

ON FLOATING DOCKS, AND OTHER ARRANGEMENTS FOR AFFORDING ACCESS TO SHIPS FOR EXTERNAL REPAIRS.

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For the purpose of affording access to the immersed parts of vessels, there can be little doubt that in the early periods of navigation the vessels were either hauled up on the beach for examination, in the absence of rise and fall of tide; or, where there was a considerable rise and fall of tide, the vessel was placed over a flat beach at high water, and allowed to ground as the tide fell. Although the latter plan is easy of application, and useful to a certain extent even for large vessels, where there is a considerable rise and fall of tide, the former mode must have been difficult to carry out except with very small vessels; and therefore it is probable that the plan of "Careening" was resorted to as soon as vessels were built of any considerable size.

This plan, more properly called "heaving down," was carried out in two ways: either as shown in Fig. 1, Plate 15, by bringing the ship near a quay wall provided with mooring rings and capstan, and attaching ropes to the heads of the masts, so as to haul the ship over into a nearly horizontal position on the water; or as shown in Fig. 2, by putting the heaving-down tackle on board another vessel, so that the operation could be performed independently of the land. This second plan had the advantage of being also independent of the rise and fall of the tide, which in the other method of course affected the position of the ship under repair.

The plan of "careening" seems to have been extensively practised in the naval arsenals of France at an early date. Whether done by tackle from the land or from a vessel afloat, the operation was of course aided by the removal of the ballast and heavy weights, so as to lighten the ship. By the mere shifting of the weights and

without the assistance of tackle, a large amount of the ship's surface could be exposed ; but this plan was of necessity attended with considerable danger of foundering, as exemplified in the fate of the "Royal George," which foundered at Spithead in August 1782, with upwards of 600 persons on board, whilst being careened. Careening is also stated to have been the cause of permanent distortion in the shape of vessels, from the exposed side being strained to an unnatural degree of convexity prior to the driving in of the caulking, which then kept the vessel to the distorted figure it had assumed.

The next mode to be mentioned is the ordinary Graving Dock or Dry Dock, which even at the present day is the plan most commonly employed in Europe, and will probably continue to be preferred in all places where there is a large rise and fall of tide, and where the ground is suitable for excavation. As regards the derivation of the term "graving" dock, it has been suggested that the name was taken from the resemblance which the dock bore to a "grave;" but the writer believes it to be derived from the operation carried on in the dock, as it appears from records of the date 1667 that what is now called "paying" a vessel with a composition was formerly called "graving;" and it would seem that this word is of French origin, and in turn owes its derivation to the place where the graving was sometimes performed, namely on a flat sandy beach or "grève." As early as 1623 there was a dry dock at Deptford, and in 1667 there was one also at the arsenal at Rochefort in France.

Various kinds of graving docks have been either executed or proposed. In many parts of England the rise and fall of the tide are sufficient to admit of a very large vessel being drawn into a dock at high water, so as to be brought over the keel blocks, on which it then settles down as the tide recedes, and at low water the dock is left dry and the vessel exposed for repairs ; the sluices being then closed exclude the water, so that the succeeding tides cause no interruption to the work. But in situations like the shores of the Mediterranean and in other places where the tide is but small, the water has to be got out of the dock by pumping, which before the days of steam power was found both an expensive and a tedious process, causing

great delay before the vessel could be reached even for slight repairs or merely for inspection. To make the operation more expeditious, large chambers have in some instances been provided below the level of the dock, sufficiently capacious to receive from the dock the whole or the greater part of the water contained in it, which could afterwards be pumped out of them at leisure. This plan certainly gave the advantage of speed in emptying the dock, but it added largely to the first cost, and moreover caused the labour of pumping to be increased, owing to the greater depth from which the water had to be drawn; nevertheless these chambers were in use at Toulon and also at Portsmouth, notwithstanding that at the latter port there is a rise and fall of about 10 feet at ordinary spring tides.

Where there was a lofty shore and a supply of water from a high level, it has several times been proposed, and amongst others by Belidor, to make dry docks as shown in Fig. 3, Plate 15, where A represents the ordinary sea level, and B a low-level dock opening into a basin in connection with the sea, and having its sides C as much above the sea level as would equal the draft of the largest ship to be docked. D is an upper dock, having the top of its sides level with C, and its floor a little above the sea level A. If a ship be floated into the lower dock B and the gates be then shut, and if water from a high level E be allowed to flow into B and D, the water will continue to rise and the ship will be lifted until its keel is high enough to pass over the blocks on the floor of the upper dock D, when it can be hauled into that dock and the sluice of the lower dock B opened so as to allow the water to escape into the sea, leaving the ship securely berthed in the raised dock.

In some few favourable situations graving docks are comparatively simple to construct and maintain, namely in such situations as Birkenhead, where the docks are hewn out of the solid rock, which while it is sufficiently hard and homogeneous to support the heavy weights is sufficiently soft to be readily worked. In these cases there are none of the dangers to be apprehended of settlement or of blowing up the bottom that exist where the dock is built in an excavation made in the earth, which is frequently of an extremely

treacherous character at river sides. As regards the mode of closing the entrance to dry docks, this has been effected either by Gates to open sideways like those of a lock, or to fall upon the bed of the river, or by Caissons. The latter, now that the introduction of iron for ship-building purposes has admitted of their being made of that material, are almost universally adopted for large docks, and have the advantage of affording the means of retaining water inside the dock as well as of keeping it out, which is of considerable importance for allowing time enough to adjust the ship properly before it settles down on the keel blocks. Among the largest graving docks may be mentioned the double dock now constructing at Brest, 721 feet long and 92 feet wide, with 35 feet depth of water over the cill; and the double dock at Portsmouth, which is 636 feet long, 88 feet wide, and 27 feet deep over the cill: and one of the largest single docks is that at Devonport, which is 415 feet long, 73 feet wide, and 32 feet deep over the cill.

The hauling up of ships appears to have been practised from a very early period in the Venetian arsenals, and also at Toulon in France, where it was applied in 1818 to a large vessel; but the ships seem to have been only brought over an ordinary building slip, and then hauled up on the ways, being steadied by a sort of sliding cradle.

A special construction of carriage for this purpose was invented in 1818 by Mr. Morton of Leith, which is shown in Figs. 5 and 6, Plate 16. An inclined slip-way A is formed on a slope of about 1 in 20, and provided with rails on which travels the wheeled carriage B, the railway being extended sufficiently below the water to admit of the ship being floated over the carriage. By then hauling up the carriage by the chains and capstan gear C, the ship being attached to the chain is drawn up out of the water and above the influence of the highest tide, and is blocked up upon the floor of the slip so as to admit of the carriage being removed. To prevent the ship from heeling over while in the act of being hauled up, the carriage is provided with bilge blocks D sliding on timbers transverse to the slip. As the ship settles down on the keel blocks and before she

is removed from the water, these bilge blocks D are hauled in until they support the bilges, the hauling being done by ropes led up to the deck of the ship. This appears to have been the first use of proper bilge-block shores which could be applied while the vessel was still afloat ; and in the writer's opinion such a mode of sustaining vessels at the bilges before the water support is taken away is of the greatest utility, on account of its importance in preventing undue straining or risk of heeling over. In ordinary graving docks, it is true, bilge shores are used ; but they are not applied until the water has been removed from the dock, and therefore not until after the ship has been subjected to the strains arising from the weight of her contents without her natural water support.

Morton's slips, which are now in extensive use, were at first intended only for small vessels, but they have lately been constructed for ships of 2000 to 3000 tons burden. With small vessels little difficulty was experienced in building the slips, especially where there was a considerable rise and fall of tide, because the lower part of the slip could be constructed at low water ; but when the longer modern vessels were required to be taken up, the length of the slip-way below the water became very great, as a slope of 1 in 20 requires the length of slip below water to be 20 times the draft of the vessel merely to reach her stem, and the slip must then be carried still further to extend under the length of the vessel. As this portion had to be constructed by the aid of divers, and its execution was attended with serious difficulty, it has been proposed to shorten the slip in the three ways shown combined in Fig. 7, Plate 16. The first plan is to make the slip of a curved form, giving a steeper slope to the upper portions of the slip, so that the length below the water line is not so great as if the slope had been continued uniform up from the bottom end ; the second mode, intended for places where there is a rise and fall of the tide, is to enclose the upper part of the slip within water-tight walls and to employ gates for shutting out the water ; and the third plan is a telescopic construction of the cradle on which the ship is lifted.

In Fig. 7 the ship is shown partially raised, and with all the lengths of the telescopic cradle fully drawn out. A A represents

the surface of the slip made to a curve ; E the gates, placed just below where the vessel will be when fully hauled up ; B the telescopic cradle, composed of lengths attached to each other by rods F, so that when it is lowered it may rest at the bottom of the slip collapsed to about one half its full length. As soon as the stem of the vessel takes its bearing on the first section of the cradle and the hauling commences, this first section is drawn out from the second to the full extent of its coupling rods, and the second is then drawn out from the third, and so on ; the result being that the vessel is securely taken up on a cradle requiring no greater length of slip-way below the ship than half the length of the ship. By these various contrivances the length of slip has been considerably shortened from what it would have been if constructed on the original system unaltered ; but as regards the dock-gates and the water-tight side walls, it may not unfairly be said that their use is inconsistent with the employment of a simple slip, nor indeed could they be resorted to in a tideless sea without the expense of pumping apparatus to empty the upper part of the slip.

