Section on the Daberkow Lur

[181] Schmidt, 1915, 100.
[182] Schmidt, 1915, Abb. 5, Abb. 39.
[183] Oldeberg, 1947, Fig. 53.

A lur fragment from Rossum in Norway shows a further refinement in the technique adopted to get a better key between the added material and tubes to be joined. In this, the end diameter of each tube was reduced and four holes were drilled around the circumference of these. Then, according to Oldeberg[184] the two ends were brought together, the bore filled with clay to form a core, the annulus formed filled with wax and then invested and cast in the usual way. (Figure 4.30(a).

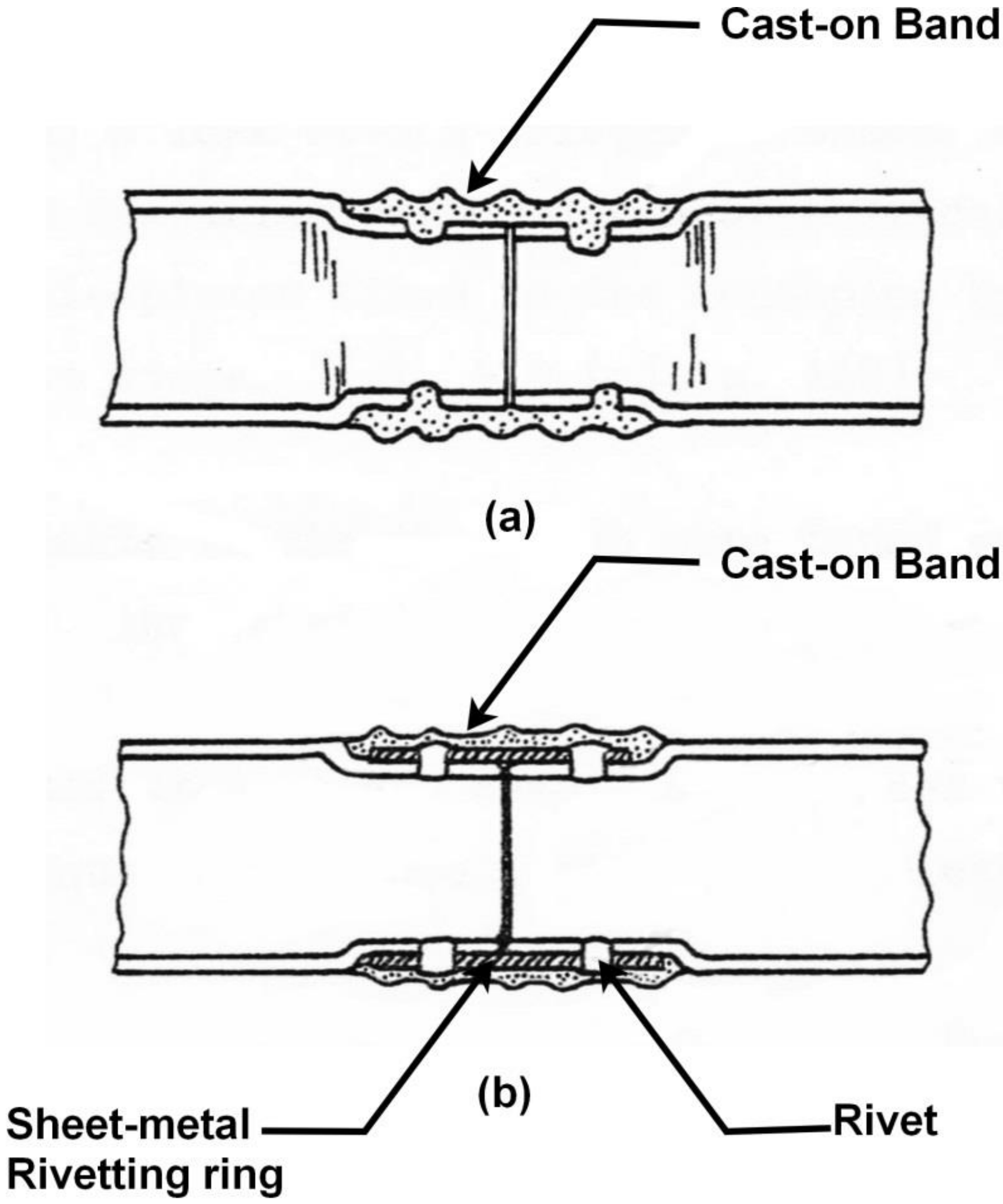


Figure 4.30: A Joining Structure on the Rossum Lur Fragment

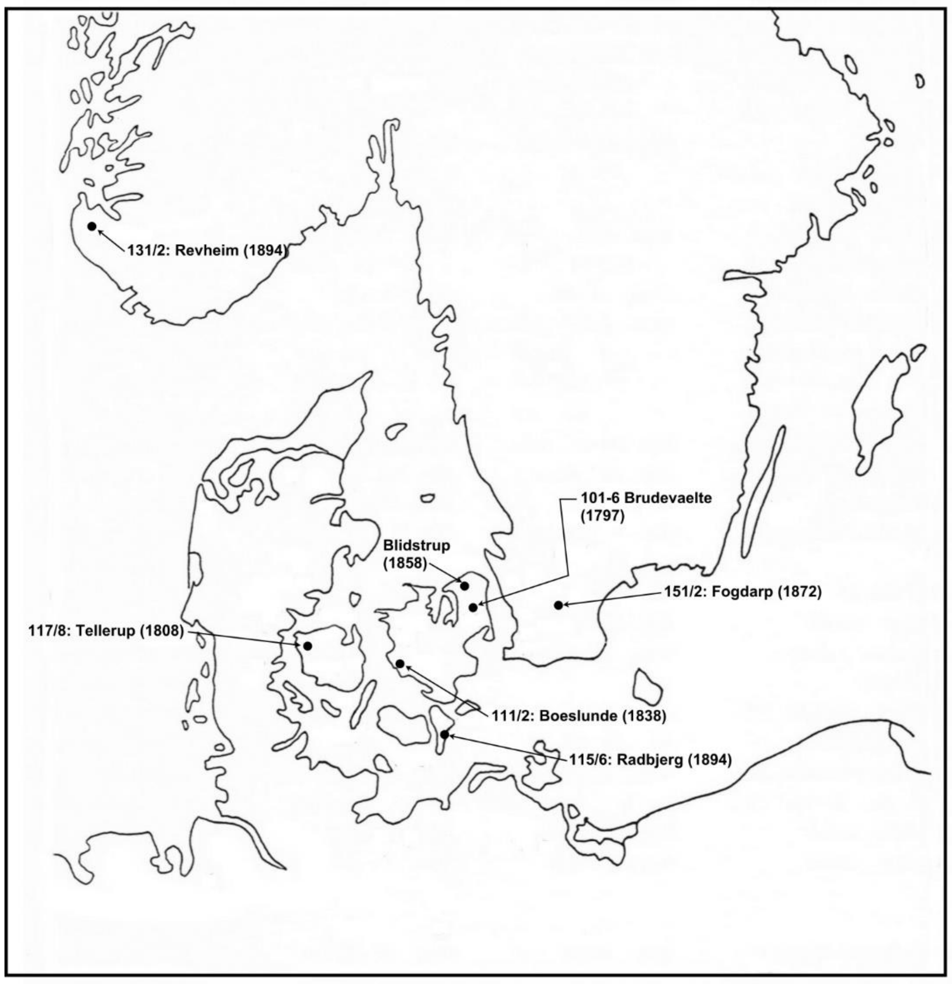
However, the bore of this joint shows no flowed-over metal either in the gap between the tube ends or around the filled-in holes. In fact, the end faces of the tube can be seen quite clearly and a considerable gap is visible all around the outer edge of the material that fills the drilled hole.[185] It appears, therefore, that the four holes on each tube end are filled by rivets which were fed through from the inside of the tube and then peened over onto a band that was wrapped around the sunken annulus. A wax ring was then formed over these with the meander decoration formed on its outer surface and this was then invested and cast. (Fig, 4.3(b)).

[184] Oldeberg, 1947, 60.
[185] Oldeberg, 1947, fig. 40.

