PHILOSOPHICAL

TRANSACTIONS.

XV. *On a new principle of constructing His Majesty's Ships of War.* *By* Robert Seppings, *Esq. one of the Surveyors of His Majesty's Navy. Communicated by the Right Hon. Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read March 10, 1814.

NOTWITHSTANDING the rapid improvement in almost every other branch of the arts and sciences within the last century, it will scarcely be credited by persons not conversant with ship-building, that little or no advancement has been made during that period in naval architecture, so far as relates to the disposition of the materials which compose the fabric of a ship, whereby alone strength and fixedness of the parts can be obtained.

This will appear the more extraordinary in Great Britain, when it is considered that our very existence as a nation depends upon our naval superiority; and when it is further understood that a deficiency of oak timber, but more particularly that of a large scantling, calls for such an application of it as will reduce its consumption, and make up for the deficiency of its size.

It is not improbable, that the responsibility which would attach to an individual who should attempt an innovation in a

structure, whereby the lives of hundreds might be thought to be endangered, together with the great opposition raised against propositions for any material change in long established customs, may have occasioned this backwardness in naval improvements.

This heavy responsibility, together with the obstacles which are so frequently thrown in the way of projectors, has, without doubt, deterred many men, eminently distinguished for professional abilities, from attempting to carry into effect their ideas on this most arduous and dangerous undertaking: to which may be added, that not merely their professional reputation, but even their peace of mind, might have been hazarded thereby. For if the ship should be lost, although from a very different cause to that of the construction, yet would the weight of censure fall upon the new principle; and the projector would have to endure the whole burthen of the charge, that his schemes had occasioned not only the loss of the ship, but also, which is of far more consequence, the lives of some hundreds of his fellow-creatures. Whilst, on the other hand, should the experiment succeed, there would not be wanting those who would be ready to detract from that merit which he so richly deserved, and which would be purchased by him at so great a risk.

The writer of the present paper, in his various propositions for the improvement of naval architecture, has constantly kept in view these two leading axioms, "That the strength of a fabric consists not so much in the quantity of the materials of which it is composed, as in the disposition, the connection, and the security of its several parts." And, "that the strength of a ship, let its construction be what it may, can never

exceed that of its weakest parts," and consequently, " that partial strength produces general weakness."

Three 74 gun ships, now at sea, have already been rebuilt at Chatham on the principle about to be explained; and, from the favourable reports of those ships, the Lords of the Admiralty have given their orders for the building of several new ships upon the same principle.

To shew, in as clear a light as possible, the advantages of the application of this new principle to ship building, it may be necessary, for the information of those who are not acquainted with that art, to give the following general outline of the structure of a ship on the old principle.

1st. The frame of a 74 gun ship is formed of more than eight hundred different timbers, placed at right angles to the keel, which may be considered as the back bone of an animal, and the frame timbers its ribs. Each rib is composed of several pieces of the thickness of fourteen inches, or thereabouts. Between the several divisions of the frame, or ribs, is a space from one to five inches wide.

2dly. The whole exterior frame is covered with planks of different thicknesses, or to carry on the figure, the ribs are covered by a skin of greater or less substance from the extreme ends of them to the keel or back bone.

The inside of the frame is also almost entirely lined with planks; within which is another partial range, as it were, of interior ribs, at a considerable distance from each other, termed riders.

3dly. Across this frame are pieces of timber called beams, united together so as to be of sufficient length to reach from one side of the ship to the other.

The use of these beams is to secure the sides of the ship, so as to prevent her upper works from spreading, and to keep that part which is under water from being compressed by the fluid. They are also the supports or bearers of the decks (or what we call in houses the girders for the floors) and must therefore be of such strength as to endure the weight of the cannon, and whatever else is to be placed upon them. The usual mode of fastening these to the sides, has, generally speaking, been merely local, by two angular pieces of timber or iron (called knees) bolted to each beam, and also to the sides of the ship, by which means they were only partially held to the side, and there was wanting that continuity of materials, and consequently of strength, which the new system gives.

Between the beams and at right angles with them are placed pieces of wood called carlings, and at right angles with these (consequently parallel to the beams) ledges, which correspond with joists in a house. The planks or flat of the deck (flooring) is laid nearly in parallel lines from head to stern, upon and at right angles with the beams, and is fastened to them and to the carlings and ledges by bolts, nails, or wooden pins, called treenails. From this statement it will appear evident, that the decks, according to the old construction, are in nowise connected with the sides of the ship.

Having thus briefly described the common mode of shipbuilding, it will next be proper to point out such of its defects as the new principle tends to remove.

In the first place, it will be perceived, that all the materials composing the fabric of a ship are disposed nearly at right angles to each other.

This disposition which, in every wooden fabric is well known to the meanest mechanic, to be the weakest, is particularly so in a ship, the immense body of which, subject to violent action from impulses in every direction, is sustained by a greater pressure on the centre than the extremities, arising chiefly from the difference in the fore and after parts of the body, to that of the midship, or middle part.

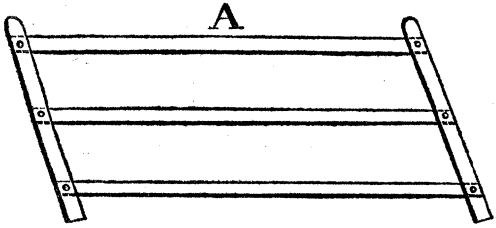
From the want of a continued succession of support from the centre to the extremities, originates the tendency to arching, or hogging. This tendency shews itself in a ship from the moment of her launching; from whence some idea may be formed to what extent it will be carried in a troubled sea, when in the act of pitching she is borne up by the fluid only in her central part, while the head and stern are forsaken, and therefore unsupported by the water.

