

NOTES ON THE STEERING DEVICES OF ANCIENT SHIPS

Our basic knowledge about steering by means of multiple or lateral devices like the ancient πηδάλια or *gubernacula*, or Medieval *temones*, can be developed from the study of the better known examples, no matter how recent they are, in order to ascertain which are the basic principles and to set up a correct classification pattern. So the study of classic steering devices can be undertaken with correct physical principles and with an experience which hopefully let us understand similarities, differences and technical needs.

Lateen medieval ships carried *temones* which, according to figurative and written documents, appear to have been quite large; they were leaning against a jock and were suspended by means of a rope, or of tackles, if the *temo* was larger, and in this last case a second leaning point

was available. The aim of the rope or of the tackled was similar: the *temo* was a heavy instrument, so it had to be hanged, secondly there was the need to lift the blade in order to diminish the immersed surface, or to avoid damage against the sea bottom or when in harbour. The *temones* in some Italian harbours had to be removed, or anyway for removing the *temo* suspension ropes or tackles were necessary. In Fig. 1 Instances from Tuscan school of sculpture are proposed: Bonino da Campione and Giovanni di Balduccio, XIV Cent, but many other examples (mosaics of S. Mark in Venice) show the interest to keep the immersed portion of the blade under control. The manoeuvre of the *temo* consisted therefore in:

- rotation around the stock by means of a tiller;
- rotation around the joke (in some cases of smaller ships) to lift more or less the blade;
- immersion at different stages of the blade, in order to correct lateral displacement of the ship; in case of bowline navigation, different immersions of the two *temones* could be of help.

Therefore the *temones* functioned also as lee-boards. The upper part is less clear: in some improbable instances it is handed like an oar; in many cases a tiller is evident for each *temo* and the two tillers are worked from an upper deck of the *paradisus* by a single man. In one case (Ottaviano Nelli at Gubbio, about 1450) there is a single tiller for the two *temones*. These elements can be completed by a selection of written sources, which define uses, proportions and behaviour:

1 - From Francesco da Barberino, *Documenti d'amore* (IX)

*Doc. IX: Se bisogna scampare,
 l'un timon leva suso:
 l'altro leggier tien giuso.
 Ma convien levar mano,
 non mica com soliamo,
 ma per contrario: e face
 così il guidar verace.*

2 - From the *Statuti* of Rimini, XV cent, recalling previous rules.

R. 217: Statutum et ordinatum est quod nullus habens navem in portu Arimini debet retinere temones in sua navi ultra unam diem postquam fuerit in portu...

3 - From the Venetian manuscript *Fabrica di galere* (1410), *nave latina*:

... (Fig. 1,D)

E vole essere el timon de questa nostra nave el terzo de rio che la longheza de la cholumba, sera adoncha passa 4, el scharon sera passa 2, el fuso passa 2 e de volzer la lagola pedi 1 per passo de la longheza del timon: sera adoncha pedi 4.

E vole esser larga la pala de questo nostro timon tanto quanto volze el timon a la gola, serano doncha pedi 4.

E vole esser longe le mize tanta quanto è tuto lo timon longo, seran adoncha passa 4, & per questa fami ogni altra raxon.

4 - Leon Battista Alberti, *De re aedificatoria* (ab. 1450) Lib. V, c. XIII:

Temonum numerus navi auget firmitatem, minuit velocitatem.

Starting from early XIV cent., single rudders pivoted around the sternpost were introduced in the Mediterranean, with a consequent change of the shape of the stern area, in terms of

surface to contrast lateral displacement (in Italian *deriva*) more than in terms of volumes, although this was not solved in the same way throughout the Mediterranean. In fact in Venice, still in the XVII Cent. The *timon alla faustina* was in use (Fig. 1 E): a remembrance of Medieval round sterns when there were two *timones*.

Lateral steering devices were kept in conservative areas, where exigencies for speed were not so important as those of *firmitas*, quickness of manoeuvre or good steering in shallow waters with wide boats. So until the 50's of this century multiple and side steering devices were used in some traditional crafts of Italian lakes and rivers. They had the same design and functions of their Medieval ancestors and in 1967 I was lucky enough to discuss this subject with a boat-builder of Lake Iseo, who probably is the last person in Italy who had personal knowledge of this type of manoeuvre.

Recent lateral or multiple steering devices in Italy were:

Steering oars (not taking into account steering made with normal oars without rudder):

Lombardy: *combàll* (Lake Como, Milanese canals), *nav/nau* (Lake Maggiore *mutajö* (Milan-Pavia canals).

Piedmont: *nau* (Lake Maggiore, Po).

Steering lee-boards:

Latium: *ciarmotta* (Tiber, before XIX Cent).

Emilia: *rascòna* (Guastalla, Boretto), *Nave* (Modena and Bologna canals before XIX Cent.).

Lombardy: *burcèla* (Milanese canals), *saràn* (Milan-Pavia canals), *barcù* (Lake Iseo), *gòndola* (Lake Come before XVIII Cent.).

Veneto: *burchio* (before XVIII Cent), use of *rascòna* from Emilian Po.

The short description of the manoeuvre of the *rascòna* published by A. Guglielmotti in 1889 can be completed with the information I could collect on the *combàll* and on the *barcù*. Unfortunately A. Cuglielmotti wrote during a period of purism common to many European languages, so his notes need some reshaping before translation:

There was one *timone* at each side, hanged to a stay by means of a binding, its blade was fastened with a *frenèllo* (rope or chain) and the *timone* was leaning to the *targone* (literally the *apostis*, but actually a hook or the joke) at the bulwarks. The tillers, which crossed each other, could be worked by a single man. Mechanic theories of angled levers, of fluids and of lateral displacement are consistent and add further details. If the blades are parallel to the centre line, they did not alter the course of the boat. If both blades were turned symmetrically to the same extent (by converging their fore edges) they slew down the headway without changing the course, but if they were manoeuvred by contrast, one parallel and the other angled with respect to the centre line, they compelled the bow to turn to the direction of the angled blade (the tiller was pulled, so the fore edge of the blade turned towards the centre line); the boat turned quicker, the longer was the brace and the wider the angle of incidence. Therefore in order to turn right, it was necessary to release the tiller of the left *timone*, so that its blade could follow naturally the direction of the stream, then it was necessary to pull the right tiller, so that the right blade hit the stream in such a way that the bow of the boat turned rightwards. These manoeuvres were well known by skillful sailors and were alive also nowadays on the boats of the low Po area; they cannot be understood by certain scholars... who would steer with the same angle of both blades. No! steering with side rudders is always by contrast, as

in F. da Barberino (see doc. 1) or in verse 1203 of *Orpheus, Argonautica*, where helmsman Anceus suddenly turns leftwards a large ship, by putting in contrast into the sea only the left rudder ((Σχαῖόν υπεγαλινός οἰήχιον).