The application of this slip to vessels of a larger class soon rendered some improvement necessary in the simple hauling chain that had sufficed for ships of 200 tons. A set of traction rods was first substituted for the body of the chain, and was hauled in by a short flat-linked chain working over a pitched wheel driven by gearing. The end of this flat chain was first attached to the foremost rod, and then hauled in until the second rod was brought up to the place of the first, when the flat chain was overhauled and made fast to the second rod ; and this operation was repeated with the successive traction rods until the ship was fully drawn up. A further improvement consisted in making the flat-linked chain endless, so as to avoid the necessity of overhauling it. For some time past however the larger slips that have been erected have been worked by the direct application of hydraulic rams to the ends of the traction rods ; and among other plans double presses have been employed, made to work alternately, so that the hauling up might be nearly continuous.

An important adjunct to the slip is an arrangement of transverse lines of rails in the building yard at the upper end of the slip, so that by the use of carriages the vessels hauled up can be shifted sideways, thereby enabling a single slip to serve for hauling up several vessels in succession, so that their repairs may be going on at the same time.

The simple plan already mentioned of placing a ship on a beach at high water, so that it may be left dry at the ebb, is still used where there is a considerable rise and fall of tide; and to enable it to be carried out without risk of unequal support to the ship, a regular open framing of beams is made on the beach, called a "gridiron," by means of which vessels can be blocked up, and properly examined and repaired at low water. There is of course the objection that at the rise of each tide the work has to be suspended; but nevertheless the system is so simple and inexpensive, and the vessels are so readily got off and on, that it still continues to be used.

In the plans previously referred to for lifting vessels out of the water, the vessels have been hauled up on an incline; and in the class of Direct Lifts, which has now to be considered, the earliest is that of Mr. Alexander Mitchell, the inventor of the screw pile, who in 1833 proposed to employ the rise and fall of the tide for raising vessels out of the water by the means shown in Fig. 4, Plate 15. Two parallel rows of piling A A are placed sufficiently wide apart to admit the vessel between them; and B B represents a permanently buoyant floor, made of light materials or of caissons. On the ebb of the tide this floor sinks between the piles, and at low water pins C C are fixed in the piles above the flooring. When the tide next rises the floor is held down by the pins, and at high water the vessel is brought over the floor and allowed to settle down on it, being maintained in an upright position by shores from the piles. At the next ebb the ship is duly propped up by bilge shores from the floor; and the side shores being then removed and the holding-down pins withdrawn, the flooring is lifted by the next rising of the tide, taking up the ship with it, which rises and falls with the

buoyant flooring at each tide until the repair is completed, when the flooring is again held down for the vessel to be floated off at the next high tide. This plan is evidently not suitable for cases requiring rapid access, as it needs at least three low and three high tides for enabling a vessel to be got on and off.

In 1827 a Screw Lift was constructed in America for raising vessels independent of the tide. This is shown in Fig. 10, Plate 17, and consisted of a platform A on which the vessel was to be lifted, the ends B of the transverse timbers of the platform being steadied by two parallel rows of piles C C, placed far enough apart to admit the vessel between them. The longitudinal timbers which connected the heads of the piles carried a number of vertical screws, as many as 46 having been used in one instance, the lower ends of which were connected to the transverse timbers of the platform, so as to raise the vessel out of the water. Since 1836 however this lift has been worked by means of hydraulic presses. Fig. 11 shows the arrangement which the writer saw at work at New York in 1853. Chains shown by the dotted lines are attached to the ends of the transverse bearers B B of the platform, and pass over pulleys to the long traction bars D, the land ends of which are connected to the hydraulic presses E for lifting the platform with the ship upon it.

In 1842 an improvement upon the screw lifting dock was proposed by Mr. Robert Mallet, which is shown in Fig. 9, Plate 16. The framework B on which the ship is to be raised is carried on a number of supports C C, hinged at their lower ends to eyes D supported on the rock or on piles, and at their upper ends to the frame B, forming a sort of parallel-ruler motion. The slings E attached to the top of the supports C are provided at their upper ends with rollers, which run within a tubular rail F having a continuous slot on its underside, as shown to a larger scale in the section Fig. 8; and the slings are hauled in by the chains G worked by powerful steam winches. The frame B being lowered and the ship drawn over it, the chains are then hauled in, so as to pull the slings horizontally, thereby raising the framing until the ship is lifted out of the water. This arrangement has the advantage of giving a

nearly uniform strain on the chains and machinery throughout the lifting of the vessel, inasmuch as at the commencement, when the supports are nearly horizontal and carry but little of the weight, the slings are vertical and the weight of the ship is almost entirely carried by the water; while by the time the ship has lost the support of the water and the slings have become inclined, the supports have assumed a position more nearly upright, and therefore, although the whole weight of the ship has now to be borne by the lift, the proportionate strain coming on the chains is but small.

In the lift designed by Mr. Scott in 1850, and shown in Fig. 14, Plate 18, the ends B B of the cross timbers of the platform A were attached to slings depending from the crossheads of a number of vertical hydraulic presses C C, the stroke of the presses being equal to the lift of the vessel. It was intended either to repair the vessel on the platform, or to move it off on railways either endways or sideways, so as to make one lift answer for the simultaneous repair of several vessels.

The ship lift of Mr. Edwin Clark, which was put to work at the Victoria Docks, London, in 1857, is shown in Figs. 12 and 13, Plate 17. The two parallel rows of cast-iron columns A A contain hydraulic presses, and the slings from the crossheads of the presses are attached to truss girders B B which extend from side to side of the dock. If the lift be used at a place where repairs are not frequent, these girders carry the framing on which the ship is to be lifted; but if the lift is expected to be much used, as in the case of the Victoria Docks, then these cross girders carry a saucer C or shallow wrought-iron vessel of sufficient capacity to float the largest ship which can be taken on the lift. The girders being down and the saucer upon them, the ship is floated and adjusted over it; and the hydraulic presses being put to work, the saucer is raised until the blocks touch the keel of the vessel; bilge blocks are then drawn in against the vessel, and the working of the presses is resumed until the saucer is raised above the water. The saucer is provided with large valves, which are opened during the time of raising, so that the water runs out as the saucer rises; but as soon as the saucer is fully up, these valves are closed, and then the repair is either done on the lift, or

else the girders are lowered again and the saucer left floating with the ship on it. The saucer is then hauled away to one of the basins D D, Fig. 13, which it just fits both in surface dimensions and draft of water; and the repairs are executed there, leaving the lift at liberty to be used for other vessels. At the Victoria Docks there are now eight of these saucers in use.

Another lift that was erected in the London Docks consisted of a pontoon carrying a deck, over which the vessel to be raised was hauled, the pontoon at the time being full of water. When the vessel was adjusted over the pontoon, the water was pumped out from it, and then the pontoon rose, lifting the vessel with it. To preserve the surface of the pontoon horizontal in rising, a number of parallel-ruler joints were connected to the pontoon and to eyes at the bottom of the basin. Unfortunately this apparatus failed before any ship had been docked upon it. The failure is believed to have been due to a want of strength in the parts, as the pontoon on being lowered sprung so serious a leak that it became impossible to raise it again, and it remains a wreck to this day.

In each of the various plans already considered, with the single exception of careening by the aid of another vessel, it has been necessary that there should be some connection with the solid ground; but Floating Docks properly so called dispense with the necessity of any such connection with the land for the purpose of support, as the dependence for support is on the water alone, the only requirements being a sufficient depth of water and a holding ground to which the apparatus can be anchored.

As early as 1785 a Floating Dock was constructed by a shipbuilder named Watson at Rotherhithe, which is shown in Fig. 15, Plate 18. It consisted of a timber vessel, 245 feet long, 58 feet wide, and 23 feet deep on the blocks, having an open end which could be closed by gates. Water being admitted into the vessel to sink it to a sufficient depth, the gates were opened, the ship to be repaired was drawn in, and then the gates being closed and the sluices shut the water was pumped out, leaving the ship in the interior of a true floating dry-dock. Mention is made of one vessel, the "Mercury," having been docked in this dock

with great success. No provision appears to have been made to regulate the descent of the dock nor to prevent it from sinking too low, and it is to be assumed that the material employed being wood was in itself sufficient for this purpose. Docks of a similar character have been constructed at various times and places; but in order to ensure stability they have been sunk between guiding piles upon a level bed, and were therefore not true floating docks, that is, docks independent of the land. Such a dock it appears was proposed to be constructed for the port of Havre about 1848.

In 1809 Trevithick and Dickinson designed a floating dock or caisson of wrought iron, with air chambers at the sides for floating the dock when its body was full of water. It was then to be sunk by admitting just as much water into the air chambers as was required for making it very slightly in excess of the specific gravity of the water; and the ship being brought over it, the caisson was to be raised by ropes until its top edge was brought just above the surface; and then the water was to be pumped out of the body of the dock, so as to make the caisson rise all round the ship, leaving the ship accessible for repair. The size of caisson proposed was 220 feet long, 54 feet wide inside, and 30 feet deep, the top being surrounded by a flat rim 6 feet wide to serve as a working platform and also to strengthen the edge. The record of this idea appears to possess considerable interest, as showing that even so early as 1809 the possibility of constructing a wrought-iron caisson of these large dimensions was contemplated.