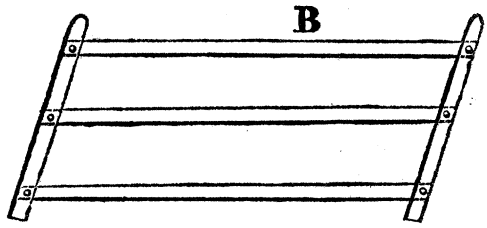
If a straight line be drawn from the head to the stern of a ship, whilst on the slip, or in the dock, no sooner has she entered her own element than each end of this line will be found to have dropped from two to five or six inches, in consequence of the weakness of the fabric, and the two extremes wanting the quantum of support which the fluid gives to the central part.

The length of a 74 gun ship being 170 feet or more, it requires but little knowledge of the strength of timber to perceive that planking of that length, however thick, or in whatever way joined or put together, must, under the present system, bend with its own weight. The fastenings, and consequently the connection of the several parts of the fabric, must therefore suffer for the want of *stiffness*, and a change of form is the consequence.

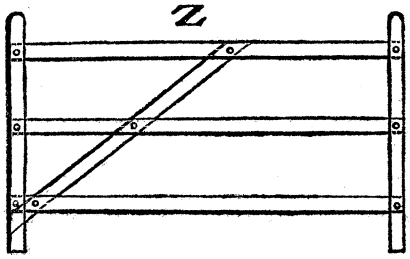
This may be shewn by putting together four pieces of wood,

and securing them with iron pins in the form of a square; which on the least pressure may be made to change its form to the rhombus; but let another piece be fixed to it diagonally, and the figure of the frame will be found immoveable. Place a bar in the middle parallel to two of the sides, and secure it firmly by iron pins, still the figure will easily be moved by the hand, like a parallel ruler, and assume the rhomboidal shape of A or B; but apply to the frame what the





carpenters term the brace in a common field gate as Z, and the figure will remain, as before, immoveable.



If this brace or diagonal piece is not fixed to it, the outer part of the gate (or that part most distant from the hinges) will have a constant tendency downwards, until at length it will reach the ground.

Let fig. 1 and 2 represent two frames of wood composed of parts strongly connected by bolts or iron pins.

Fig. 1. Will represent the principle on which the present system of ship building is conducted.

Fig. 2. The new principle.

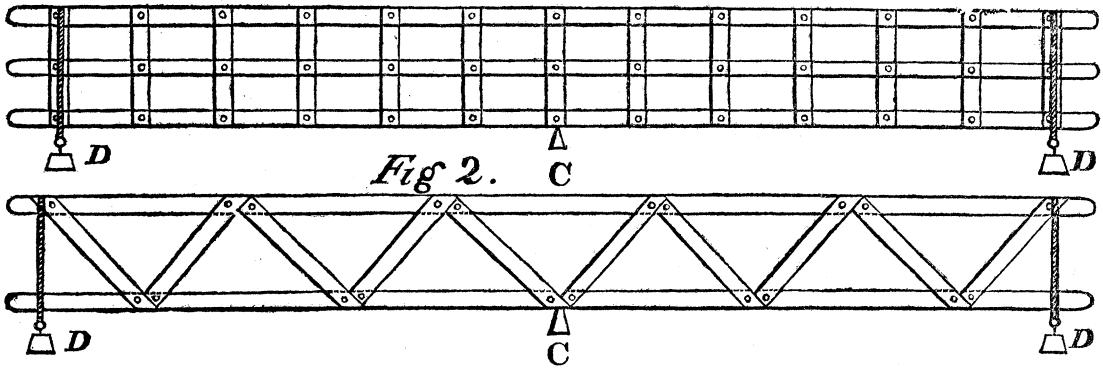
Let CC represent the fulcrum, or point of support.

And DD two weights attached for the purpose of ascertaining the comparative strength or stiffness of each frame.

This experiment will shew that the stiffness of fig. 2 is to that of fig. 1, as 6 is to 1, and the strength as 3 to 1.

The greater the length of the frames, the greater will be the advantages of the new principle, both in stiffness and strength.

Fig 1.



The substitution of the triangle, as in the frame of fig. 2, for the rectangle in the frame fig. 1, comprehends the principle of the new system, the use and advantages of which will be sufficiently evident.

The arrangement of the materials in the triangular mode is such, that the pieces disposed horizontally are acted upon as ropes are by a strain of the fibre, whilst the other parts, composing a series of triangles, are pressed upon as pillars; in other words, the pressure acts in the direction of the fibres of the wood; whereas upon the rectangular, or old plan, the fibres are acted upon transversely, or across the grain, in the same manner as a stick is when placed across the knee and pressed

by the hands at each end, which first bends, and then breaks.

To prevent any transverse action upon the fibre of the timber, is one of the benefits arising from the new system, and to impede a longitudinal extension of the structure, is another.