In the last part of this passage it appears that A. Guglielmotti generalizes the manoeuvre of quick steering, also in case of any danger, such as that of stranding.

On Lake Iseo the side *timù* (*timone*, rudder, Fig. 2 C) was considered as a good device to assure a sure course to the large flat bottomed *barcù*. The boat could be up to 28 m long and carry 50-80 tons. The *timù* was applied to the side of the stern by leaning against a *rampi* (hook) of walnut root at the bulwarks; its stock was bound against a vertical pole (*omasi*, stay), where a suspension rope from the blade was fastened or arrived at a block. The suspension of the blade and the binding of the stock against the stay could be adjusted in order to have the *timù* more or less immersed, according to the state of the lake and to the load of the boat. After such adjustment the *timù* was manoeuvred like a normal rudder with its tiller. When the boat was taken in the dry for repairing it was necessary to take its rudder out, because it was so heavy that it could have distorted the stern of the boat. On the contrary when the rudder was immersed it did not give any difficulty of weight and of uneven lateral displacement.

The steering oar, such as that of a *combàll* (Fig. 2 E), normally was not manoeuvred alone, but with the help of one or two oars at prow, or simply pushing poles, mainly when boats were large. *Nau* (or *nav*) of Lake Maggiore had also lee-boards to help keeping the course, when the wind tended to be transverse, but this is a limited example. The long steering oar of the *combàll* needed a heavy counterweight (a stone) and was moved simply left and right; very seldom its blade was turned like that of an oar.

Ferry boats of the Po near Turin, which were made of twin boats (*nau*), had two rudders at the ends of the platform, between the two hulls (Fig. 2 D). They were worked like the multiple rudders of the ferry boats of the Strait of Messina of the beginning of this century and I could watch their efficiency while the ferry boat was crossing the river. Also in this case the two rudders worked by contrast.

Connections between the parts of the *timoni* were made normally with wooden pegs, with the help of metal stripes or of the lower horizontal wooden board composing the blade of the *timone* of the *rasona* (Fig. 2 B). This last item had two functions: preventing adsorption of water from the cut perpendicular to the fibers and to strengthen connections made of wooden pegs among the parts of the blade and with the stock. The blade of the steering oars of the *combàll* was only nailed to the stock without any mortise, sometimes with iron stripes or rope bindings.

These elements coming from the Middle Ages and our traditions can be completed with some physical principles, to approach the study of ancient πηδάλια.

The composition of forces exerted on a rudder of compensated type indicate that quickness and capacity of steering is proportional to (Fig. 3 C):

- surface of the blade,
- ratio between the surfaces of the blade fore and aft the centre of gravity,
- brace between the centre of gravity of the hull and the point of appliance of the force N (or T), or centre of gravity of the,
- angle of incidence,

— velocity of the ship.

If there are two side rudders, the above points can be affected as follows:

— the surface increases,

— the torque theoretically may double, but hydrodynamically there is a lower yield, because resistance and whirlpools affect negatively the forces N and T. Moreover brace a is shorter. Differences of angles a and a' make the forces not arithmetically addable. However the overall behaviour improves the steering capacity of the system, even though speed is diminished.

The single steering oar, such as that of the *combaj* (Fig 2 E) takes advantage of the increase of the brace a of the torque.

The effect of the surfaces of the πτέρυξ implies also their balance with the vertical surface of the immersed part of the hull, which contrasts lateral displacement. In ancient ships the shape of the stern was much curved, often fairly symmetric with that of the prow (Fig. 3 D), but in many cases not, because the stempost could have been almost perpendicular to the keel, or there was a cutwater or a ram (Fig. 3 E). The surfaces of the blades could have been effective to balance those surfaces, since they provided auxiliary surfaces to contrast locally or generally lateral displacement. We do not know which was the balance among the centres of sail, immersed hull (*carena*), surface contrasting lateral displacement (*deriva*) and of gravity, however it is clear that the surfaces of the steering lee-boards played an important role in it. In fact, for instance, when the cog was introduced in the Mediterranean, the stern had a small surface added (Fig. 3 F), in order to compensate for the lower surface of the rudder in comparison to the previous two side *timoni*. The mentioned difference between the *timone alla Faustina* and the *timone alla ponentina* (Fig. 1 E,F) is in the same background.

The volumes of the immersed part of the hull exerted another influence on the steering capacity. Larger volumes (Fig. 3 H) or rammed prows gave to the hull a reserve of buoyancy, which affected positively the trim and the tendency to bear up. But a larger volume, even with similar longitudinal section of the immersed part of the hull (*piano de deriva*), increased the resistance, but not that towards lateral displacement. Therefore a larger surface of the πτέρυξ of the πηδάλιον was necessary to keep a reasonable steering capacity and to reduce sagging to leeway.

By bearing in mind these principles and the functional differences mentioned above ancient steering devices can be catalogued in the following way.

Egyptian ships had paddles, oars and single and double steering devices. Double side rudders are documented already during the Old Kingdom, single rudders appear mainly in Middle Kingdom models and figures, but evidence of them is found from the VI Dynasty. Determinatives and words used to define steering devices are rather generic, however they are different from those which defined oars or paddles. Single or double side rudders had the same arrangements and functions as those described for our traditional *barcù* (Fig. 4 C,D and 2 C): all details fit well within a similar pattern as represented e.g. by Deir El Bahari reliefs or published by Reisner or by Landström.

Aegean crafts appear to have had a similar evolution from paddles (Cycladic craft) to single side rudders (Thera, Aegina, Jolkos, Pilos, Tragana, Melos, Skyros, etc.), to double side πηδάλια, sometimes coexisting with the single arrangement (definitive from the IX Century: Geometric, Cyprus). In these cases documents are more evocative than descriptive, so that it is necessary

to come to later times before identifying technical details with some chances of probability. Unless we transfer directly Egyptian typology to some of them (Thera, Aegina), which is not always possible, due to an apparently less rigidity of the systems of Aegean crafts, we have to come to Geometric and Attic figures before finding something sufficiently descriptive. As described in appendix, Greek πηδάλια appear to have been worked with a higher degree of freedom in comparison to the well fixed Egyptian devices, therefore the Greek helmsman had to work with a different skill, different also to that of the Italian traditional boatmen, since the κυβερνήτης needed to keep the οίαξ in his hand, but also to adjust more frequently or continuously the immersion of the πτέρυξ.