On the island of Zeeland, a fairly uniform design of instrument emerged that incorporated many of the developments described above, these here being called the Zeeland group. The standard instruments of this group, all have a slightly hemispherical mouthpiece (trombone type), a mouthpipe joined by cast-on or added ferrules, a lock with a triangular tenon, a separately cast bell-disc featuring pronounced hemispherical bosses and a number of rattle-plates fixed to the mouthpipe by means of integrally cast rings. (Plate 4.3 (a))

The Brudevaelte Lur Pair

Of the instruments in the group, ten were found on the island of Zeeland itself, the remaining six being very widespread (Map 4.2). However, in spite of this group having a large cluster of similar attributes, there remain differences that, expressed in terms of sequences produce a conflicting picture.



Map 4.2: The Distribution of the Zeeland Group Lurs

The lurs in this group can be roughly sub-divided into one group with meander joints in the bell yard and the other with the cast-on bands joining tube units together. A further sequence can be constructed based on the complexity of bell disc decoration. (Figure 4.51) This figure places the simplest bell disc decoration first and, hence, places Brudevaelte (SD101/2) before the Boslunde instruments, i.e. contrary to the yard construction sequence.

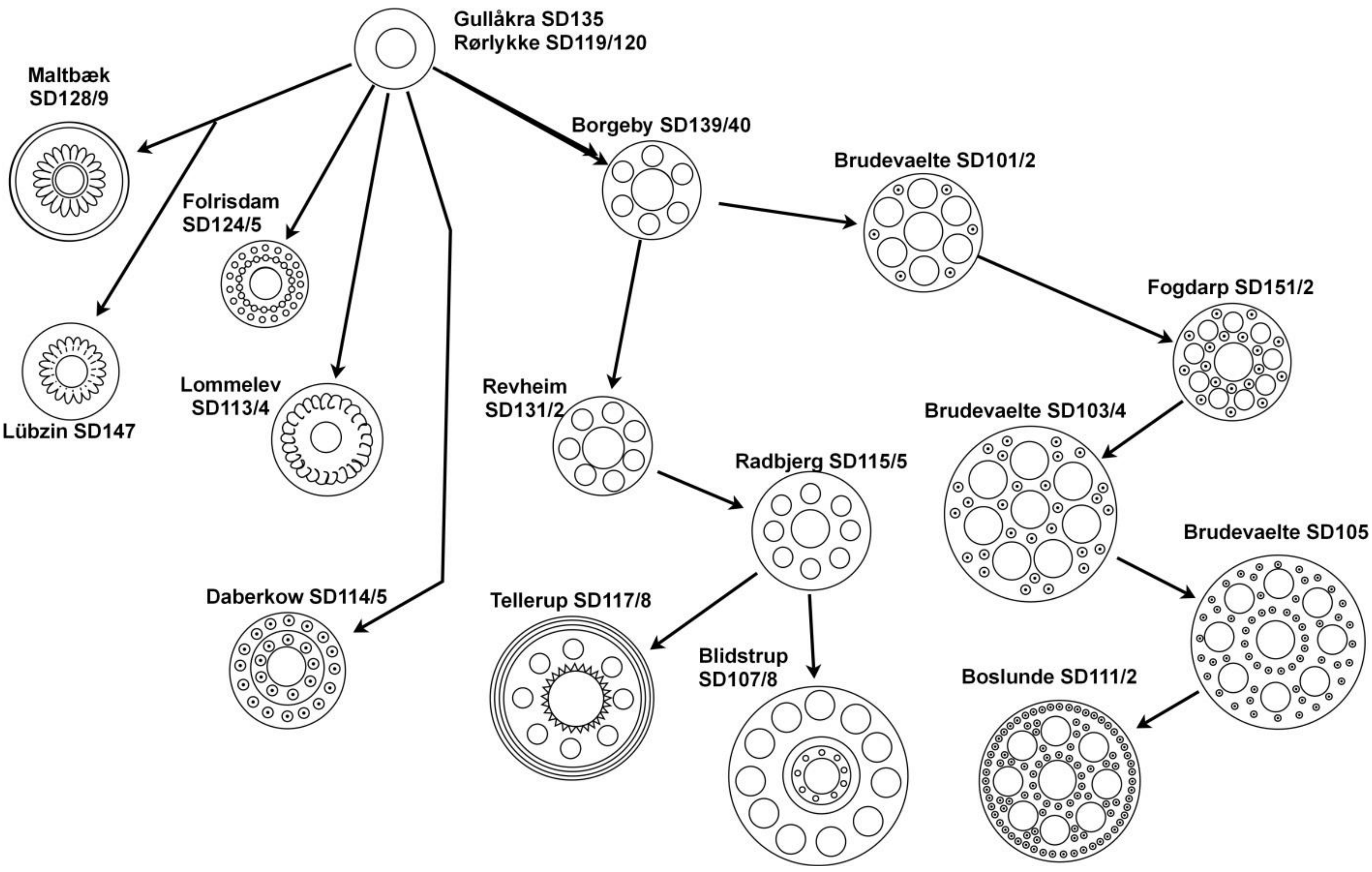


Figure 4.31: Bell Disc Designs

BELL-DISCS OF THE ZEELAND GROUP

The characteristic feature of these bell discs is their large domed bosses which stand forward of the disc surface. On the simplest of these, on the Revheim instruments, these are something less than true hemispheres and although round, variations in roundness can be detected by eye. These are the only instruments on which these hemispheres stand on a plain background, all other bell discs in this group being surrounded by a rim. (Plate 4.6 (c))

Plate 4.6(c)

These later discs also have larger bosses whose size necessitates their separate manufacture, i.e. they can no longer be produced from sheet wax by pressing through as this would cause too much thinning of the material. Instead, they must be made separately and then added to the disc proper.

The most elaborate of these bosses, on the Boslunde instrument, have a form that protrudes even more than a hemisphere and is shaped rather like the sharp end of an egg i.e. ovoid. However, measurements taken of the diameter of the complete bosses (the bell disc is rather fragmentary) are tabulated on table 4.4 and show these to be very round. These figures show a mean value of boss diameter of 50.58*mm* with a variation on this mean of +0.32, -0.68*mm* or expressed roughly as ±0.5*mm*. This suggests very strongly that these bosses were made using a forming tool, thus producing them to a given standard.

Boss No.	AZIMUTH (Degrees from vertical, clockwise)					
	0	20	45	90	135	170
1	50.30	-	50.75	50.90	-	-
2	50.60	-	50.70	50.70	50.85	50.70