For as the diagonal frame, composed of a series of triangles, aided by diagonal trussing between the ports, prevents the fabric from being acted upon transversely to the fibres of the materials horizontally placed, so the wales, the planking, the shelf pieces, the improved waterways, and the decks systematically secured, become the tie beams of the structure. In a word, the system of triangles is so constructed, in conjunction with the planking of the ship, as conjointly to possess that property of a triangle already explained, viz. that its figure is as unalterable as the compression or extension of the fibre of timber will admit it to be.

The strength of the principle has hitherto been considered as applying to, or resisting an alteration of, the figure, by giving great stiffness. It is now to be taken in another point of view, that of rendering the strength of the fabric as general and united as possible. For let it be again observed, the strength of any body is but equal to that of its weakest part.

In the new system, the openings between the ribs are filled in with slips of timber nearly to the height of the orlop, or lower tier of beams; which being then caulked, and paid or pitched over, makes the frame from head to stern, and within a few feet of the greatest draught of water, one compact and water tight mass of timber; so that were any of the outer planking of the bottom to be knocked off, the ship would not only still keep afloat, but would be secured from sinking. In

the old system the starting of a plank would be, and often has been, fatal.

The mode of filling in these openings between the frame, where the width of the space does not exceed three inches, is by driving in slices of wood cut wedge-like; two of which being driven, one from the outside, the other from within, form the parallel space of the opening, thereby bringing the parts into the closest contact. In the openings exceeding the width of three inches, the space is occupied by pieces corresponding with the openings, the fibre of such pieces being laid in the same direction as that of the frame timbers.

These fillings occasion no consumption of useful timber, as one fourth of the produce of slab, and other offal now sold as fathom wood, would supply a sufficient quantity for the consumption of the whole navy.

The advantages obtained by filling in the openings are these. To add to the strength and durability of the fabric, to preserve the health of the crew from the effects of the impure air arising from the filth which soon collects in these openings, to render the ship less liable to leakage, as well as to facilitate the stoppage of any leak, and lastly, to increase, as it may be said, the thickness of the bottom from four or four and a half, (the usual thickness of the plank) to about sixteen inches, thereby lessening very considerably the danger to be apprehended from getting on shore, or foundering at sea. That it tends also to the durability of the ship, will be inferred from the following positions.

1st. That the openings in the old principle are, after a ship has had any considerable length of service, choked up in many parts with an accumulation of filth.

2dly. That no free circulation of air can be obtained in these openings by any means.

3dly. That timber being either freely exposed to, or excluded from the air, is equally preserved.

4thly. That it has been found on examining the frame and plank of old ships, that those parts (now filled in), generally decay sooner than the rest, viz. from the floor-heads in the midships, and from the deadwood forward and abaft to the height of the orlop clamps.

If the above positions be true, it will follow, that by filling in these openings, much will be added to the durability of the ship; which also will be further promoted by omitting in these parts the inside plank, leaving thereby the surface of the frame timbers exposed to a free admission of air as often as the ship's hold is unstowed, and by the filling in, excluding the air from two of the sides of every timber.

By omitting the inside plank, much is added to the internal capacity of the ship's hold. For though the trussed frame projects from the timbers more by five inches than the thick-stuff at the floor heads, yet, as in the old system, the perpendicular riders are brought upon the thick stuff, their projection into the hold is more by eight inches than that of the new, the advantage therefore as to stowage is in favour of the diagonal frame. A tier of iron ballast will also be disposed of in this principle many inches lower, whereby an increase of stability will be given with less weight, which will favour the ship in carrying her ports higher out of the water, inasmuch as greater stability will be given with less ballast.

An accurate conception of the state of the ship's hold may be formed, by referring to the longitudinal section (Pl. X.

figure 1, which is termed the Jesuit's perspective, or bird's eye view) of the internal part of one side of a 74 gun ship in a complete state, with fillings in the openings between the timbers of the frames instead of the planking over them.

In this state the diagonal timbers are introduced, intersecting the timbers of the frame at about the angle of 45 degrees, and so disposed as that the direction in the fore, is contrary to that of the after part of the ship (as may be seen in the engraving), and their distance asunder from six to seven feet or more; their upper ends abutting against the horizontal hoop or shelf piece of the gun deck beams, and the lower ends against the limber strakes, except in the midships, where they come against two pieces of timber placed on each side of the keelson for the purpose of taking off the partial pressure of the main mast, which always causes a sagging down of the keel, and sometimes to an alarming degree. These pieces of timber are nearly as square as the keelson, and fixed at such a distance from it, as that the main step may rest upon them. They may be of oak, or pitch pine, and as long as can be conveniently procured.

Pieces of timber are next placed in a fore and aft direction over the joints of the frame timbers at the floor and first futtock heads, their ends in close contact with, and coaked or dowelled to the sides of the diagonal timbers. In this state the frame work in the hold presents various compartments, each representing the figure of a rhomboid.

A truss timber is then introduced into each rhomboid with an inclination opposite to that of the diagonal timbers, thereby dividing it into two parts. The truss pieces so introduced into the rhomboid, are to the diagonal frame what the key stone

is to the arch; for no weight or pressure on the fabric can alter its position in a longitudinal direction, till compression takes place at the abutments, and extension of the various ties.

This arch-like property of the diagonal frame, not only opposes an alteration of position in a longitudinal direction, but also resists external pressure on the bottom, either from grounding or any other cause, because no impression can be made in its figure in these directions, without forcing the several parts of which it is composed into a shorter space.