However a "fixed" system was known also by the Greek helmsmen, such as that of the Amathus terracotta ship at the British Museum, the rudders of which could be turned around the stock by means of the οίαξ and from time to time could be immersed more or less with vertical displacements and different fixing points of the stock (Fig. 5 A).

When the αποστεις was introduced (with the trireme) the πηδάλια were displaced to the back ζευγα of the αποστεις (Fig. 5 B), thus eliminating the rail system of the previous arrangement. With the new system the stock could rock around the ζυγόν and in the meantime it could be turned with the οίαξ. It is difficult to think of the possibility to diverge the bottom end of the πτέρυξ. The rocking movement was limited by a transverse frame above the main ζυγόν, so that the πηδάλιον could be put almost horizontally (as in Lindos relief), but not perpendicularly with respect to the floating line. It was necessary, anyway, to achieve a good balance, the importance of which can only be assumed and tested in physical tests.

Coming to pre-Roman and Roman documents, we still have single rudders and steering oars. The Novilara boats of VII-VI Cent (Fig. 6A) had a single steering device which was worked both as an oar and as a rudder with a small tiller and a counterweight. The Etruscan stele of Bologna (Fig. 6B) still has some Attic remembrances, however it is clear that the rudder is single.

The *caudicariae* of the Tiber (Fig. 6C) had a steering oar similar to that of our traditional *combàj* (Fig. 2E), and this is in line with the usual river crafts manoeuvres.

But generally Roman ships appear to have inherited the Hellenistic arrangement, as clearly shown by the first Nemi ship (Fig. 7A) and by figurative documents. As soon as the volume of the hull became larger it was necessary to increase the size of the πηδάλιον and consequently its weight. The Torlonia relief and the mosaic at the Antiquarium of Rome show that the blade was suspended to a hoist (Fig. 7B). Part 1 of the rope was fixed e.g. to the upper transverse frame and part 2, after passage through a block or something similar beyond the hole of the blade, could be pulled and fixed elsewhere in order to adjust the height of the heavy *gubernaculum*.

The stock had to be bound some way to the joke, otherwise the system was not fixed enough and written documents let us think that there were two series of bindings: one for supporting and one for adjusting the position of the blade. In the Acts (VIII-40): εἰων εἰς τῆν θάλασσαν, ἀμα ἀνέντες τᾶς εὐκτηρίας τῶν πηδαλίων, καὶ ἐπάραντες τὸν ἀρτέμωνα τῆ πνεοῦση κατεῖχον εἰς τὸν αἰγιαλόν, hint is made to loosening the bindings of the *gubernacula* in order to leave the blade follow the course of the waves without contrasting them, still with a minimum control of the course also with the ἀρτέμων. This could be possible by loosening the bindings of the stock against the joke, but by keeping the hoist in function, since we understand from the text

that the ship did not lose her *gubernacula*. Also Vegetius refers to similar bindings: (Re. Mil. 4-46) *secreto incidunt funes quibus adversariorum ligata sunt gubernacula*, and Theophilus' translation of Jerome (Epist. 100,14) describes the function of the tightening ropes and mentions the manoeuvre by contrast (*flectentes in diversum gubernacula*):

sicut enim gubernatores magnarum navium, cum viderint immensum ex alto venire gurgitem... spumantes fluctus suscipiunt, eosque prae obiectione sustentunt, flectentes in diversum gubernacula, et prout ventorum flatus et necessitas imperarit, stringentes funiculos vel laxantes; cumque unda subsederit, ex utroque navis latere laborantia clavorum vincla dimittunt, ut parumper quiescentia venturo gurgiti praeparentur; qui cum rursus advenerit, stringunt clavorum capita et palmulas dilatant, ut huc atque illuc scissis flatibus, aequalis sit utriusque lateris labor, et quod simul non poterat sustineri, divisum tolerabilis fiat.

This arrangement and manoeuvre can be extended to the cases of double steering systems: one at stern and one at prow. In a manner similar to that seen on traditional ferry boats, large ships like the Syracusia or the second Nemi ship needed another pair of *gubernacula* in order to make the manoeuvre quick enough or to turn the vessel more efficiently, as it was tested by Chabrias, according to Polyaeus (3.11,14): Θάτερα δια της παρεξίρεσίας κατά τας θρανίτιδας κώπας παρετίθει, τους αυχένους έχοντα και τους οίαχους υπέρ του καταστρώματος ώστε εξαιρομένης της πρύμνης τούτοις την ναίν κατευθύνεσθαι.

So we arrive to a situation similar to that documented for the Middle Ages and a direct link between Antiquity and oral tradition is indicated also by the relics of ancient technical words in our dialects. Mainly in Como Lake area we have remembrances of these words and this is consistent with the preservation of shell building technique. We have in fact:

guernàcc = *gubernaculum*, gouvernail, rudder

caviicc = *clavus*, tiller

penna = *pinna*, *palmula*, blade

In Sicily the tiller is *iàsciu* (οίαξ - οίαχον), a form which follows the history of this Greek word through Byzantine and neo-Hellenic languages. Similarly *temo* at an unknown time of late Antiquity was used to indicate the tiller (instead of *clavus*) and then it became the general name for the rudder in Italian languages. The intermediate phase of this generalization remained in neo-Hellenic τιμόνι, clearly derived from Latin (not from the Medieval *lingus franca*), referring to the tiller.

At this stage of the research we cannot say that the circle is closed: during the centuries some aspects may have been lost or other traditions may have complicated the picture. Norman ships from Southern Italy (from XII century) do not appear to have affected steering techniques in local traditions. German types from the Bodensee have some common features with the *barcù* of Lake Iseo: bottom frames are called *söi* (Säule), sails have similar bowline ropes. Ladi such as these of a XVII Cent. glass painting in Kostanz or a XIX Cent Model in Rorschach Heimatsmuseum had side rudders, but different from their Mediterranean relatives since they were hinged like doors, but we cannot exclude possible links.

The items discussed so far hopefully describe the main functions and needs of a manoeuvre like that of the ancient side *πηδάλια*. On this light the discussion given in appendix may be an example, but conclusions are still far from definite.

Appendix: hypothesis about the πηδάλια of the Kirinia ship.

The study of geometric and Attic figures leads to set some technical features of steering devices. The comparison with Kirinia ship is possible due to the peculiar similarity of the Attic kylix at the British Museum and of the almost contemporary Campanian askos (on Attic-like style) found in Spina (Ferrara).