3	-	50.60	50.50	49.00	-	-
4	-	-	50.80	50.50	50.90	50.90

Table 4.4: Diameters of the Bosses on the Boslunde Bell Disc

On only one of the bosses was it possible to measure five stations and this gave a value of diameter = 50.71, +0.14*mm*, -011*mm*. If this is a true measure of the roundness of these bosses then the tool that formed these was clearly manufactured by a generating process probably on a lathe.

The value of ± 0.13*mm* quoted above is the product of several stages of manufacture, during each of which degradation of the roundness figure for the former would have occurred. Thus, the original tool is likely to have been much rounder than this.

From an aesthetic point of view it is the front surface of the bell discs that is important. Thus, the wax used in forming the pattern was pushed into a female mould to form this surface accurately. This mould was most probably expendable as it would be impossible to remove a fine wax sheet from a mould of the depth seen on these bosses.

A further element of decoration was added to later instruments, the standard form of this being a circular pip with concentric circles around it. On Daberkow and Brudevaelte SD101/2, two concentric circles surround this pip while on some later instruments such as Brudevaelte SD105, and the two bell discs found at Fogdarp, three concentric circles are seen. (Plate 4.7 (a)) These latter discs, found in 1972, were studied by Lars Larsson who measured the concentric circles on these and concluded that they too had been made by means of a die as they "coincide within one tenth of a millimetre" (Larsson, 1975, 184).

Plate 4.7(a): The Concentric Circles on the Fogdarp Bell Disc

A bell disc, cast in bronze, is a relatively strong item, additional strength coming from its three-dimensional form i.e. the bosses. This is not true of the wax pattern for such a disc, however, and, on this the protrusion of the boss is a distinct disadvantage because of the low strength of the wax. The smith of the Bronze Age, when producing thin sections generally formed them onto a surface and thus never handled the delicate wax patterns as such and this is probably how bell discs were made too.

Starting with a piece of clay this would be rolled to produce a flat surface and the basic geometry of the disc scribed on this. The punch, with the male form of the boss turned onto it would then be pushed into the clay at the appropriate points. The second punch, with the pips and concentric circles on would then be pressed in to form this secondary decoration. Any other features such as the circumferential re-enforcing rim would then be cut into the clay and the whole surface of this finally cleaned up to a satisfactory state. This would then be left for a week or so to dry out thoroughly and to harden. Once hard, circles of wax would be warmed and, when soft, pressed carefully into the large boss cavities, these would then be left to harden off.