The connection which is kept up by means of this trussed frame firmly attached to the timbers of the ship by circular coaks and bolts, together with the shelf pieces united to the sides and to the several beams by means of the same sort of fastenings, gives such unity to the whole as to bear no comparison with that heterogeneous and badly connected mass of materials for which it is substituted.

It has hitherto been a generally received opinion, that stiffness or inflexibility in a ship is not strength, but that a yielding or bending of the fabric is an essential quality to preserve it from being destroyed by the shocks which it is destined to sustain.

This misconception must have arisen from an equally incorrect idea, which is, that a ship is an elastic body, because there is a considerable degree of elasticity in the materials of which it is composed. But it should be remembered, that this elasticity of the materials must be very inconsiderable, inasmuch as the minute degree of elasticity in each piece must necessarily be neutralised in the fabric, by the various directions and tendencies of the numerous parts of which it is

composed, so that a ship, let her construction be what it may, either loose or firm, is not in any case elastic. It follows then, that every action and reaction of the sea operating upon different parts of the fabric at different times, occasions, for the want of unity of the whole of the parts, a constant and increasing weakness, which by some may have been taken for elasticity.

When a sea strikes a ship forward, the bow will rise with the sea; which passing aft, lifts the midships in succession, leaving at this time, in a great measure, the fore and aft parts of the ship with comparatively little, or no support. Such shocks, acting upon a body whose parts are not firmly connected, produce a bending and rebending of the fabric, so that the several planks of the sides play over each other, and the fastenings are strained and loosened by a repetition of this action and reaction. On the contrary, when a body is constructed with such general unity and fixedness of all its parts, as that if one is moved the whole must move with it, then it may be said that all the parts of the structure bear their portion of the strain.

The decks come next under consideration, the beams of which are disposed in the new system nearly as usual, except that in midships, where a ship necessarily requires the greatest security, two additional beams have been introduced.

The beams of the several decks are attached to the ship's side in the following manner.

1st. By shelf pieces or internal hoops, distinguished by the letter E, figure 2. These shelf pieces are composed of several lengths of timber scarphed or joined together by coaks, or circular dowels, so as to form a kind of internal hoop, extending

from the hooks forward, to the transoms abaft, to the underside of which, as well as the under parts of the beams, they are securely coaked, and being then firmly bolted to the side, instead of becoming a mere local fixture of the beam to the ship's exterior frame, as knees were, they are one continued and general security. The shelf piece is also a tie to the topside in a fore and aft direction, cooperating with the trussed frame, as already explained.

2dly. By chocks, represented in figure 2, letter H., which are placed under all the shelf pieces in wake of the beams, except the orlop, in such a manner as to receive the up and down arm of the iron knees. The lower ends of those under the gun-deck shelf piece, step on the ends of the orlop beams, and those of the several decks above, step on the projecting part of the spirketting below. The chocks, particularly those between the orlop and gun decks, admit of their being driven into their respective places very tight, thereby acting like pillars. Another advantage attending them, is their great tendency to stiffen the ship's side, and to prevent the beam ends from playing on the fastenings when the ship is rolling, or straining under a press of sail.

The curved iron plate knees for securing the orlop beams, and the iron forked knees of the other decks, are described in figures 3 and 2.

The flat or planks of the several decks being, on the old system, each of them a mere platform, or in other words a cover to a box unconnected with the sides, are here so disposed of, as not only to oppose an alteration of figure from a force acting on the ship in a lateral direction, but also are made subservient towards securing the beams to the sides of the ship.

The framing and flat of the decks (excepting the quarter-deck, forecastle, and round-house, which are laid upon the old plan) are disposed of, as represented in figure 5. The former, that is, the framing or ledges and beams in ticked lines, the latter or planks in black; those of the starboard side being laid contrarywise to the larboard. The midship ends of the diagonal planks abut against two strakes laid in a fore and aft direction without side of the comings of the hatchways; the other ends approach the timbers of the frame, and the buts at each end are secured to a tier of carlings placed for that purpose. The flat or plank of the deck so disposed is connected with a certain number of coaks to the hooks, beams, and transoms. When the decks are thus laid, waterways, described in figure 2, are brought upon, and coaked to the ends of the plank. These waterways being then bolted through the ship's sides, and also, in an up and down direction, through the flat and shelf pieces, combine the whole in one homogeneous mass of strength.

Few ships are without some complaint of apparent weakness after three or four years service. These defects among other places shew themselves at the beam ends, which partial complaining proceeds in a great degree from the local attachment of the beams to the ship's side, and the flat or covering being in toto unconnected, as already explained. The extreme ends of the beams not being properly secured, play and work upon the fastenings, so that it is not unusual to see the bolt holes cut to an oval figure by the friction of the bolts. The remedy usually applied to a ship in this state is to load her with additional materials, such as iron knees, standards, breasthooks, &c. thus adding greatly to the original

weight of the fabric. Now it is evident, that the first gale of wind the ship encounters, after being thus partially strengthened, she must be reduced to the same state of weakness she was in before the remedy was applied.

This mode of strengthening ships may be compared to that of a raft firmly secured in the first place by strong lashing, which after some time works loose, or rather by working is stretched. As it might be too tedious a business to secure the raft by retightening the lashing, a small cord, or some twine, would be used to answer the purpose. It is clear that whilst the small cord or piece of twine remained tight, no part of the strain can bear upon the strong, but loose lashing, till the other stretches or breaks; so it is with a ship that has additional securities given her without refastening those which had worked, or were much strained.