The Sectional Floating Dock, invented about 1837 in the United States, is shown in Figs. 16 and 17, Plate 18. The sections AAA, from which the dock takes its name, are each composed of a bottom caisson B, on the ends of which are raised frames CC carrying platforms and houses DD. The frames are made high enough for the greatest depth to which the dock has to be sunk, so that the platforms and houses may at all times be out of the water. In the frames are placed air tanks EE, capable of vertical movement within the frames; or rather the frames are capable of movement past the tanks, as the latter remain without much variation in reference to the level of the water that the dock is floating in. The

connection between the tanks and frames is made by means of rack and pinion gearing, worked off shafting which extends along the dock from the engines in the houses on the central section. The same shafting also works, in all the houses, pumps connected with the bottom caissons B. In applying this dock for lifting a vessel, a number of the sections are brought together and secured to one another by tie beams; and sluice valves being opened to admit water into the caissons B, the dock begins to sink. The gearing connected with the air tanks E is then put to work, so as to allow the tanks to remain at the surface of the water while the dock sinks to the desired depth, at which it is then held suspended by the air tanks. The sluice cocks are then shut, and the vessel is drawn into the dock and secured in a central position by "breast shores." The pumps are then all put to work to raise the dock until the vessel takes the keel blocks, when the bilge blocks are hauled in to support her, and the pumping is continued, causing the dock to rise, lifting the vessel with it. In the act of rising the whole is in a state of unstable equilibrium and would be liable to turn over, were it not for the air tanks, which by means of the gearing are still kept at the water level. By this arrangement, if the dock endeavour to heel over, it is at once restrained by the air tanks, as it cannot change its perpendicular position without drawing those on one side partially into the water, and raising the opposite ones an equal amount out of the water. Thus if due precautions as to bulkheads be taken in the construction of the dock, to prevent an excessive force from being applied to turn the dock over, the side air tanks are sufficient not merely for determining the point to which the dock shall sink, but also for giving it stability both in rising and in sinking. These sectional docks have been connected with a system of railways, so that a vessel might be run off the dock on to the rails and be repaired there, while the dock was used to lift another vessel.

The Balance Dock or Box Dock, introduced in the United States in 1839, is shown in Fig. 18, Plate 19, and consists essentially of a pontoon bottom with two side walls. The pontoon possesses sufficient displacement to carry the whole weight of the dock and of

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any ordinary vessel that has to be raised. The side walls are hollow and of considerable width, serving the same purpose as the air tanks in the sectional dock, namely to prevent the dock from sinking too far and to preserve its stability in rising and sinking. Port holes are made in these walls to assist ventilation, and the walls afford the means of shoring up the ship by breast shores as in a stone dock; on the top are the enginehouse and pumps and the working platform. For lifting the heaviest vessel that could be taken inside the dock, gates have been fitted at the ends of the dock, so that it might float with the surface of the pontoon below the water and thus acquire an additional amount of buoyant power according to the depth of immersion.

Several balance docks have been constructed in America, which the writer believes have all been built of wood. The dock at Havana was built at New Orleans in 1858, and was towed out without accident to Havana. It is 300 feet long by 79 feet broad, and the hollow floor is 9 feet 6 inches deep; it can lift a vessel of 20 feet draft. It is provided with one steam engine, having a cylinder 12 ins. diameter and 30 ins. stroke, working with 60 lbs. steam, and driving seven pumps with barrels 24 ins. diameter and 30 ins. stroke, making about 14 double strokes per minute. Being constructed of wood, with a solid thickness of 2 ft. 6 ins. of timber in the flooring, the floating power of this dock is so great, that for sinking it not only has all the available space to be filled with water, but 500 tons of ballast have to be added. The total cost of this dock was £100,000.

In 1859 the writer, in conjunction with Messrs. Miers and Maylor of Rio de Janeiro, designed for the Brazilian government a plan of Floating Lift which combined the principles of the American hydraulic lift and of the floating dock. This is shown in Fig. 19, Plate 19, and consisted of two parallel floating pontoons A, carrying between them a framing B, on which the ship was to be lifted by chains, pulleys, traction bars, and hydraulic presses C, precisely as in the American arrangement. Two presses however were here applied to each traction bar, one at the further end and one half-way, whereby the strains on the traction bars, and therefore

their requisite sectional area, were diminished; and the presses were so arranged that they made the lift in two strokes of half the length. The pontoons were arranged to separate into parts, when required for shorter vessels at different places; but when these parts were used combined together for the largest ships, means were provided to ensure the preservation of the full strength of the pontoons as girders.

In considering the essential principles of a good Floating Dock, and the defects most important to be guarded against, the first and principal requirement appears to the writer to be that the ship should be supported on as rigid a bottom as when on a building slip or in a stone dry-dock. This condition however is not universally recognised, and on the contrary it is urged that, if a vessel has assumed a certain distorted form in the water, this form ought to be retained when out of the water for the purposes of repair; and it is alleged that this can be accomplished by giving the ship an elastic bearing, such as that afforded by the separate portions of the sectional dock, or by the somewhat yielding saucer of the Thames graving dock. The employment of an elastic bearing appears to the writer however to be erroneous, because it is based on the assumption, either that the ship having already gone out of shape to a certain extent will not yield further; or that all the parts of a vessel are of equal weight per foot run, so that the elastic bearing will yield to an equal extent at all parts throughout the entire length of the vessel, which is evidently contrary to fact.

The other requirements of a floating dock are,—stability—ventilation—facility for repair of the dock itself—and a minimum expenditure of power and time in lifting the dock. The materials employed should also be arranged in such a manner as to obtain a maximum of strength from a minimum of material; and the design should be one admitting of many repetitions of a few forms, so as to allow of the work being done to a few standard templates, avoiding as far as possible any necessity for welding heats and smith's work.

As regards the question of stability, the difficulty is experienced not when the dock is raised with the surface of its floor fairly above the

water, but during the time that it is in the act of raising or lowering a vessel. The stability of the dock when raised is great, as illustrated by Fig. 20, Plate 19, where A represents the centre of gravity of the dock with the vessel, B the centre of buoyancy when the dock is not heeled over, and C the new centre of buoyancy when the dock is heeled over. It will be seen that the new centre C is far outside the perpendicular from A, and that there is therefore a strong tendency for the dock to right itself. But when the dock has been sunk so that the bottom is entirely below the water line, then some contrivance must be resorted to not merely for keeping it from sinking to the bottom of the sea but also for keeping it from turning over.

When the vessel in the dock is equally loaded on each side of its centre line, and is placed on the keel blocks perfectly in the centre of the dock, then during the raising of the dock the whole is free from any tendency to turn over to one side more than the other, but at the same time is manifestly in a state of unstable equilibrium. Now if the dock heel-over a little under any influence, such as the wind, the causes which would increase its inclination and turn it over are, first, the fact of the centre of gravity of the ship and dock being no longer over the centre of support; and secondly and largely, the fact that the water remaining not yet pumped out shifts its position in the dock, and thereby seriously affects the stability, unless proper arrangements be made for preventing such an occurrence. In some docks that have been constructed due attention appears not to have been paid to this point, and the writer believes it is principally from this cause that failures have occurred in floating docks.

If a floating dock made without any longitudinal water-tight bulkheads, as in Fig. 21, were half full of water, and were to be heeled-over sideways so that the surface of the water should extend as a diagonal from corner to corner, the result would be to shift the centre of gravity of the water to A, one-third the width of the dock from the lower side or one-sixth from the middle. But if the dock have one longitudinal water-tight bulkhead along the centre, as in Fig. 22, then the same amount of heeling-over will cause the surface

of the water to assume the shape shown in each compartment, which may be looked on as being divided into two equal parts, a parallelogram and a triangle. The centre of gravity of the two parallelograms B C D E will of course be the same as before the dock was heeled over, while the centres A A of the triangles being one-sixth of the total width from their lower ends, the common centre of gravity G of the two will be at one-twelfth of the width from the centre of the dock, or only half the distance of the centre of gravity in the former case; but as the contents of the two triangles taken together are equal to only half the triangle in the former case, the effective moment tending to turn the dock over is only 1-4th of that which it was without a bulkhead. Similarly if three bulkheads were put in, so as to divide the dock into four compartments, the effect of the water in turning the dock over would be reduced to 1-16th of what it was when there was no bulkhead; and generally, the tendency of the water to turn the dock over when it is at all inclined diminishes in the ratio of the squares of the number of chambers into which the dock is divided.

The foregoing principles were kept in view by the writer on the occasion of having to design a Floating Dock for the Danish Island of St. Thomas, in the West Indies. This dock has been prepared in England, and is now in course of erection at St. Thomas; and it is shown in Figs. 24 and 25, Plates 20 and 21. The leading particulars are as follows: length 300 ft., external width 100 ft., clear width between the side girders 72 ft., depth of bottom 9 ft. 9 ins., extreme height 42 ft. 3 ins. The dock can take in and lift, leaving an adequate amount of free board, a vessel drawing 24 ft. of water and not exceeding 4000 tons of actual weight, not tonnage; and the weight of the dock, with machinery and all complete, is about 3400 tons.