Meanwhile a circle of wax sheet would be cut out to the maximum diameter of the bell disc and the position of the large bosses marked out on these. Having been produced using dividers of some form, these scribed lines remain as incised evidence in the rear of some bell discs. (Plate 4.7 (b)) Circles slightly smaller in diameter than the bosses would then be cut out in the appropriate places and the circle of the appropriate diameter removed in the central part of the disc. This sheet of wax would then be laid over the clay mould, lining the holes in it up with the bosses beneath. These bosses would then be welded to the disc of wax, where necessary adding a filler of wax rod. The small concentric circles would then be impressed into the front surface by pressing the wax into them, possibly using a hot spatula. Surface features on the rear of the disc would then be added by welding these onto the tip of the disc. After allowing the wax to harden the whole assembly would then be invested in clay, probably a heavily grogged one to minimise shrinkage, and the necessary runners and risers provided in this.

Plate 4.7(b): Scribed Arcs on the Rear Face of a Bell Disc

Several bell discs have features which correspond with having been made this way such as evidence of the weld around the edge of the boss. On others, hooks or eyes are cast integrally with the rear face of the disc indicating that this was accessible at some stage of manufacture to enable these pre-formed features to be added. (Larsson, 1973, Figure 11)

This specialised technique for manufacturing bell discs was practiced principally on Zeeland and perhaps in Scania. However, in other areas the large bosses do not appear at all. On the Daberkow instruments, pips with concentric circles around the bell aperture, completely fill the disc. (Figure 4.1) On the Island of Funen,on the Tellerup instruments, a more complex method of fixing the bosses to the disc was utilised, perhaps resulting from failure when casting bosses the Zeeland way. On one of these instruments the bosses were cast separately and provided with two eyes on the edge of the boss. This part of the boss was then fed through the aperture on the disc and a pin wedged through the eyes to secure the assembly (Plate 4.9 (a)).