To remedy defects, whether arising from the decay of the materials, or from any other cause, the principle now applied has many advantages, of which a slight inspection of the ship's hold (figure 1,) will convince, but in no respect is this advantage greater, than in the decks, for by shifting them when worn too thin for caulking, the original connection between the beams, decks, and sides, will be restored as perfect as at first.

The tendency of the ship to stretch or draw asunder in her upper works, being by no means obviated by the short planks on the inside between the ports, a truss piece of plank is substituted in lieu of them, which being well secured at the abutments, very materially aids the trussed frame, and gives great stiffness, thereby opposing the inclination to arch or hog aloft.

Figure 4 represents the stern of a ship with the trussing and iron work for its security. By this the helm port transom, which consumes one of the largest and most difficult trees required for a ship, is dispensed with.

Those essential qualities of strength, safety, and durability, having been detailed, a few observations with respect to the economy of the new principle may not be misplaced, which though but of a secondary consideration compared to the others, yet as the royal navy cannot be kept up without a supply of foreign timber, it evidently becomes a subject of considerable moment, that upwards of one hundred and eighty oak trees should be saved in a seventy-four, and a greater number in larger ships, allowing each tree to measure a load, or fifty feet rough contents.

The consumption of this scarce article may be further considerably lessened in the new system by the use of inferior, and old ship timber, which cannot be employed in the other, and if old ship timber was to be generally introduced, as was done in the Ramillies, one seventh part of the English oak required for a new 74 gun ship might be saved.

The facility of ascertaining the state, and making good the defects of the frame in the lower part of the ship, in consequence of omitting the inside planking, will also occasion a considerable saving of timber and workmanship, indeed the great ease by which any part of the diagonal frame may be replaced, justifies the making use of fir timber, particularly for the longitudinal piece and trusses.

But should the well grounded hopes of durability be realized, the saving of timber, and indeed of every article required for this enormous branch of the national expenditure, would be immense.

The author of this paper cannot conclude without observing that the appointment of most excellent and meritorious officers to the ships already completed on his principle, may be considered as a most favourable circumstance towards ascertaining the real merits of the construction.

Indeed, the orders for carrying this new principle of constructing His Majesty's ships into effect, were directed by such an honourable spirit of liberality; and so unshackled was the authority given, to enable the writer to carry his plans into execution, that no subterfuge can avail him should any failure be found in the system.

Fig. 4.

Plan of the Stern.

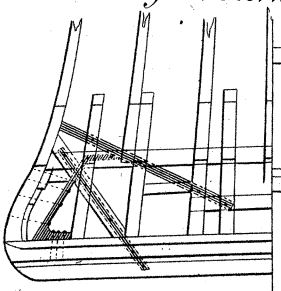


Fig. 2.

A Transverse Section.

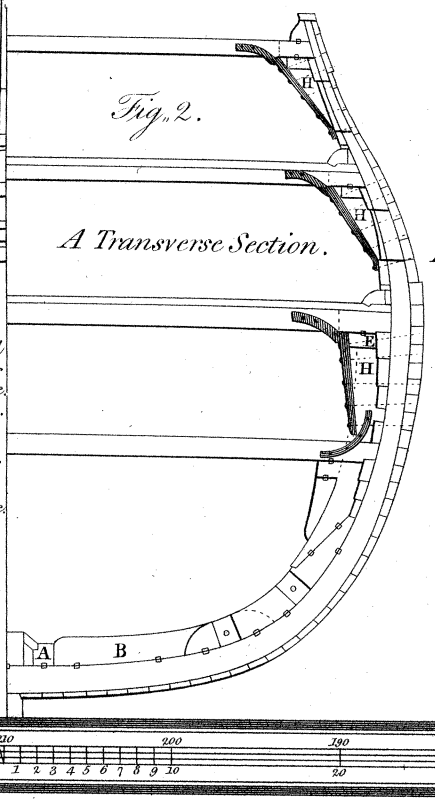
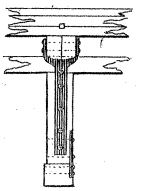
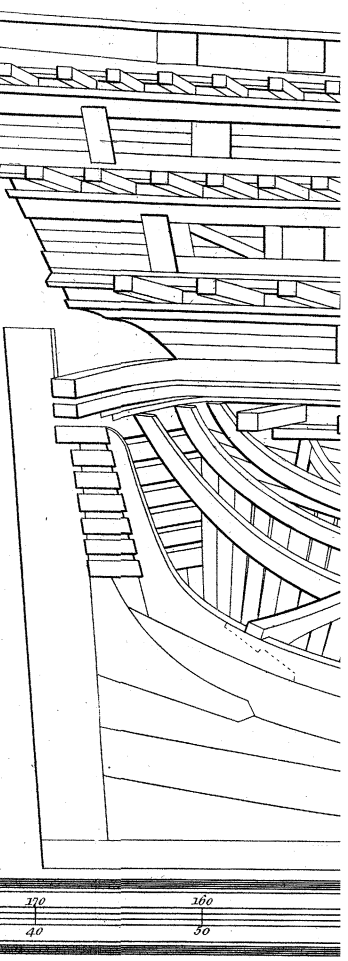
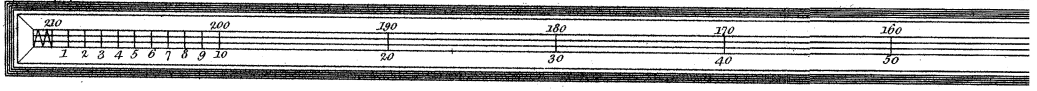


Fig. 3.