- The stock is bound against the joke;
- it is well balanced around its bindings, with a long upper part and, in some instances (Fig. I,2), with a counterweight.
- it has a tiller.
- a particular rail of the stern supports the stock; in some cases the stock is enclosed by the rail (Fig. I, 2.5.6) and in other cases it is bound outside the rail (Fig. I, 1.4).
- vertical frames of the rail project outboard in the first case, in order to give room to the stock of the πηδάλιον, and this appears to be indicated also by the Etruscan painting of the Tomba della Nave in Tarquinia.
- In case the stock is bound outside the rail, vertical frames are just straight vertical, as in the Athenian bronze lamp from Erecteum.

Such arrangement, in the first case, has the following advantages:

- the stock does not need being always bound against the rail;
- the helmsman needs only pushing and turning the tiller, with little worry about the verticality of the πηδάλιον, since this last is kept by two points: the binding against the joke and the rail, with the help of the topgallant bulwarks when the οίαξ is pulled.

The waves could not push the blade against the hull's side, since the rail limited lateral displacements of the stock within a definite angle (Fig. II). The steering device could be pushed until the second frame of the rail and pulled backwards as far as the first frame allowed (Fig. II, 1). In addition to these, normal rotation round the stock was possible. In describing the movement of the tiller, probably Aristotle (Mech. 6) mentions one of the first two or both together, although he does not appear to have correctly understood the lever system of the oars (the fulcum is not the thole, but the point of immersion of the blade).

If the πηδάλιον is well balanced (a fairly easy thing when it is in water, but more delicate when it is outside) the above manoeuvres are not difficult, provided a good binding system is used. The bindings of the stock against the joke should be not too tight, to allow rotation of the stock and the other movements, but also not too loose, to avoid sinking of the rudder or undue lateral movements. This aim, according to some tests made on models, could be achieved with two bindings: one fairly loose, but heavy and strong, which I would define the main ευχητήρια and another, which could be a loop around the main binding, which could be made of a thinner rope, adjusted by the helmsman according to the manoeuvre he had to perform.

So, when the helmsman thought that the immersion of the blade was correct to adjust lateral displacement, he could bind the stock against the rail, tighten a little the loop around the main binding and make rotatory movements of the tiller. If more complicated manoeuvres were needed, he could loose the binding against the rail and the loop around the main binding and trust partially on his forces to avoid undue sinking or lateral movements of the rudder. If the system was well balanced and the main binding not too loose, the helmsman's work should not have

been too hard even in dramatic events.

The results of the study of the items discussed above are given in Fig. II, where a re-shaped stern of the Kirinia ship is proposed.

A wood fragment found in the Kirinia wreck has been first interpreted as a part of the πτέρυξ of one of the πηδάλια. The following actual features can be observed (Fig. III):

- three mortises for tenons are present, only one of which is passing, the other two being blind and on the same side;
- one passing square nail;
- a rabbet in one of the longer parallel edges;
- two wooden pegs on the same edge of the rabbet;
- two parallel scarfs on both faces of the end part of the board, which is obliquously cut.
- one wooden peg near and parallel to the passing tenon;
- the board is 7 cms thick and is made of oak.

All above indicate that:

- a second board was joined by means of the rabbet and the two wooden pegs;
- metal bindings, a double series of bronze stripes, clamped the two pieces together, with a characteristic angle;
- on one side a longitudinal piece of wood was connected with three tenons, one peg and one nail;
- on the opposite side another piece of wood was connected with one tenon (the passing one), the peg and probably the nail; this had a different joining system if compared to the other, a little looser; we cannot exclude that metal bindings could have held also the superimposed pieces of wood;
- it can be assumed that the second board could have had a size similar to that of the first and a similar end angle.

By connecting these elements and comparing them with that has been discussed so far about steering devices, we should exclude that this part belonged to the πτέρυξ for the following reasons:

- the piece is too thick;
- connections with other parts could support relatively low stresses;
- connections with other parts have different structural solutions on the two faces of the board;
- connections between the stock and blades of the πηδάλια, according to the Nemi found, to recent tradition and to logics of avoiding structural interruptions of the stock, were different and resulted in a symmetrical structure, as shown by the most elaborated figures (Lindos, Sperlonga).

At the present stage of our researches it is not possible to propose any credible hypothesis about the nature of this fragment.

Marco Bonino

Via S. Petronio Vecchio No 42

I - 40125 BOLOGNA

Bologna: 4th December 1988

L'esame dei documenti medioevali e tradizionali italiani sui sistemi di governo laterali o plurimi consente di definire alcune caratteristiche e necessità di manovra dei *gubernacula* antichi e di studiare i principi fisici alla loro base. Ne risulta, tra l'altro che tali sistemi antichi avevano la funzione di deriva, oltre che di manovra. In questa luce vengono esaminati i sistemi egizi, egei, greci e romani, con cenni ai timoni singoli egizi, pre-romani e romani ed ai doppi sistemi di πηδάλια a prua ed a poppa di età ellenistica e romana. Ricordi antichi, oltre ai tipi tradizionali citati all'inizio, sono nei termini dialettali usati nel Comasco ed in Sicilia.

Descritti i criteri generali validi per le varie età antiche, si considerano in dettaglio i documenti geometrici ed attici, nell'intento di dare indicazioni per la ricostruzione dei πηδάλια della nave di Kirinia. Un esame attento del frammento dal relitto di Kirinia, a suo tempo interpretato come parte del πτερυξ di uno dei πηδάλια, fa escludere tale interpretazione.