Plate 4.6(d) The Front Face of the Tellerup Bell Disc

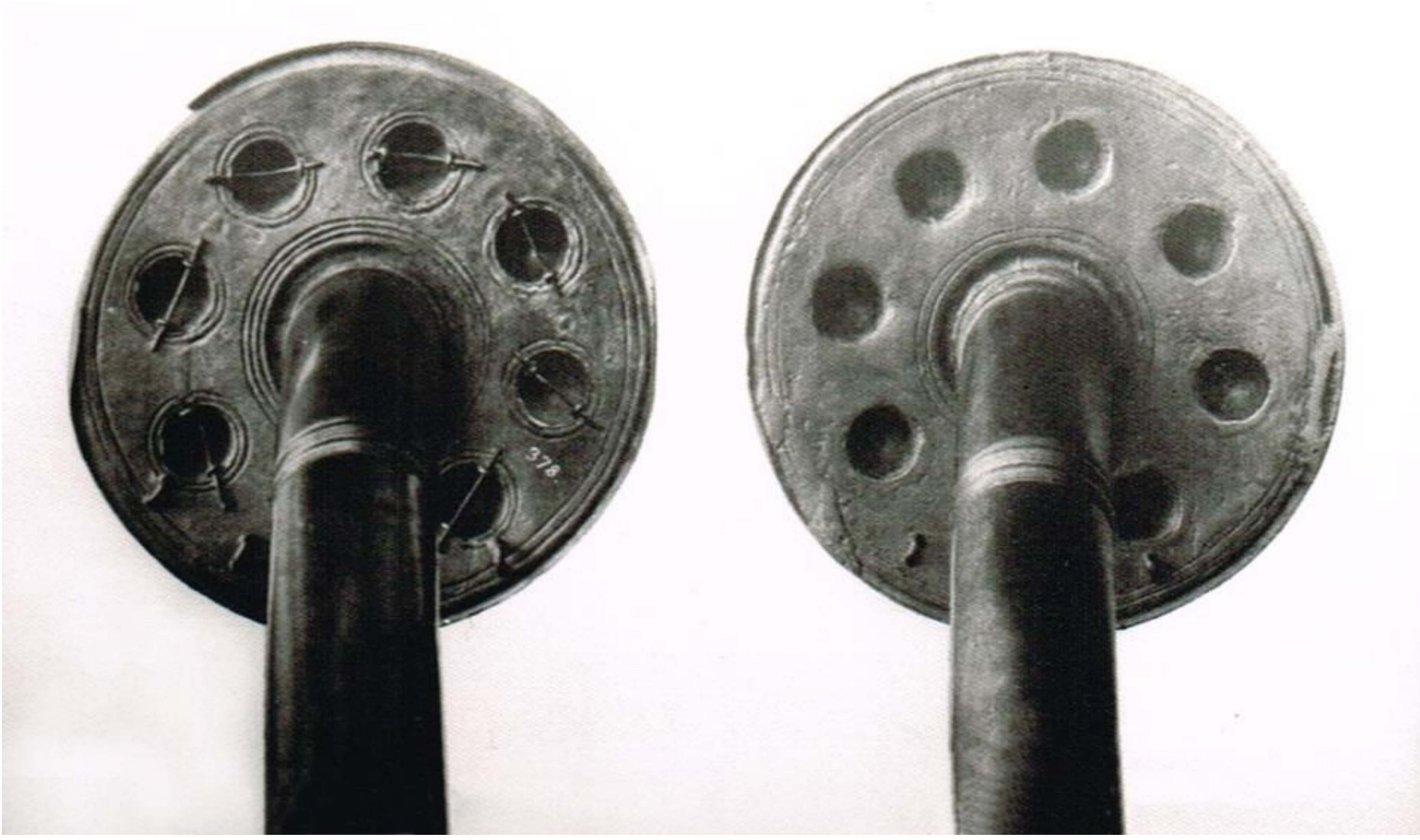


Plate 4.9(a) The Rear Faces of the Tellerup Bell Discs

These bell discs were clearly influenced by the Zeeland group but have other features more typical of other instruments from that region. The main one of these is an engraved wedge-shaped pattern around the three concentric corded circles that enclose the bell aperture.

Requiring as they did, a manufacturing technology somewhat different from instrument tubes, the lur bell discs could well have been made by different makers. The technical processes involved in the manufacture of a bell disc required precision but were much more similar to those of the general bronze worker than were those involved in the manufacture of tubes. In the case of the Folrisdam instruments, for instance, the bell discs and tubes are markedly different in their quality of manufacture. The Fogdarp find, although it is the only find of discs alone, is another indicator of separate manufacture. Of the nature of this find, Larsson (1973) draws no clear conclusions but clearly, the presence of bell discs along with other bronze objects shows that at one stage they existed separate from the lur tubes. Furthermore, close examination carried out in this study revealed no signs of these discs ever having been placed on the bell end of a lur and certainly none of them having had the bell's metal peened over to retain them, Whatever the nature of this deposit, therefore, these discs were probably in transit, having been made but not used.

AN OVERALL APPRAISAL OF THE LURS

There is little doubt that the lurs are PVAs of a sophisticated type deliberately made in pairs, to match acoustically. This they do remarkably well, the written notation for the pairs Brudevaelte 101/2, 105/4, Tellerup 117/8, Folrisdam 124/5 and Maltbaek 128/9 being absolutely identical. In addition to this Brudevaelte 103/4 and 105 match together, producing the tones shown on Figure 4.51. The actual frequencies of these tones are shown below the stave, indicating the very close similarity between all three instruments. (All frequencies in Hz).

SD103	-	77	-	153	234	317	394	477	549	632	700	790
SD104	-	75	-	150	226	307	391	466	550	634	700	794
SD105	-	79	-	153	229	312	409	-	573	-	723	822