A A are the main longitudinal girders, and B the separate transverse water-tight pontoons, six in number, forming the bottom of the dock. These have "set downs" at the ends, where they receive the bottoms of the main side girders, as shown in Fig. 25; and as any one pontoon may have either to support the girders or to be partially supported by them, the connection has been made by

means of very strong attachments rivetted to the pontoons and having shanks extending down to the very bottom of them. Cross plates are placed over the diagonals of the main girders, near the junction of the diagonals with the uprights; and on these plates bear strong cotters, so that if one of the pontoons were quite full of water it could be lifted by the others without the least injury. This attachment of the pontoons to the girders is one which can at any time be readily undone, so that any pontoon can be detached and floated away, and then taken up on the remaining pontoons for examination and repair.

The ship is supported in the usual way upon the keel blocks C, which are provided with folding wedges. These blocks are secured to the upper decks of the pontoons immediately over the longitudinal bulkhead D, which extends along the centre line of the dock in each pontoon. In this way a portion of the weight of the ship is transmitted directly to the bottom plates, say over the area E F. Another portion of the weight is transmitted by the two sloping ties I of the athwartship trusses to the water-tight bulkheads J, and by these to the bottom plates, which take off a further portion represented by the spaces F G. A further portion is transmitted through the ties K to the uprights L, and thence to the bottom at G H, and so on to the end. There are nineteen of the athwartship trusses above described, placed side by side in each pontoon; and at the point M is provided a system of fore-and-aft trussing, whereby the whole of these athwartship trusses are connected with the fastenings by which the pontoons are hung up to the main girders A A. In this way the weight of that part of the ship which bears on any pontoon is upheld either entirely by that pontoon alone, or by transmission of the surplus weight through the main girders to some more lightly loaded pontoon; and in order to enable any lightly loaded pontoon to receive the load brought upon it by the girders, each pontoon is provided with a reverse set of diagonals in the athwartship trusses, which transmit the weight from the sides towards the centre.

The bilges of the ship are supported by the hinged bilge-shores N N, which are provided with soft wood caps and wedges to take the

immediate bearing against the ship, and are upheld by pauls of two different lengths, so that when the range of the shorter pauls is passed the longer pauls come into play. These pauls take into rack plates, which are supported on transverse timbers. The pressure produced by the bilge-shores is transmitted mainly to the longitudinal watertight bulkheads J in the pontoons. This system of bilge-shores was proposed by Messrs. Miers and Maylor in the Brazilian hydraulic dock before referred to.

When the dock is fully up with the ship on it, the pressure from the water is comparatively trifling, being not more than about 9 feet head of water against the bottom plates; but when the dock, after being sunk to its full depth and having received the ship, is in the act of beginning to rise by the water being pumped out, then the pressure of the external water upon the bottom plates of the sunken portion is about 28 feet head of water or about $12\frac{1}{2}$ lbs. per square inch or 4.5ths ton per square foot. In order to economise material, the writer determined on resisting this pressure, not by means of "frames," as in a ship, because for so large an extent of surface their weight would have been excessive; but by means of a system of inverted queen trusses O O. As regards the vertical plates, forming the sides and ends of the pontoons, these trusses are in most cases complete; but as regards the top and bottom plates and a few of the vertical plates, advantage is taken of the various diagonals of the main trusses to form portions of these minor trusses so far as they extend. This arrangement does not require one piece of metal to fulfil two duties at a time, inasmuch as when the main trusses are fully loaded, by the dock being fully raised and carrying the whole weight of the vessel, the pressure produced by the water is then but slight, and therefore the small trusses come upon the main trusses for only an inconsiderable amount of assistance; whilst when the dock is sunk and the full strain comes upon the small trusses by the pressure of the water, the main trusses are not then required to exert any resistance in respect of the vessel, which at that time is borne by the water.

The bottom members of each of the main girders A A are formed not only to resist extension, but are provided with sufficient lateral

stiffness for resisting compression, by being composed of two parallel double girders P P, connected at the bottom by horizontal struts and diagonal ties. The top member of each main girder is composed of two small girders Q Q, similar to those of the bottom member but united at their lower edges by a floor R forming a trough section. This trough has its sides and bottom made water-tight, and is covered with a wooden deck carried on iron deck-beams; and within it are the various shafts and gearing for the working of the dock. The diagonals of the main girders A A are formed each of two plates, connected by stretchers, bolts, and lattice bracing. The uprights of the girders are made of open lattice columns with strong angle-irons at the corners; and to these angle-irons are rivetted plates and other angle-irons, which act as guides for the floats T. From each of the uprights and from the junction of the diagonals extend the main altar frames S S to the top of the pontoons; and between each pair of these main frames are intermediate lighter altar frames. The feet of all the altar frames are secured to the pontoons by being placed within angle-iron wedging pieces, and by being bolted to the pontoons. This arrangement is adopted to admit of any pontoon being disconnected from its altar frames, when that pontoon requires to be docked for repair. The upper slopes of the altar frames are provided with steps, which receive the wood blocking for the purpose of applying shores to the ship when necessary, and also to afford support for the gangway boards which extend longitudinally from altar to altar. The risers or spaces between these boards are left open, so as not to interfere with the ventilation.

There are in all twelve floats T, one to each of the bays of the two main girders A A; each float is 46 ft. 9 ins. long, 11 ft. 3 ins. wide, and 5 ft. deep. A longitudinal central web extends from end to end of each float, worked out in three places to form boxes for receiving the tubes of the nuts through which pass the three regulating screws U. The floats are made with angle-iron "frames" placed transversely at frequent intervals, and every second frame has diagonal ties added which transmit the upward strain to the central web and thence to the screws. Immediately opposite each screw there is

a transverse truss having double diagonals, to take the weight of the float when lifted for repairs at any time while the dock is above water. The exterior of the dock is protected by wooden waling pieces and fenders.

It was the original intention to deck over the pontoons with a wooden deck laid with $\frac{1}{2}$ inch spaces upon beams placed on the tops of the pontoons; but fears were entertained that during the repairs of iron steamers this deck might be set on fire. The wood deck was therefore abandoned, and a Portland cement deck 3 ins. thick was decided on; but experience has shown that this is not necessary, and that a coating of cement and tar $\frac{1}{2}$ inch thick is all that is required for protecting the tops of the pontoons. Portland cement however has been used in the interior of the pontoons, to fill up all confined places where decay might arise.

The deck on the top of the main girders A A of the dock is widened by brackets for a length of 100 feet at the centre, and on this part are erected the enginehouses W W with workshops at the ends. Each enginehouse contains a boiler of locomotive construction, having a firegrate 3 ft. 4 ins. square, and a barrel 3 ft. 6 ins. diameter and 7 ft. 6 ins. long, containing 110 tubes 2 ins. diameter. The boilers are fed by injectors with fresh water carried in tanks made in the top of the girders. A wrought-iron well is also provided to each enginehouse, which hangs down between the central uprights of the main girders and contains a feed pump to draw water from the sea whenever required. Each boiler supplies steam to a pair of inverted direct-acting engines, having cylinders of 10 inches diameter by 15 inches stroke, working the pumps through the line shafts V V which extend along each side of the dock. The pumps are placed inside the uprights of the main girders, in the spaces between the ends of the floats T. At the centre upright there are two pumps, one of which pumps out the pontoon to the left and the other that to the right. In each of the next two uprights on either side there is one pump connected respectively with the second pontoon and the third or end pontoon. The pumps are 17 inches bore, and the stroke can be varied from 12 inches to 24 inches by altering the position of the crank-pin in the disc driving each pump. The

R

linings, buckets, and suction-valve seats are of gunmetal, and there are doors by which the valves and buckets can be examined or removed when the dock is raised; means are also provided for drawing up the bucket and valve when the dock is sunk, or for sending down another valve on the top of the first without removing it; or the lateral outlets through which the pumps discharge can be closed, and the bucket being withdrawn a workman can descend to the suction valve itself. Each pump is provided with a pipe between the clack and the bucket, by which air can be admitted, so as to stop or check the action of any one pump out of each set of three, the admission of the air being governed by a cock. A float in each end of every pontoon indicates the quantity of water in the pontoon; and the tubes through which the float-rods pass up serve as air tubes to the pontoons.

Two small direct-acting inverted engines are also placed in each enginehouse, fitted with link motions and driving by gearing the shafts XX, which extend right and left along the top of the dock to work the regulating screws U, of which there are three to each float T. These screws are 6 inches diameter and $1\frac{1}{2}$ inch pitch; their bottom ends are formed with collars like the thrust bearings of a propeller shaft, and cased with gunmetal; they are supported in steps fitted with bearing surfaces made of discs of *lignum vitæ*. The screws work in cast-iron nuts, which are contained in deep cast-iron tubes fixed to the floats. The spaces in the tubes above and below the nuts are filled up solid with tallow. As the screws make only 200 revolutions during the whole ascent or descent of the dock, the speed of the engines has to be greatly reduced by the gearing; it can however be varied at pleasure, so as to allow for greater rapidity in the descent than in rising.

On each side of the dock a screw-cock inlet-valve is provided on every pontoon, to admit the water for sinking the dock. These valves are worked in four separate sets of three each, by handwheels in the enginehouses, gearing with the shafts YY extending along the top of the dock. In each enginehouse there are two tell-tales, to show the fore-and-aft and the athwartship level of the dock; each consists of an index magnifying by means of gearing the angular

movement of a pendulum. Speaking tubes extend from one enginehouse to the other, and also from each enginehouse to the bridge at the end of the dock, from which the orders are given ; this bridge is closed, as shown in Fig. 24, except when the very longest ships are taken in.