REFERENCES

- L. Basch, *Le musée imaginaire de la marine antique, Inst. Hell. pour la Préservation de la Tradition Nautique, Athènes 1987.*
- M. Bonino, *Barche tradizionali delle acque interne (...)*, "Quaderni dell'Atlante Linguistico del Laghi Italiani", No 1, Nuova Guaraldi, Firenze 1982.
- M. Bonino, *Le barche tradizionali del Lario (...)*, Soc. Arch. Comense Quad. No 3, Noseda, Como 1978.
- M. Bonino, *Barche, navi e simboli navali nel cimitero di Priscilla*, in "Rivista di Archeologia Cristiana", Roma A. LIX, p 277 sgg, Fig. 12 (*codicaria*), 1983.
- M. Bonino, *Lateen rigged medieval ships (...)*, in "The Int. Journ. of Naut. Arch. and Underw. Expl"; N. 7, pp 9 sgg, Fig. 1,¹¹ 1978.
- M. Bonino, *Un modello di nave cipriota (Amathus)...*, in "Rivista di Studi Liguri", A. XXXI, 1965, pp 301-310, Bordighera.
- M. Bonino, *L'attività navale in età protostorica*, in "Studi e Documenti di Archeologia", IV, pp 69-78, Nuova Alfa, Bologna 1988.
- L. Casson, *Ships and seamanship in the ancient world*, Princeton Univ. Press 1971, reprint 1986, chap. XI, pp 224-229.
- M. Cortellazzo, *Terminologia marittima bizantina e italiana*, in *XXV Settimana di Studio: La navigazione mediterranea nello Alto Medioevo, Aprile 1977, Centro It. Studi sull'Alto Medioevo, Spoleto 1978*, pp 759-773 (iasciu).
- C.H. Ericsson, *Navis oneraris*, in "Acta Academiae Aboensis", Vol 63, n. 3, pl XXIII, p. 66 (detail from Tomba della Nave in Tarquinia), Abo 1984; questionable in some parts, but I agree basically with pl. XXIII. The reconstruction of the figure has been corrected in my: *Imbarcazioni arcaiche in Italia, le navi usate dagli Etruschi*, II Congress of Etruscology, Florence 1985, Atti, Vol. III, Roma 1989, p.p. 1517-1536.
- A. Guglielmotti, *Vocabolario marino militare*, ed Voghera, Roma 1889, anastatic reprint, Mursia, Milano 1967.
- B. Landström, *Ships of the Pharaohs*, Allen & Unwin, London 1970.
- J.S. Morrison, R.T. Williams, *Greek oared ships*, Cambridge Univ. Press, Cambridge 1968.
- C. Boreux, *Etudes de nautique Egyptienne*, Cairo 1924-25.
- Stefano de Zuanne, *Architettura navale*, Ms. Add. 38655 British Museum.
- R. Steffy, *The Kyrenia Ship: an interim Report on its Hull Construction*, in *American Journal of Archaeology* N.89, 1985, pp. 71-101.
- A.L. Ermeti, *Il rilievo navale di Lindos*, in *Atti Acc. Naz. Lincei, A. CCCLXXXV, Rendiconti XXXIII*, pp 1-24, Roma 1978 (Lindos and Sperlonga).
- G. Ucelli, *Le navi di Nemi*, Libreria dello Stato, Roma 1950, Fig. 179, 223, 286, 292, pl II, VI, V.
- M. Vocino, *La nave nel tempo*, Alfieri, Milano 1948, p. 141 mosaic at the Rome Antiquarium, good fac simile at the Museo Navale Romano in Albenga.

APPENDIX

Fig. I

1. Protoattic fragment from Sunion, Analates Painter, National Museum Athens (700-650 B.C., Morrison Arch. 2, p. 73). The steering devices are leaning against the joke. The rail appears to be strictly connected to steering, although it is not clear whether the stock is inside or outside the rail.
2. Attic fragment from Athens, Akropolis (600-550 B.C., Morrison Arch 34, pp 85-86). The stock is bound against the joke and is inside the rail; it has a counterweight on top and a tiller.
3. Corinthian plaque from Penteskouphia (600-550 B.C., Morrison Arch. 40, p. 87): a *πηδάλιον* with a long stock leans against the *ζυγόν* and is pivoted around it, as shown by the different slope of the left *πηδάλιον*. Probably the stock is outside the rail and bound to it.
4. Dinos by Exekias, Rome, Museo di Villa Giulia 50599 (550-530 B.C. Morrison Arch. 53, pp 93-94): the stock is outside the rail and bound to it. The *ζυγόν* is not shown; the rail is an individual structure connected to steering.
5. Attic dinos in the manner of Antimenes, Louvre, Paris, F. 61 (530-510 B.C., Morrison Arch 67, p. 103): the stock is inside the rail, which appears to be strictly connected with steering.
6. Attic black figures cup, Berlin, Antiquarium (530-510 B.C., Morrison Arch 74, p. 104-105): a situation similar to that of Fig. I. 5.
7. Attic black figures cup, London, British Museum 436 (510-500 B.C. Morrison Arch. 85, p. 109): The stock is lashed to the joke, between the two upper wales. The upper end of the *πηδάλιον* is represented in a simplified way: the rail is not complete, but it appears that the stock of the *πηδάλιον* is inside it.

Fig. II

Reconstruction of a possible steering device for the Kirinia II replica.

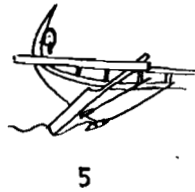
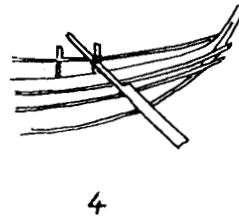
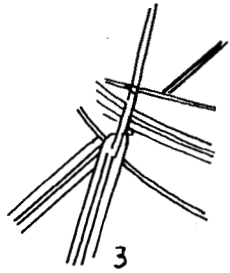
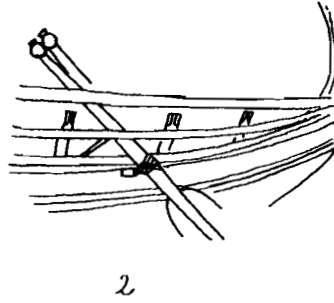
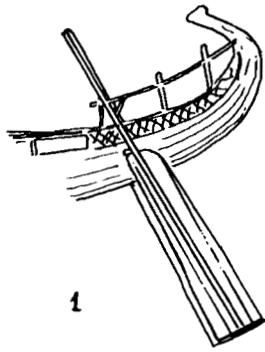
Fig. III

Fragment from the Kirinia II wreck, formerly interpreted as a part of the *πτέρυξ* of one of the *πηδάλια*.