Plan of Iron Knee.







References.

A.A. *Limber strake and additional Keelson, forming abutments for the lower part of diagonal frame.*
B.B. *Timbers of the diagonal frame.*
C. *Longitudinal pieces to Ditto.*
D. *Trusses to ..... Ditto.*
E. *Internal hoop or Gundeck shelf piece forming abutment for the upper part of the diagonal frame.*
F. *Abutment pieces for Trusses between ports.*
G. *Trusses.*
H.H. *Chocks under Shelf piece for Iron Knees.*

Plan of the Breasthooks & Crutches.

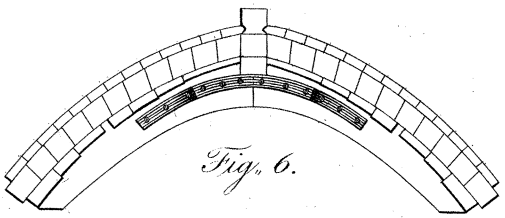


Fig. 6.

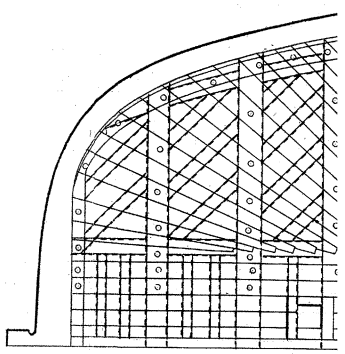


Fig. 1.