Figure 4.: The Notes Produced on the Brudevaelte Lurs

These instruments plus, presumably, Brudevaelte (106) could have performed together with no difficulty, such deficiencies in tuning as exist being readily corrected by lip by an experienced player. The precision with which these instruments were made was most probably, a result of the desire for tuning of pairs and even pairs of pairs. Consequential on the uniformity of conicity on these instruments was the harmonic relationship between their formants. Such is the precision of this, that it seems most unlikely that the instruments were used other than polyphonically. "Wrong" notes played during unison

passages would produce re-enforcement of frequencies in their sound spectrum and, possibly lead to the use of harmonies deliberately produced in this way. The production of a range of notes on these instruments was favoured by the development of mouthpieces to a high degree. Their rim, cup and throat, all combined to produce mouthpieces well suited to the instruments to which they were attached. On the earliest of instruments such as Gullåkra, the facilities for blowing constituted little more than a mouthsupport, as on the Wismar and Teterow horns. This was progressively refined, however, to produce a conical, French-horn type mouthpiece. (Plate 4.8 (a), (b))

Plate 4.8(a & b): A Typical Conical Lur Mouthpiece

This itself then appears to have yielded to a type with a more spherical cup, the mouthpieces on the latest lurs, being very similar to those seen on modern tenor trombones. (Plate 4.9 (b))

Plate 4.9(b): A Typical More Cup-shaped Lur Mouthpiece

Most of the rock-carvings show instruments played in pairs and frequently in connection with, or on boats. (Plate 4.1(b)) This suggests some form of ritual in which the lurs were blown, perhaps to signal the return of a boat and procession from this to the sacred place. From what the boats return is hard to say but it seems unlikely to have been a raiding party as a pair of lurs would be the last thing to take on one of these. It could well have been a rite of passage probably a men's ceremony carried out at a secret place, away from the women. The return from such an occasion could well call for a solemn procession with the lurs playing their ceremonial part in this. The presence of pendants on the mouthpipes of many lurs points to their use on the move as these provide an ideophone accompaniment. Other workers have identified the dots on rock carvings as stars and suggest a calendrical association with the ritual. Taking place at night, this would certainly be enhanced by the lur's voice.

Tacitus, writing about 100 AD tells of a cult practice of the peoples of this area (Jutland and the Danish Islands) in which Mother Earth (Nerthus) was worshipped. In this spring-time cult, a wagon containing a hidden goddess and drawn by cows would process among the people. From the description, Tacitus seems to be describing a fertility cult held at the re-awakening of the year. (Larsson, 1973, 250) In spite of the 700 years or so that separate Tacitus from the Fogdarp bell discs, such a ritual could well be a survival of the ritual from earlier times, when the lurs were used in such a cult procession.

No lurs have been found in the vicinity of rock-carvings and it has been suggested that these instruments were not made to be seen by other than the initiated. This could account for the burial of many instruments, presumably between one ritual use and the next.

In the case of the Brudevaelte instruments, for instance, the contemporary report of their finding states that "instead of the horns lying in pairs the mouthpieces were found together, and here traces were found that seemed to indicate that same must have been tied together with a triple-braided rope."[186] The pendants on Långlots Norregård instruments were "wrapped up with a band of bast-like material, which is still there, together with fragments of birch bark," (op. cit., 32) and on the mouthpipe of the Maltbaek instrument were found the "remains of a winding of a bast-like material."

It has been suggested the lurs found in such burials were deposited as votive offerings but this seems not to be so. Many were found disarticulated and carefully placed together, frequently where the peaty sub-soil met an underlying clay stratum. This was the case in Stavanger where a pair of lurs were found near the entrance to a natural harbour. Although it is possible that this area was marshy during the Bronze Age there is no other evidence in this area (Rogaland) for votive offerings.

Against this idea of their secret use is the fact that many rock- carvings depict lurs. This could be accounted for by local variation in custom and perhaps change of custom with time. Only on Zeeland do the latest type of lurs appear on rock-carvings, i.e. those with bell discs. It could be, therefore, that only in this area did the ritual permit the uninitiated to see the instruments. If this is so then a further explanation needs to be sought for their burial here - perhaps it was simply a case of protecting them against marauders.

The dimensional analysis of these instruments has shown that they developed as precision products, manufactured with what would appear to be clear organological aims, i.e. the production of harmonically related formants. For the user to formulate this design requirement, he would need to be a sophisticated performer and hence, to practice on the instrument. Many features serve to re-enforce this view, from the development of mouthpieces to the uniform conicity of the instrument tubes. The lurs, therefore, must appear to the modern performer as instruments not only made to be played but made to be played well. They seem almost as far-removed from simple ritual sound producers as one could imagine. When their performance involved the use of pairs of instruments, this would call for serious and concentrated practice of the performers. Such a pattern of usage would hardly include a period of burial of the instrument as the users of these would, most likely be specialised in this role and, hence feel that they had a distinct proprietorial interest in them.