The mooring of the dock is made from a single mooring anchor placed to windward, to which is secured a chain of 35 fathoms length, made of flat links of the form employed in suspension bridges, with the eyes rolled in the solid. To this chain are attached two smaller chains, each 35 fathoms long, which are made fast to the mooring rings on the head or windward end of the dock. At the stern end there are two small mooring chains, led away at an angle to two mooring anchors ; these chains pass over rollers up to capstans at the top of the side girders, by which they can be hauled in as required. There is a one ton crane on each of the four quarters of the dock, for raising or lowering material, &c.

From the foregoing description it will be seen that, for the purposes of working, the dock may be considered as divided into four independent sections ; for in each of the two enginehouses the engineer has the power of working independently the set of three pumps on the right and the set on the left ; and the same with regard to the floats and the inlet valves. In order to lower the dock for receiving a ship, the inlet valves are all opened to admit the water into the ends of the pontoons as far as the water-tight bulkheads J ; the central portion never requires to be filled, inasmuch as the whole buoyancy of the dock can be overcome by the admission of water into the side compartments. While the dock is sinking, the engines working the regulating screws U are put to work at such a speed as to keep the floats T always one half immersed in the water. When the dock is sunk to the required depth, the inlet valves are shut, and the ship, which has been moored close to the dock moorings and therefore directly to the windward of the dock, is hauled in over the keel blocks and adjusted by means of breast tackles and shores. The pumping engines are then put to work, and the dock is raised until the

keel blocks just take their bearing against the vessel; and the bilge shores being hauled taut so as to secure the vessel thoroughly, the pumping is resumed, and the screw engines are put to work at their slow speed, so that as the dock rises the floats are still maintained just about half immersed. In Fig. 25 the float T on the left-hand side is shown raised into an intermediate position, which is the position it would occupy when the dock is rather more than half raised: when the dock is fully up, the float is in its lowest relative position, having its bottom level with the underside of the girders P P, which form the bottom member of the main girders A A; and when the dock is sunk to the extremity of its range, the top of the float is up against the underside of the girders Q Q, which form the top member of the main girders A A.

In a properly constructed dock it is difficult to see what influence could force the dock out of level under any circumstances; but supposing it were ever found that, in the raising of the dock now described, one corner was becoming low and the opposite corner high, this would immediately be corrected by altering the working of the screw engines, so as to depress the three floats at the low corner, and elevate those at the high corner. This alone would always be sufficient to adjust the dock, without interfering with the pumping, which might go on continuously; but there is in addition the power of throwing any three of the pumps out of gear while keeping the others at work, and the inlet valves of the high corner might even be opened to let the water in again, if this were desirable in an extreme case.

In designing the construction of Floating Dock that has now been described, the object of the writer was to supersede the objections that appear to him to attach to the Morton slip and other ship lifts, and also to the two principal of the previous floating docks, namely the Balance dock shown in Fig. 18, and the Sectional dock shown in Fig. 16. The reason for discarding the use of slips and lifts was that they are dependent on the earth for their support. This objection however did not apply to the sectional or the balance dock, both of which, like the St. Thomas dock, have

the important advantage of being wholly independent of the land, and are therefore capable of use in any place where there is sufficient shelter and depth of water, combined with the means of mooring. The grave objection in the writer's opinion to the sectional dock is its entire want of rigidity. Although this does not apply to the balance dock, yet this dock also involves objections which the writer believes to be of importance. One is that, as ordinarily built in one entire structure, the balance dock requires either an excavation into which water can be admitted to float the dock after its completion, or else the construction of very large and expensive launching ways. Moreover the rigidity and also the stability are obtained by the use of complete side walls, which have a large displacement when the dock is sunk. As far as the question of rigidity is concerned, the writer believes that these side walls involve the use of more iron than is required in an open girder to obtain the same strength; while they absolutely preclude efficient ventilation at the sides of the ship, and present a large extent of surface for reflecting the heat of the sun and for the wind to act upon. The engine power for pumping out the water is also increased as compared with open sides by the greater displacement of the solid sides when sunk, which involves a corresponding increase in the quantity of water to be taken in and subsequently pumped out.

In the St. Thomas Dock, although the lower part is composed of six separate pontoons, for facility both of original construction and of subsequent examination and repair, the objection applying to the sectional dock is got over by the use of the strong side girders. These are provided with a double set of diagonals, and have their top and bottom members made of such strength as to be capable of resisting a strain tending to depress either the middle or the ends. Thus supposing the dock is in the act of raising a paddle-wheel steamer, which has a large portion of its weight accumulated in the centre, and only a small portion at the ends, the girders will transmit the surplus floating power of the end pontoons to the assistance of the heavily loaded central pontoons; and in the event of two small but heavy vessels being taken on at the ends of the dock, the girders will convey the extra flotation of the central pontoons to those at the extremities of the dock.

As regards the important question of stability and the means of controlling it, it is to be observed that even with the balance dock shown in Fig. 18 there is nothing to fear so long as the upper surface of the bottom is fairly above the water, because on any attempt at heeling-over, the rectangular bottom produces a change in the position of the centre of buoyancy so rapid compared with any slight inclination of the dock that the tendency to right itself is very strong indeed. Moreover at that time the dock is pumped dry, and the danger arising from shifting the centre of gravity of the internal water is at an end. In Fig. 23, Plate 19, taking *AB* as the water line, the balance dock is shown fully raised and heeled-over; and the power of restoring an upright position to the dock under these circumstances has already been fully investigated in reference to Fig. 20. But when the dock while in the act of being raised or lowered has its floor wholly immersed, as shown by the water line *CD*, then the tendency to restore equilibrium is not so great, as the effect of the whole triangle *EFG* is diminished by that of the interior figure *HIKL*. Moreover there is at that time within the dock a large amount of water, the centre of gravity of which is of course shifted by the heeling-over; and the effect of this is most serious, unless a sufficient number of bulkheads be provided to subdivide it into small sections. From whatever cause however the stability of a balance dock may have been disturbed, it is clear that the effect of its sides to restore equilibrium can be increased only in proportion to the amount of heeling-over, and can never be caused to exert any effect in excess of this. If therefore a balance dock has once heeled-over, it cannot be righted by its sides, so long as the force which caused the heeling-over is continued.

With the side floats however in the St. Thomas dock the case is different, as the position of the floats in reference to the dock can be controlled as desired; and therefore in the case of any heeling-over an extra immersion can immediately be given to the floats on the low side, while those on the high side can at the same time be raised more out of the water. By this means when the heeling-over is only slight and therefore the tendency to heel-over further is also slight, the floats can be made to exert as great a counteracting power as the walls

of the balance dock would have when the heeling-over was great and therefore the tendency to go further also proportionately increased.

Another important reason for preferring the open sides of the St. Thomas dock to the close sides of the balance dock was the saving of time in pumping for raising the dock. Supposing that the St. Thomas dock had been made with close sides, these would have had each a sectional area of 14 ft. wide by 25 ft. deep when fully immersed, which with 300 ft. length would give 210,000 cubic feet total displacement for the two sides. The section of the bottom is equal to 900 square ft., which with 300 ft. length gives 270,000 cubic feet, or 7700 tons; but as the dock with all its machinery complete weighs 3400 tons, only 4300 tons of water have to run in, equal to 150,500 cubic feet. Hence the close sides would have added 21-15ths to the amount of water to be pumped out; so that the time required for pumping out the dock if the box sides had been used would have been in the ratio of 36 to 15, or 12 to 5, as compared with the open sides.

In respect therefore to the three questions of ventilation, stability, and economy of pumping, the writer trusts that he has shown satisfactory reasons for preferring the open lattice girders with moveable floats to the close box side-walls of a balance dock.

Mr. R. MALLET remarked that the paper just read gave a clear account of the successive methods employed for docking vessels, and of the latest improvements that had been effected in the construction of floating docks. At the present time the use of floating docks was becoming more and more important at foreign stations as the number of iron steamers increased; and he thought they would to a great extent supersede the ordinary masonry docks, except for the purposes of extensive arsenals and large dockyards. In the St. Thomas floating dock described in the paper, the addition of the series of adjustable air-floats in the open sides of the dock appeared a most important

improvement, affording the means of preserving the dock always truly level, by regulating the depth of immersion of the floats by means of the vertical screws. One of the principal difficulties attending the adoption of floating docks for foreign stations was the necessity of transporting them from the place of construction to their destination: if they were sent out in one piece, there was the danger attendant upon towing them across the open sea; while if sent in a number of separate pieces, there was the serious increase in expense for putting them together at a foreign station, often with imperfect appliances, and for launching them where there might not be sufficient shelter. If a floating dock could be contrived which should be furnished with the means of navigating itself out to its destination, he thought it would combine the two elements necessary to a complete commercial success; and a model was shown in the present International Exhibition of a floating dock furnished with screw propelling power and similar in external shape to a ship, obviously for the purpose of working itself out to its destination, and perhaps intended to retain its power of propulsion for future use while employed in docking ships. He enquired whether it would have been considered an advantage, in the case of the St. Thomas floating dock, to construct it so that it could be sent out from England complete without taking to pieces. Another interesting contrivance shown in the Exhibition for lifting ships was a steep slip, somewhat similar to the Morton slip described in the paper, but arranged with a considerable number of parallel chains for bringing up and launching a ship broadside on instead of endways; a slip on this plan had been constructed by Messrs. Labat at Bordeaux, and had been in actual use for several years, and by this means vessels could be taken up or lowered down at a single tide.