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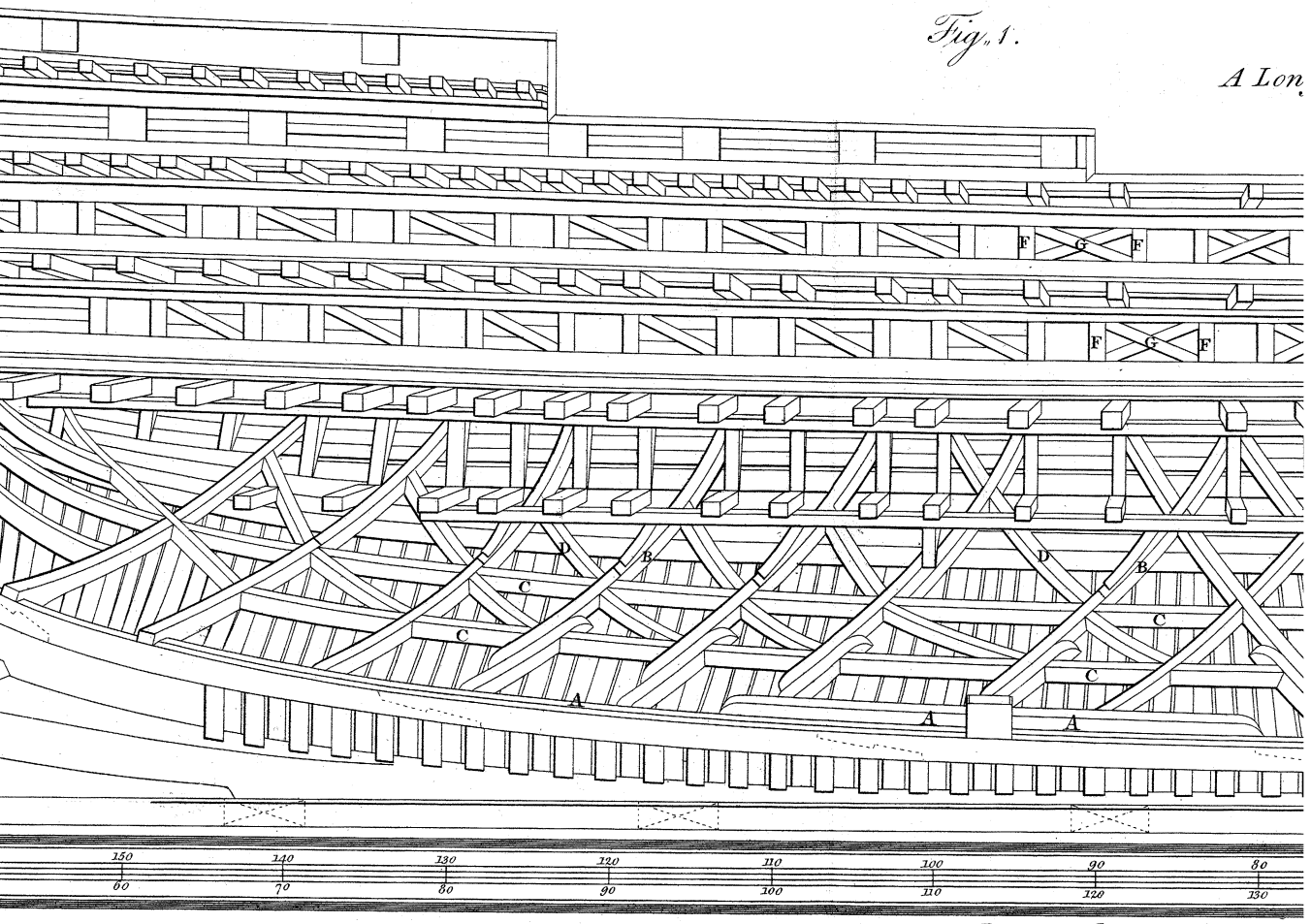
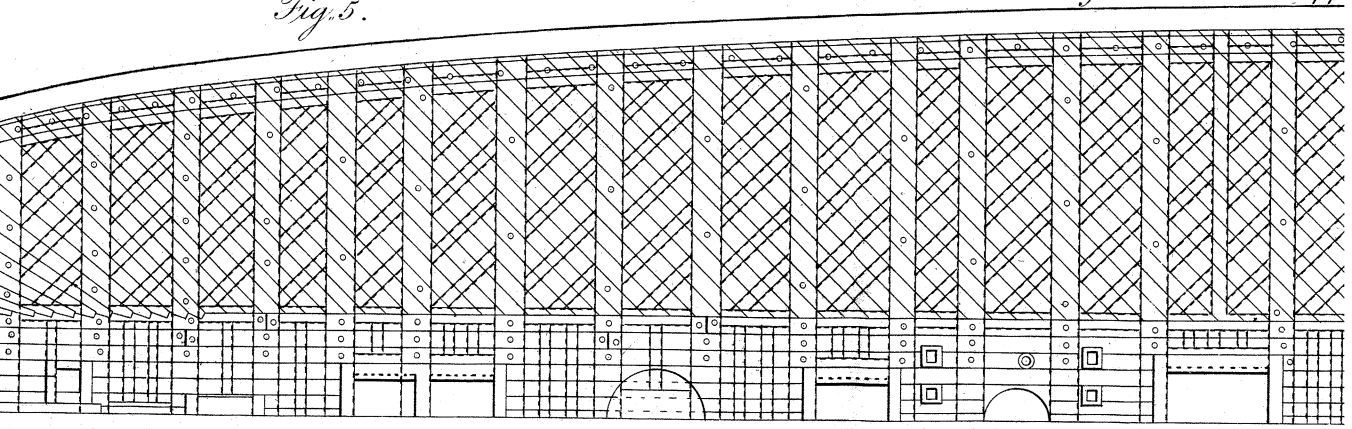
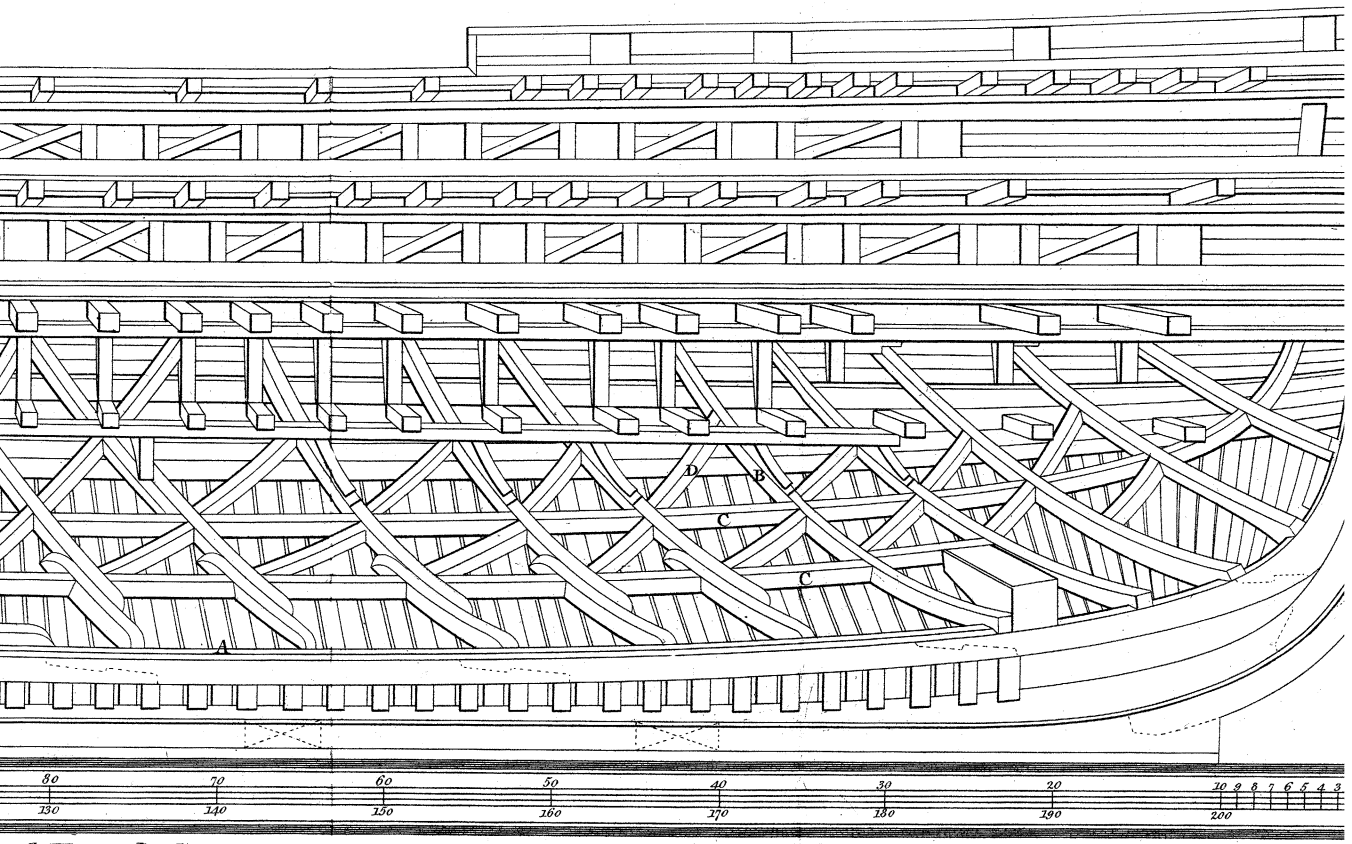