It is clear that a school of craftsmen developed manufacturing technology very specific to these instruments which was capable of production to a close tolerance. In the process of this they appear to have adopted or developed such features as the plane surface, the lathe, the straight edge or the technique of using a taut wire/cord and spacer to form a straight edge. Whatever the techniques used, they were deliberate, with a deliberate aim. What has been lacking in this study is information on tube wall thickness as no equipment was available to measure this. This situation may well have changed now, as ultrasonic inspection equipment now appears to be available to measure this to the required

[186] Broholm, 1947, 16.

accuracy. The value of this information is clearly considerable as measures of the outer diameter of a tube-wall contains error both from the out-of-roundness of the core and from errors in wax sheet thickness. Values of wall thickness would enable these errors to be separated and valuable - information on manufacturing techniques to be deduced.

The span of usage of the lurs is variously quoted, generally being considered to be between 1500 and 500BC. However, no lurs have been found in contexts that allow precise datings, although the Fogdarp find gives some indication of a date. These discs are dated by Larsson[187] to Period V which by comparison with other recent datings he identifies as between 900 and 600BC. Many questions remain to be answered about the relative chronology of the lurs, however, in particular with respect to the rate of their development from simple forms such as Gullåkra to the complex Zeeland Group. Conventional dating would suggest that this process took some 500 years or so and was, thus a very slow developmental process. However, it has been suggested here that developments that took place with the later instruments were deliberate and resulted from directed effort by the maker or user. If this were so, then the time-scale for significant development could be of the order of a lifetime and hence, much more rapid than conventional dating would allow. Just when development changed its pace from serendipitously-sourced change to change of a deliberate nature is hard to determine but it could well be that for the majority of years during which development took place it was only chance development. If this is so, it is hard to see why so little remains of the early material unless this was scrupulously recycled as a scarce commodity, all bronze being imported from the South. Thus, the lurs may have existed for the thousand or so years generally suggested but with development proceeding at an exponential pace with the Zeeland group developing in only a generation or so from earlier instruments.

Among the remarkable features of this group, is the dimensional stability of their form. It is clear that more than visual perception was used to store the information and it seems likely that units of measurement were used as a basis for these standards. Much more work must be done on the lurs to investigate this phenomenon, if they ever become available for study again.

Quite dramatically, at the end of the Bronze Age the lurs ceased to be made. Instruments from this area during the Iron Age utilise the animal horn in their construction. One of these, SD249 from Stenstugan is made from an animal horn with wrought fittings and appears to lack a developed mouthpiece. The other two instruments, SD271 from Konsterud and SD272 from Sandbacksmyen, are both cowhorns with integral mouthpieces and five and four finger-holes respectively. All three instruments represent a considerable change from the tradition that led to manufacture and use of the lurs.

Many factors could have led to the demise of the lurs and it is hard to assign orders of importance to these. Above all, however, the lurs were cult objects and changes in the cult could well have brought about a lack of demand for their use, or perhaps even a prohibition. More prosaically, a lack of bronze, the basic raw material of the lurs, could have brought about a scarcity of instruments and, hence, an accommodation in the ritual

187 Larsson (1973, 169 ff.

to suit. At their peak, during the time of the Zeeland group, the lurs had a very stable and consistently made form and this manufacture could well have been carried out by a small group of smiths on the north of this island. They would have developed and refined the manufacturing technology, passing it on from father to son. ln this way, the development could proceed rapidly but was very liable to be upset by any development which disrupted this group. Any attack from outside, in destroying this school of manufacture could, in effect, destroy the Zeeland group. Perhaps the group of six lurs found at Brudevaelte (SD101 - 6) represent the attempt to preserve these in the final stages of this group's manufacturing activity.

Whatever happened, by the close of the Bronze-Age, lurs were no longer made in Scandinavia and, presumably, no longer used. The death of the cult may have required the burial of the sacred instruments, perhaps in some form of ritual, preserving for us a sample of the latest of the line. Scandinavia then settled down to producing simpler finger-hole horns which offered the potential for melodic performance and were similar to those still made today in that area.