Mr. BRAMWELL believed that the plan of drawing vessels up a slip broadside on instead of endways was originally suggested by Mr. Scott Russell, but he was not aware of its being carried out in practice. With regard to the question of conveying a floating dock to its destination, the floating dock at Havana was towed out from New Orleans without accident, as mentioned in the paper; but on the other hand, in the case of towing out a floating dock in the

Adriatic to the Austrian port of Pola, the towing ship was lost in a storm, and the dock itself was cast ashore, but was not injured. It was therefore a question to be decided for each particular case, whether it was preferable to put the dock together beforehand and incur the risk of towing it out complete to its destination, or to send it out in separate pieces to be put together on the spot at possibly a somewhat greater cost. The floating dock that had been referred to as fitted with the means of propulsion, of which a model was shown in the Exhibition, was not intended he imagined to navigate itself across the open sea to its destination; but he thought the propelling power was more probably provided only for enabling the dock to shift its position with facility through short distances at the station where it was employed. A floating dock now being constructed at North Woolwich for the Bermudas was also being provided with power for propelling itself.

Mr. R. W. THOMSON remarked that with regard to the advantage of sending out a floating dock in pieces, to be put together at its destination, it should be borne in mind that all work which required only rivetting could easily be put together at any foreign station at a cost not much exceeding the sum paid for the same amount of rivetting in this country; and it was only when smiths' work was required that the expense of erecting abroad would be seriously increased. Having had to design a floating dock for Java in 1859, which was constructed by Messrs. Randolph and Elder of Glasgow, he had arranged all the plates of the sides and bottom to be precisely alike in every respect, and the rivet holes were all punched accurately to templates, so that any of the plates would go together indiscriminately with perfect accuracy; and the same principle was carried out as far as practicable in the construction of the girders and other portions of the dock. The result had been that the whole of the work went together with the greatest facility, and the cost of erecting was also extremely moderate, the whole cost of the entire work being very much less than could have been the case if the dock had been made to take itself out to its destination. He had had the opportunity of seeing this dock put together abroad, and had never seen anything of the kind in boiler

work which went together with less trouble; and he therefore considered it was more economical and satisfactory to send out a floating dock to a foreign station in pieces than in any other way. The difficulty of launching appeared to him to be somewhat overrated, because a construction of that character he considered would not draw more than from $2\frac{1}{2}$ to 4 feet of water; and by erecting it in a small basin excavated to just that depth below high-water level, the dock was readily floated out when the fore-shore of the basin was removed. By this method the dock already mentioned had been successfully floated at Surabaya in Java, although it had unfortunately been lost subsequently through carelessness in sinking it before the sides had been caulked completely water-tight. Two more floating docks had been constructed at the same works on substantially the same plan, one of which was now in use at Callao in Peru, and the other at Saïgon in Cochin China; and no portion of these was put together at home.

Mr. W. CLAY remarked that he had lately seen at Copenhagen a floating dock in which the water was driven out of the pontoons by the pressure of air forced in by an air-compressing pump, instead of pumping the water out in the usual manner, the object being to save power by avoiding having to pump the water up to any greater height than necessary, as the dock gradually rose out of the water; and he understood that this mode of working the dock was very successful in practice.

Mr. C. W. SIEMENS observed that the plan of raising a floating dock by forcing in compressed air to expel the water did no doubt possess the advantage pointed out, that it avoided raising the water to a greater height than the external level; but in practice he thought there was not really any saving of power by this plan, because in the ordinary plan of pumping the water out each gallon of displacement in pumping represented exactly one gallon of water pumped out; whereas in employing compressed air it would be necessary to force in more than a gallon of air of atmospheric pressure for each gallon of water expelled, according to the depth of immersion of the dock; that is, supposing the diameter of the pump and number of strokes to be the same in both cases, a longer

stroke would be required for compressing and forcing in the air than for simply pumping out the same bulk of water. Moreover in the employment of compressed air in the manner described, he was not fully satisfied that the action would be uniform in expelling the water and raising the dock; it would have to be ascertained by practical trial whether the accumulation of compressed air in the pontoons would not give rise to an uneven and spontaneous action in expelling a large volume of water through expansion, when a reduction in the resisting head of water had once taken place.

In the St. Thomas dock described in the paper he fully concurred in the advantage of the regulating air-floats for adjusting the level of the dock in rising or sinking; and he enquired whether there would be any liability of the dock heeling over towards either side, in case it ever happened to rise or sink more rapidly than the floats could be adjusted in height by means of the regulating screws. In the instance of a large floating dock which he had seen constructing at Carthagena in Spain two years ago, he had observed that an expensive masonry dock was also being constructed, which he understood was intended to contain the floating dock; and he did not see what was the object of building the masonry dock as well as the floating dock, since it appeared the St. Thomas floating dock and others described in the paper were constructed for use in open harbour.

Mr. BRAMWELL was not aware of the reason for building a masonry dock to contain the floating dock at Carthagena, unless it was intended simply as a guide for the floating dock in sinking and rising, the masonry dock being without a gate, and in that respect differing from an ordinary dry dock. The same was the case also in regard to some of the American sectional floating docks, which had stone chambers constructed to contain them; but if a floating dock were so built as to be really serviceable for the purposes of a floating dock, he was at a loss to understand the desirability of constructing in addition a masonry dock to receive it.

With regard to the plan of expelling the water from the pontoons of the floating dock by forcing air in, he had been much inclined to adopt that method for the St. Thomas dock; but he had feared

the possibility of some such accidental mishap as had been alluded to, from the dock being brought up with a rush by any sudden liberation of the compressed air forced in; and he had therefore preferred to adhere to what appeared the safer plan, namely to pump the water out. In the event however of constructing any other floating dock like that for St. Thomas, he should certainly go into that question fully, and make a point of seeing the Copenhagen dock at work, in order to ascertain the real results of the experience in that instance. One objection to pumping the water out of the pontoons for raising the dock was that this produced of course a tendency of the hollow pontoons to collapse under the external pressure, and they had to be properly strengthened to resist that pressure; whereas in injecting air to expel the water this difficulty was got rid of, as the internal pressure of the air was at least equal to the external water pressure. On the other hand a much better class of workmanship was required in the pumps for dealing with air than for pumping water; and much more work was thrown upon the pumps in injecting air, as they had first to compress the air to the required pressure before they could force it into the water chambers of the pontoons.

In reference to the working of the adjustable air-floats in the St. Thomas dock, it would not be possible for the dock ever to sink more rapidly than the floats were allowed to rise, because the floats when only half immersed had buoyancy sufficient to sustain the dock when the water chambers of the bottom pontoons were full of water; and in rising, if the floats were prevented by any accident from descending rapidly enough, the rate of pumping out the water could be reduced to as slow a speed as desired, or the inlet-valves could be opened again to re-admit the water to the pontoons on either side of the dock. By these arrangements ample provision was made against any possibility of the dock heeling over either in rising or in sinking.

Mr. R. MALLET enquired whether the water pumped out of the pontoons was discharged by the pumps always at the same level.

Mr. BRAMWELL replied that the discharge orifices of the pumps were situated at only 5 feet height above the top of the pontoons forming the bottom of the dock, so that during the greater

portion of the time of raising the dock these orifices were under water, and therefore the water pumped out was not lifted unnecessarily above the level of the external water; and it was only when the dock was almost fully raised that these orifices came above the external water level, and even then the height of lift for discharging the water was so small as to be practically unimportant.

From the particulars given in the paper of the previous constructions of floating docks, it would be evident that there had not been much room for introducing any entirely new features in the St. Thomas dock; and in designing the construction that had been described his endeavour had been, not so much to do something that had not been done before, as to combine the advantages that were offered by the principal plans previously employed, while at the same time avoiding the objections which he conceived to attach to each. He had thus combined the open sides and repetition of similar parts which characterised the American sectional dock, with the rigidity which constituted the important superiority of the box dock; thereby avoiding the objections of the flexibility of the former, and the want of ventilation of the latter, together with the want of sufficient power for controlling the dock in rising or sinking. The harbour of St. Thomas was the principal depot for the West Indian mail steamers, but as there had hitherto been no dock at that station large enough to receive these vessels, they had been obliged to go for repairs to the box floating dock at Havana; this dock was found troublesome in working from the difficulty of keeping it level in rising, so that it was apt to go sideways in the water, requiring the pumping to be stopped and the water to be re-admitted into the dock, which involved much delay in the operation of raising a ship for repairs. By the open sides of the St. Thomas dock however, not only was good ventilation ensured, but all the time and labour were saved that were required in the box dock for pumping out the large quantity of water contained in the closed box-sides.

With regard to the importance of making the several parts to fit together in erection with the greatest facility, he had kept this object in view in the design of the St. Thomas dock, in which the plates of the bottom pontoons were made exact repetitions of the same pattern,

so as to go together indiscriminately, and consequently no difficulty whatever had been experienced in the erection. At the same time great care had been taken to avoid any necessity for smiths' work in the operation of erecting the dock at its destination, and everything had been done to get plain rectilinear work alone. The putting together at St. Thomas had been commenced on 24th April last, and the dock would probably be completed ready for work in about two months from the present time, making about three months for the entire erecting.