Plan of the Gun and Upp

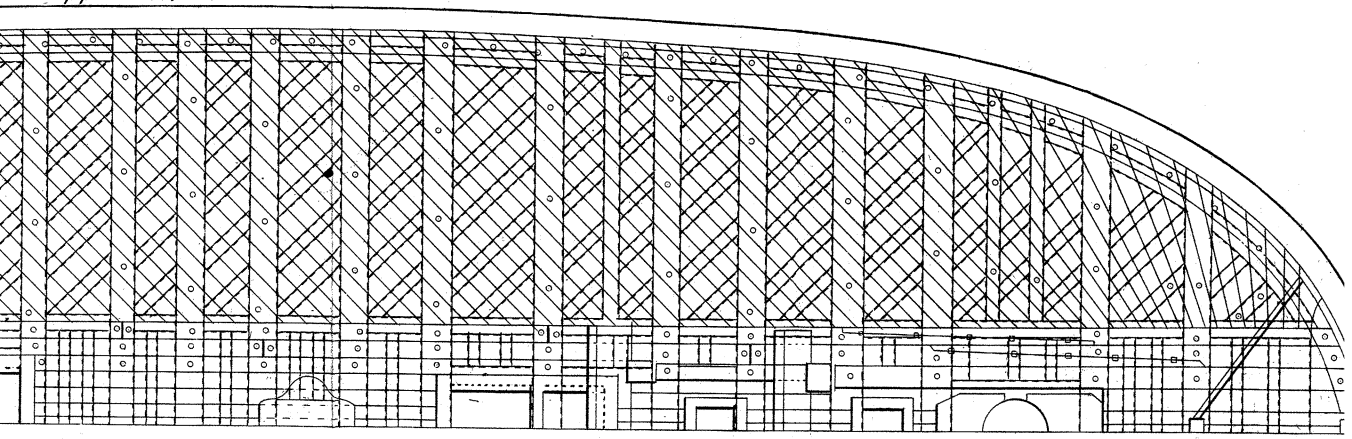
Fig. 5.



A Longitudinal Section.



nd Upper Decks.



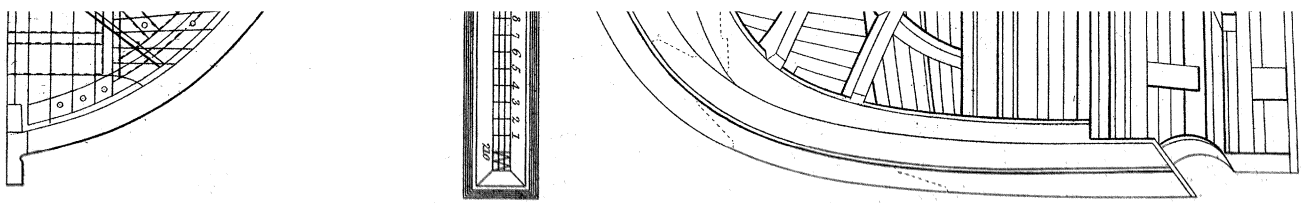


Fig. 4.

Plan of the Stern.

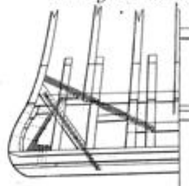


Fig. 2.

A Transverse Section.

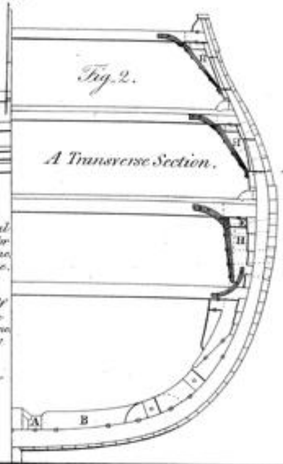
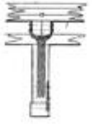


Fig. 3.

Plan of Iron Knee.



References.

A.A. Limber strake and additional Keelson forming abutment for the lower part of diagonal frame.
B.B. Timbers of the diagonal frame.
C. Longitudinal pieces to Ditto.
D. Trusses to ..... Ditto.
E. Internal hoop or Gundeck shelf piece forming abutment for the upper part of the diagonal frame.
F. Abutment pieces for Trusses between ports.
G. Trusses.
H.H. Chocks under Shelf piece for Iron Knees.

Fig. 1.

A Longitudinal Section.

Plan of the Breasthooks & Crutches.

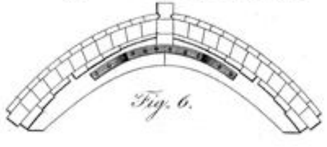


Fig. 6.

Fig. 5.

Plan of the Gun and Upper Decks.