FIGURES

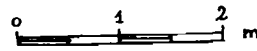
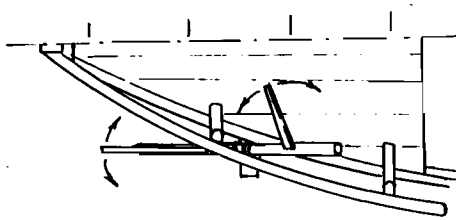
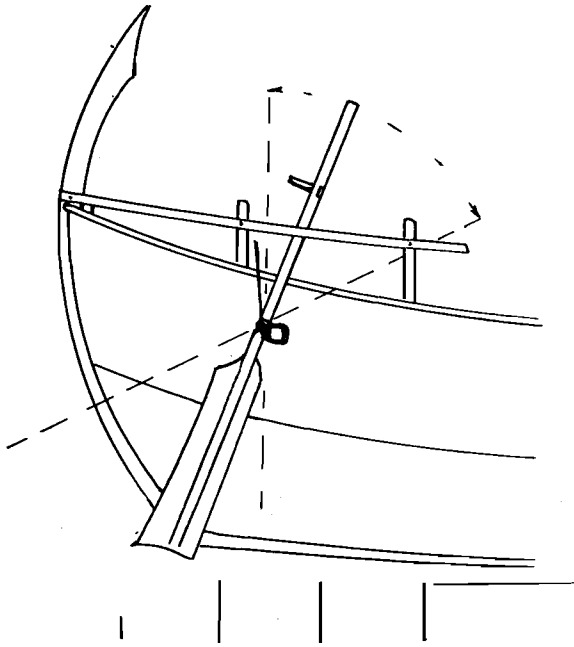
- 1 – A, B: Bonino da Campions, Pavia, S. Pietro in Ciel d'Oro (1362-1406);
C: Medieval stern, from G.Di Balduccio, Milan, S. Eustorgio, 1340.
D: From the treatise: *Fabrica di galere*, 1410.
E: Stern *alla Faustina*, Stefano de Zuanne, Venice 1686.
F: Stern *alla Ponentina*, Stefano de Zuanne, Venice 1686.
- 2 – A: *ciarmotta*, Tiber 1680
B: *rascòna* of the Po, Boretto end of XIX Cent.
C: *barcú*, Lake Iseo, 1950.
D: *port* (Ferry boat made of twin *nau*), Piedontese Po, 1950.
E: *combàll*, Lake Como, Milanese canals, early 1900.
- 3 – A: steering forces with a single rudder;
B: steering forces with two rudders;
C: forces exerted on the blade of a rudder;
D: surface contrasting lateral displacement (*deriva*) of a hull;
E: auxiliary surfaces of *deriva* on ancient ships;
F: surface of *deriva* added to the hull of a cog (XIV-XV Cent);
G-H: transversal sections of hulls with the same surfaces of *deriva*: more volume is displaced in case H.
- 4 – Egyptian steering devices.
- 5 – A: stern of the Amathus boat, British Museum, V cent B.C.
B: *πηδάλιον* arrangement of a Hellenistic polieres.
- 6 – Single steering devices of Pre-Roman and Roman boats:
A: Novilara (Pesaro), VII-VI Cent. B.C.
B: Bologna, V Cent. B.C.
C: *caudicaria* of the Tiber, I-III Cent. A.D.
- 7 – Roman *gubernacula*:
A: First Nemi ship;
B: From Torlonia relief and the Antiquarium mosaic (II-III Cent A.D.)

APPENDIX FIG I



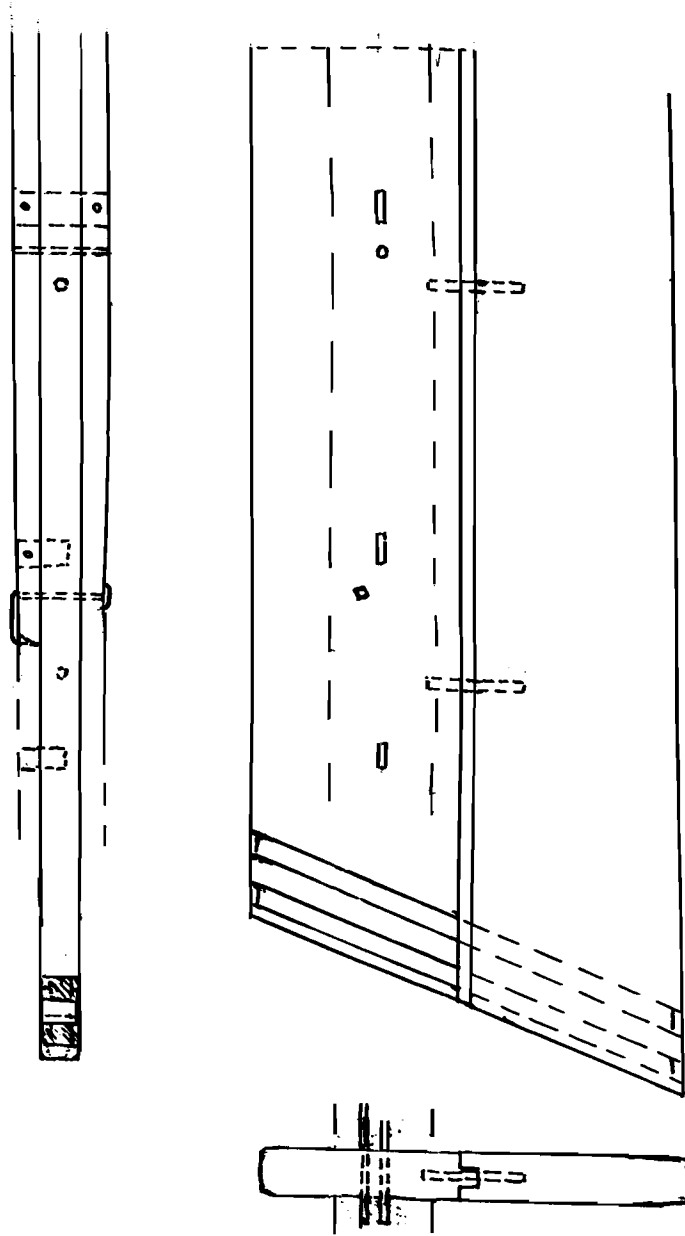
B
80-IV-97

APPENDIX FIG. II



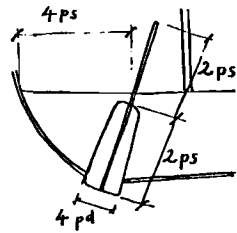
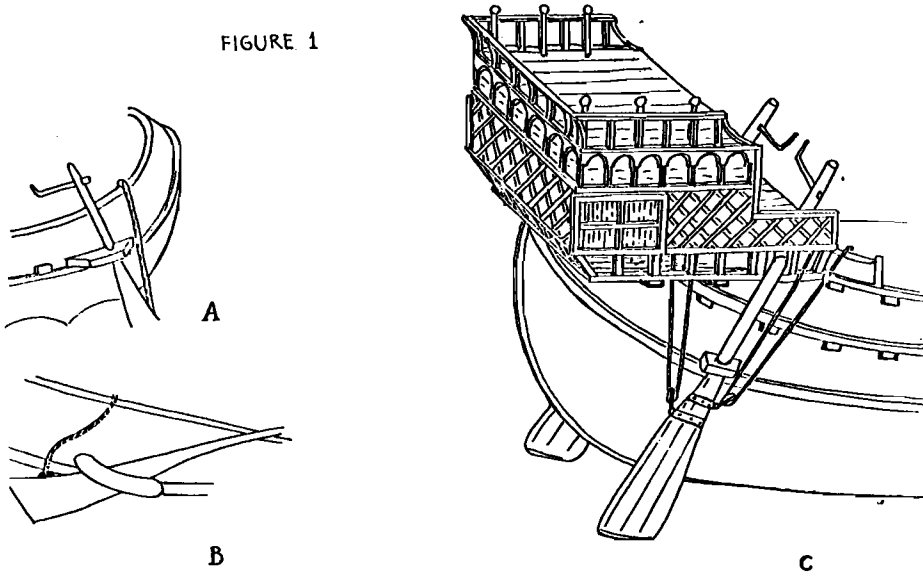
B
80-IV-87