The PRESIDENT remarked that the paper which had been read gave a very complete idea of the gradual development of this important branch of engineering; and he moved a vote of thanks to Mr. Bramwell for his paper, which was passed.

The Meeting was then adjourned to the following day.

The Adjourned Meeting of the Members was held in the Lecture Theatre of the Conservatoire Impérial des Arts et Métiers, Paris, on Wednesday, 5th June, 1867; JOHN PENN, Esq., President, in the Chair.

The following paper, by M. Tresca, Engineer Sub-Director of the Conservatoire Impérial des Arts et Métiers, was read :—

FLOATING DOCKS.

Plate 15.

Fig.1. *Careening, alongside a quay.*

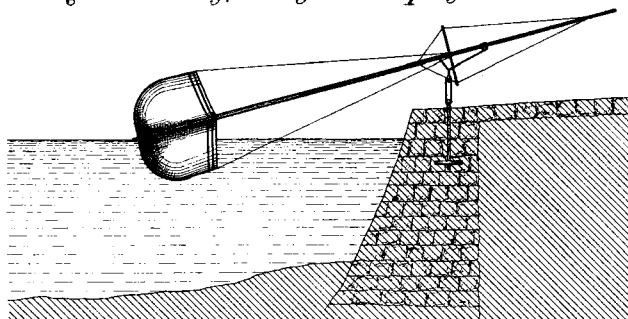


Fig.2. *Careening independent of land.*

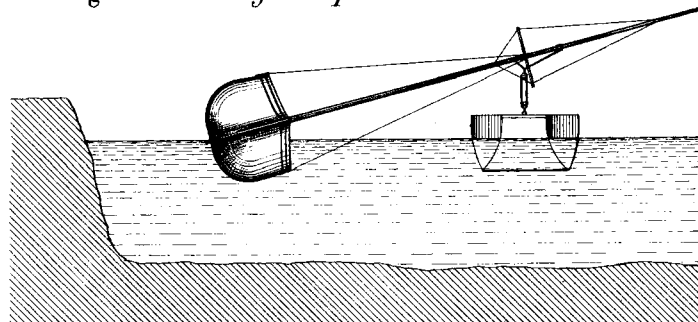


Fig.3. *Graving Dock.*

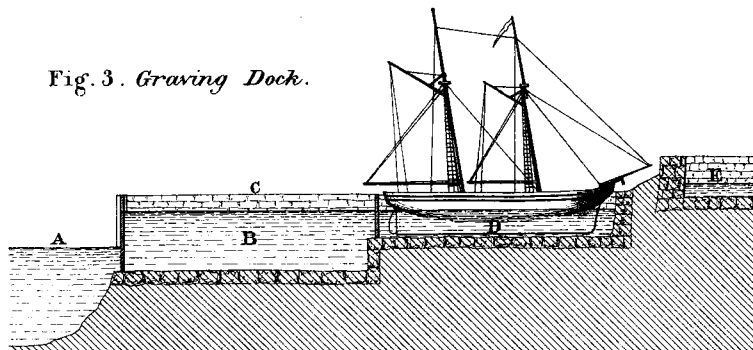
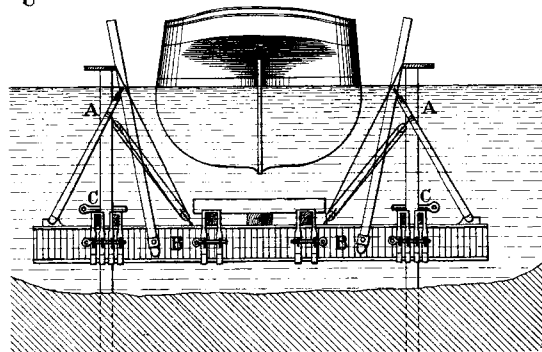


Fig.4. *Mitchell's Tidal Lift. 1833.*



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FLOATING DOCKS.

Plate 16.

Fig. 5. *Morton's Slip*. 1818.

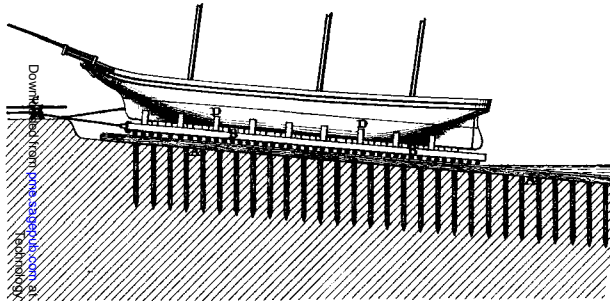


Fig. 7. *Curved Slip, with Dock Gates and Telescopic Cradle.*

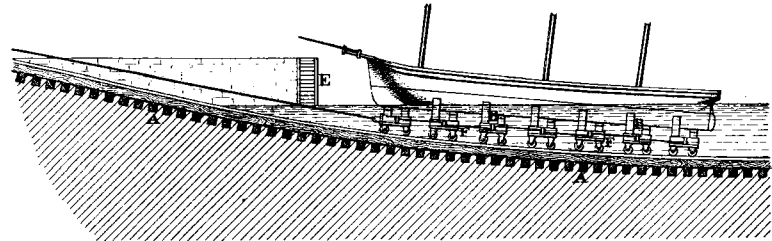


Fig. 6. *Transverse Section of Morton's Slip.*

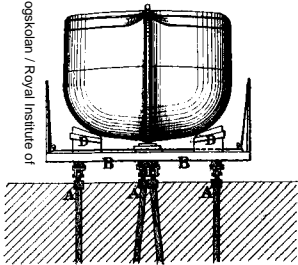


Fig. 8. *Section of Tubular Rail carrying slings.*

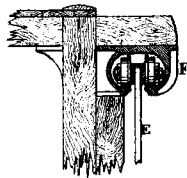
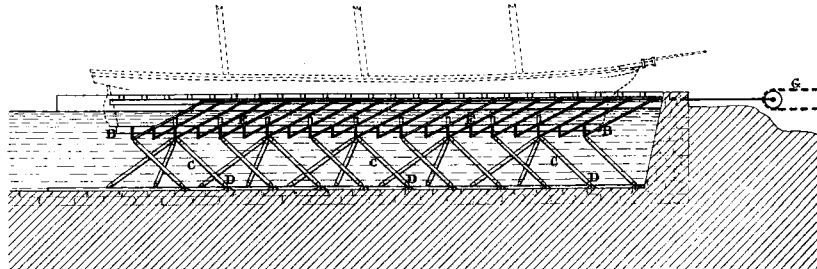


Fig. 9. *Mallet's Parallel - Slings Lift*. 1842.



FLOATING DOCKS.

Plate IV.

Fig. 10. *American Screw Lift*. 1827.

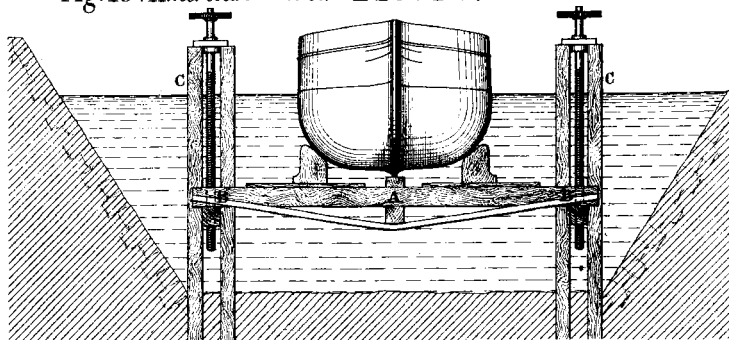


Fig. 11. *American Hydraulic Lift*. 1836.

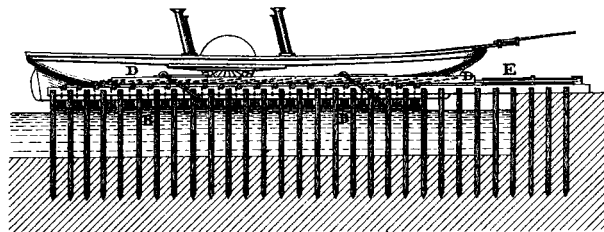


Fig. 12. *Clark's Hydraulic Lift at Victoria Docks, London*. 1857.

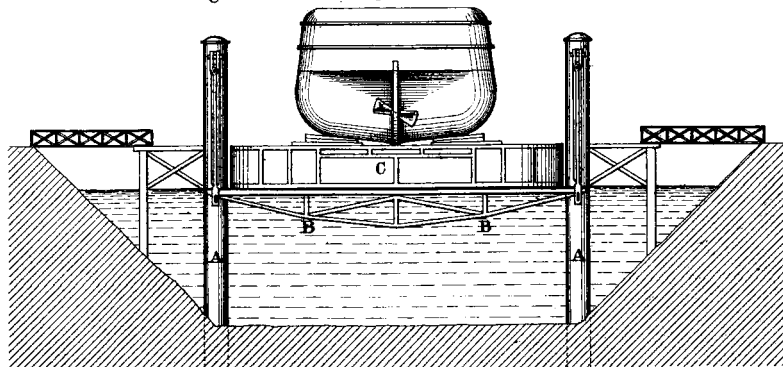
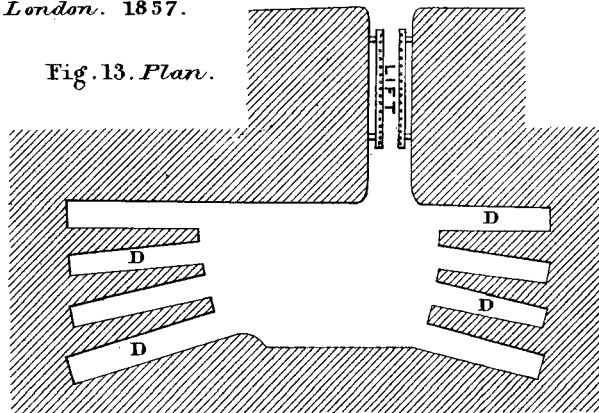


Fig. 13. *Plan*.