APPENDIX FIG. III



0 10 20 30 40 50 cm

FIGURE 1



D

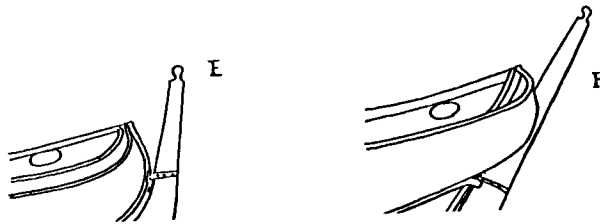
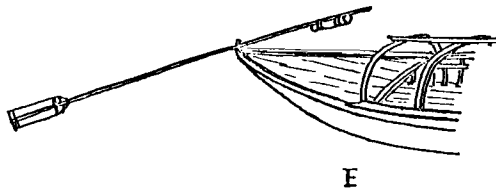
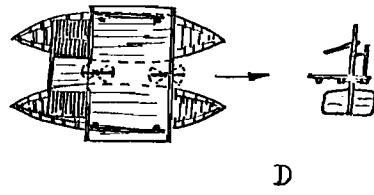
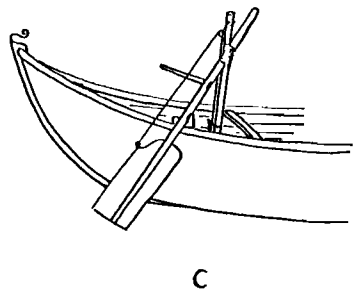
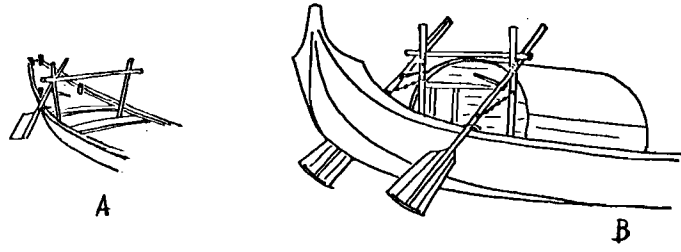
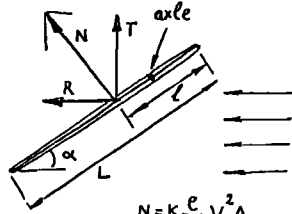
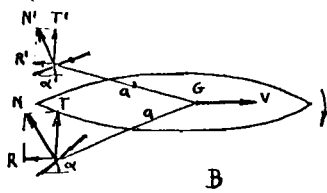


FIGURE 2



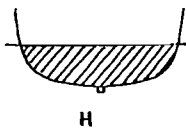
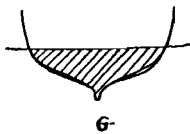
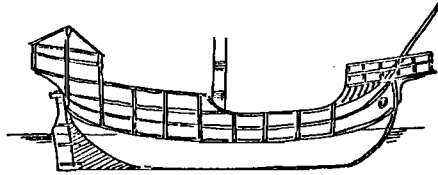
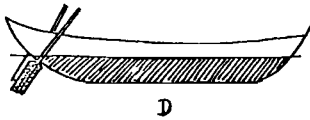
IB
80-VII-87

FIGURE 3



$$N = K \frac{\rho}{2} V^2 A$$

K increases with α and $\frac{1}{L}$
 ρ = density of the fluid.
 V = velocity.
 A = area of the blade.



Handwritten signature
 D.D. VII-17

FIGURE 4

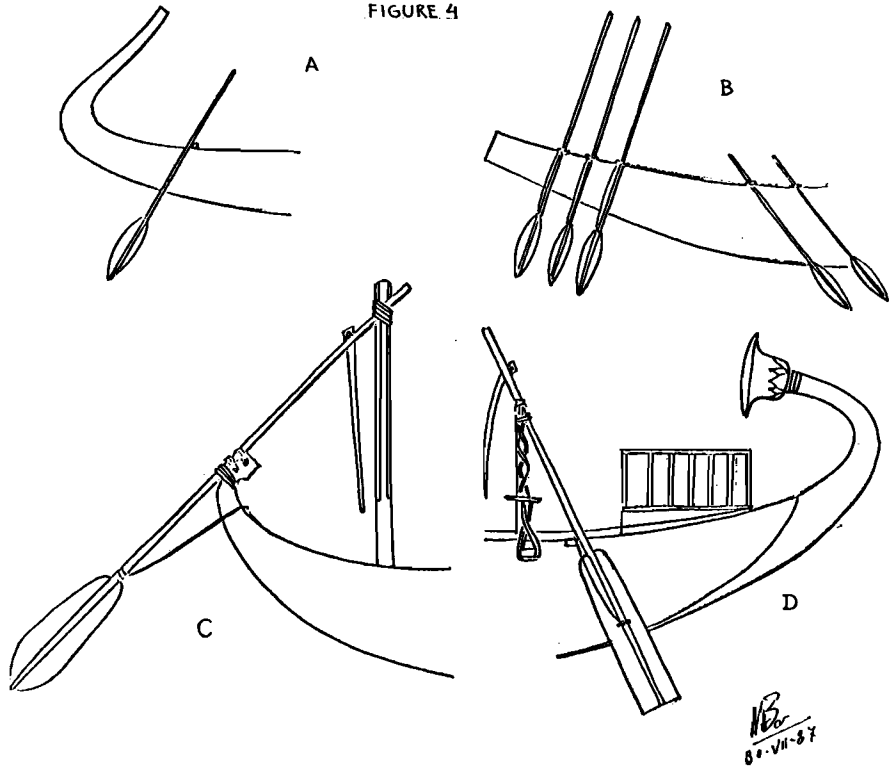
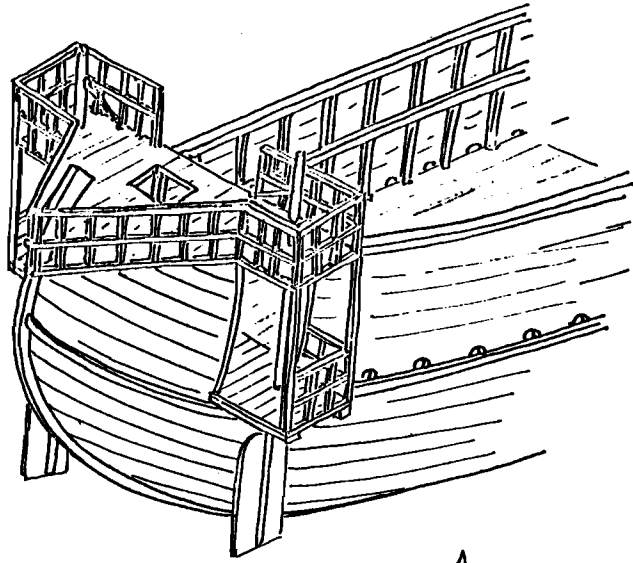
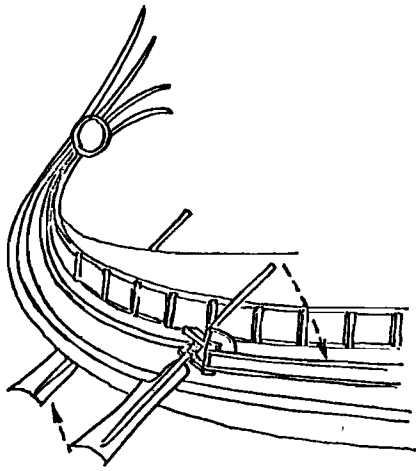


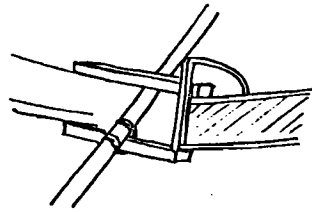
FIGURE 5



A

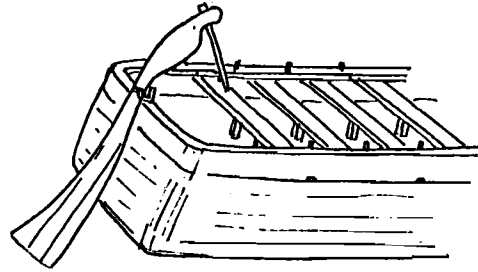


B

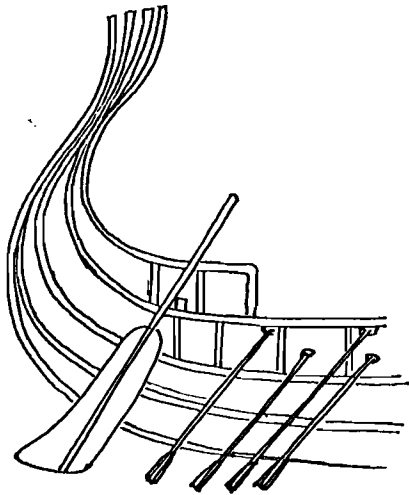


KB
DD-VII-27

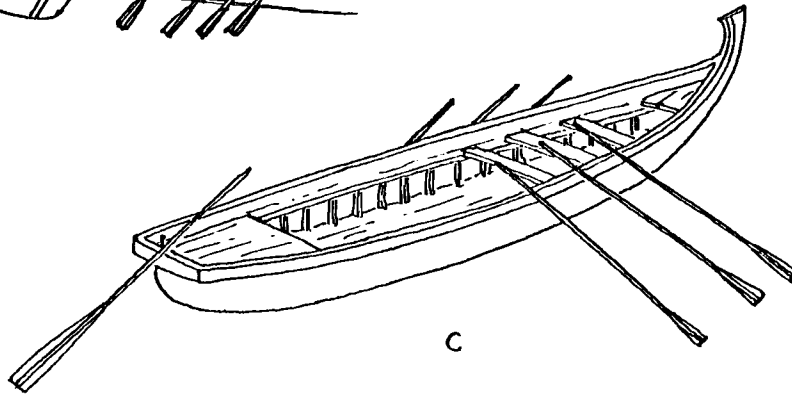
FIGURE 6.



A



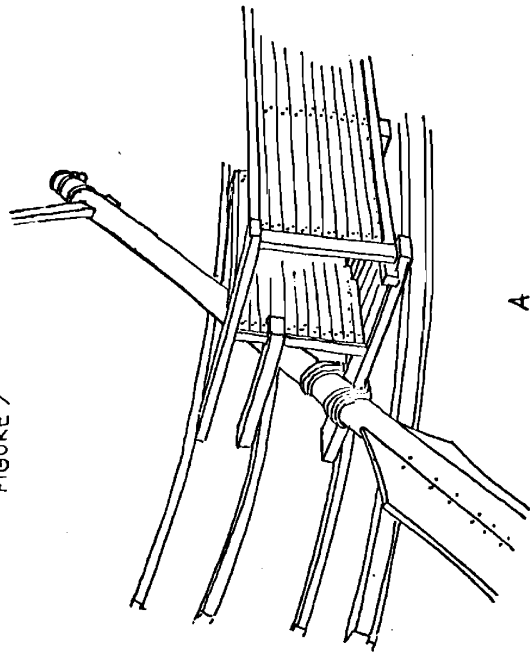
B



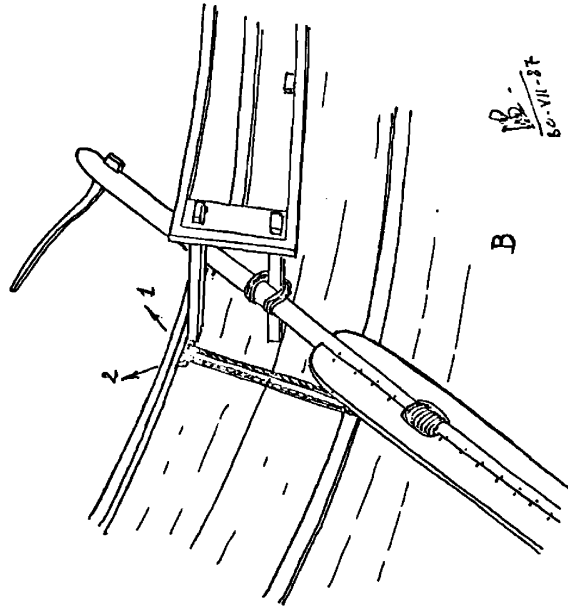
C

NS
R.O. VI-37

FIGURE 7



A



B

186.
60-VII-37