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FLOATING DOCKS.

Plate 18.

Fig.14. *Scott's Hydraulic Lift.* 1850.

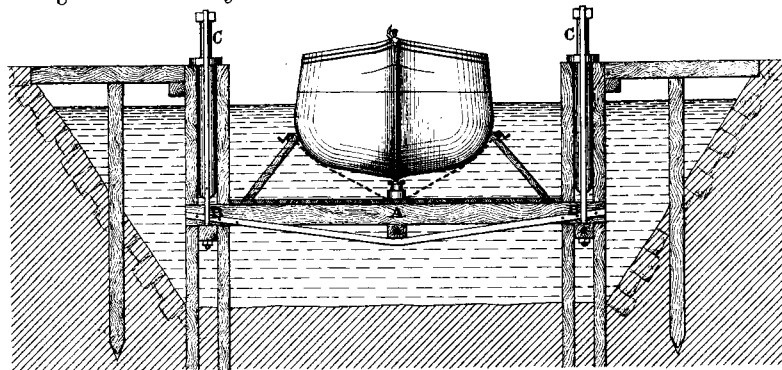
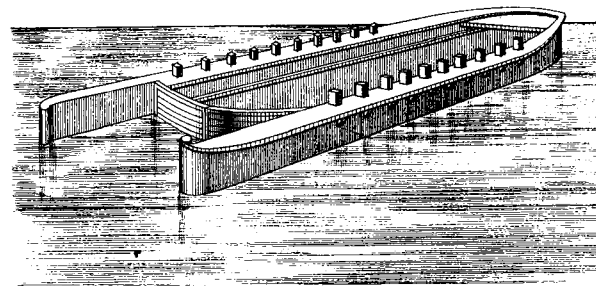
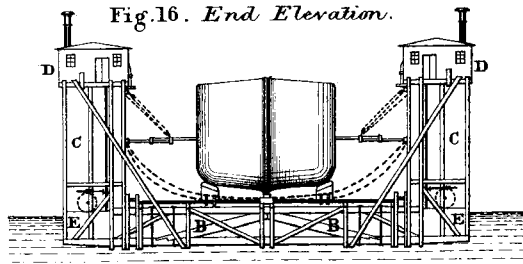


Fig.15. *Watson's Floating Dock.* 1785.



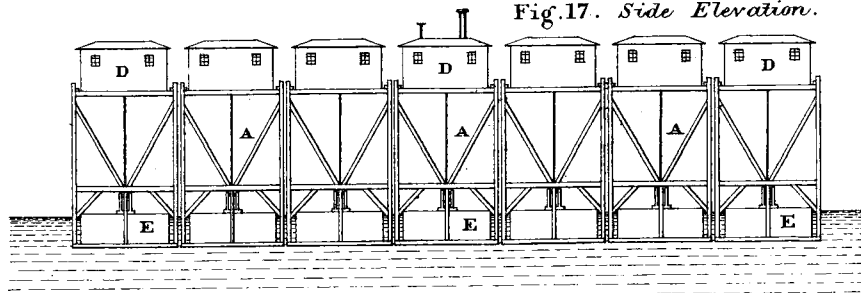
American Sectional Floating Dock. 1837.

Fig.16. *End Elevation.*



(*Proceedings Inst. M. E.* 1867. Page 80.)

Fig.17. *Side Elevation.*



FLOATING DOCKS.

Plate 19.

Fig. 18. *American Balance or Box Floating Dock.* 1839.

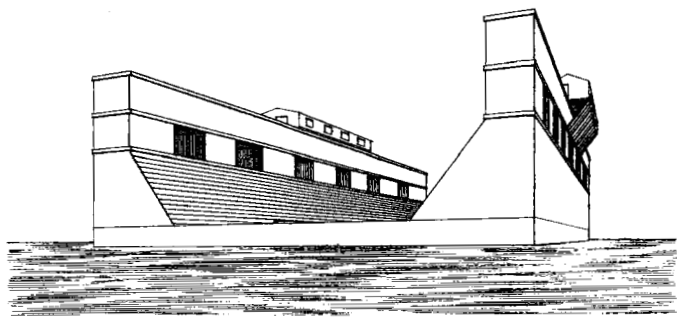
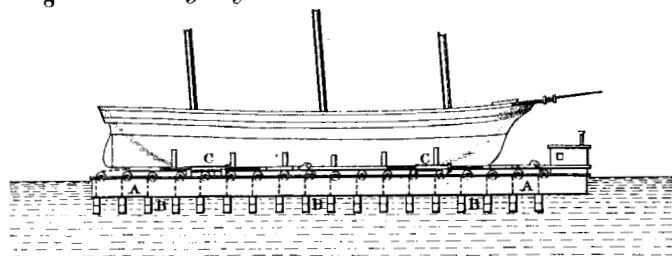


Fig. 19. *Floating Hydraulic Lift for Brazil.* 1859.



(*Proceedings Inst. M.E.* 1867. Page 80.)

Fig. 20.

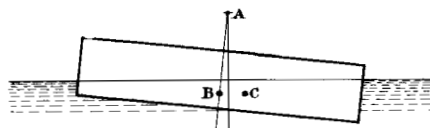


Fig. 21.

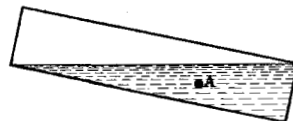


Fig. 22.

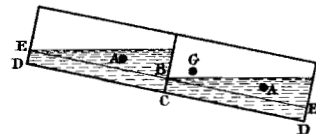


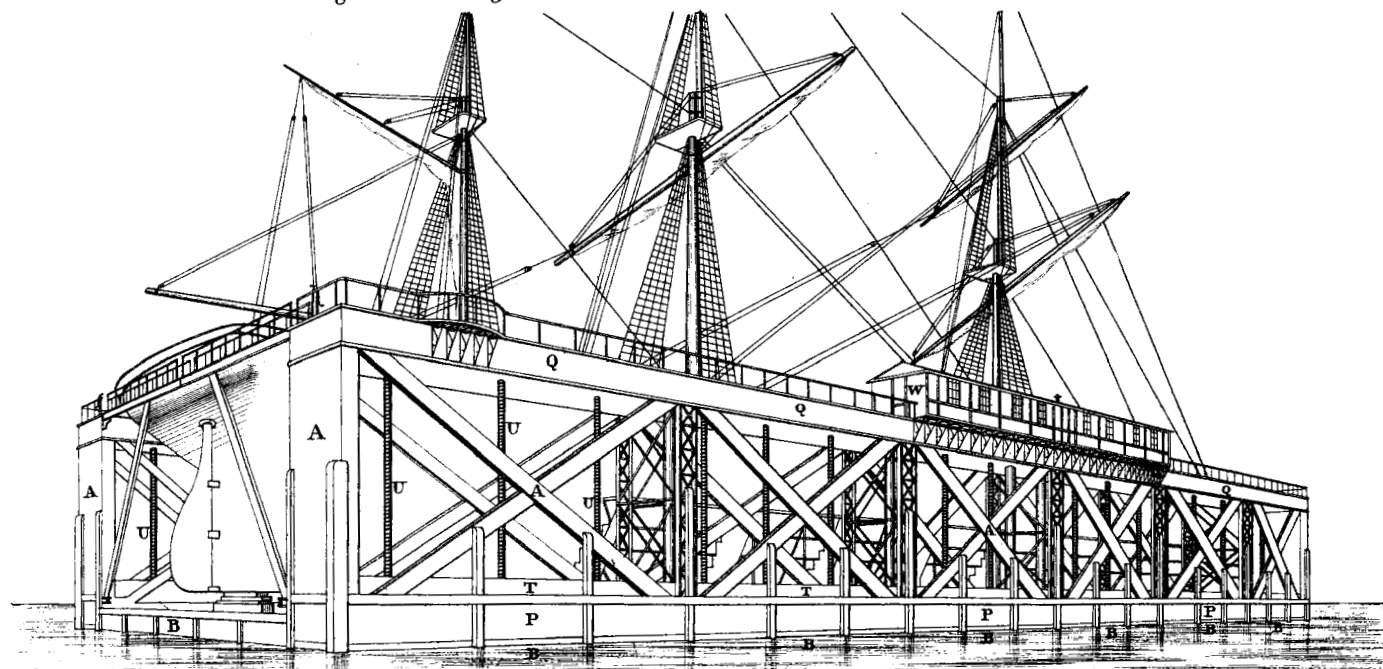
Fig. 23.



FLOATING DOCKS.

Plate 20.

Fig. 24. *Floating Dock for St. Thomas, West Indies. 1867.*

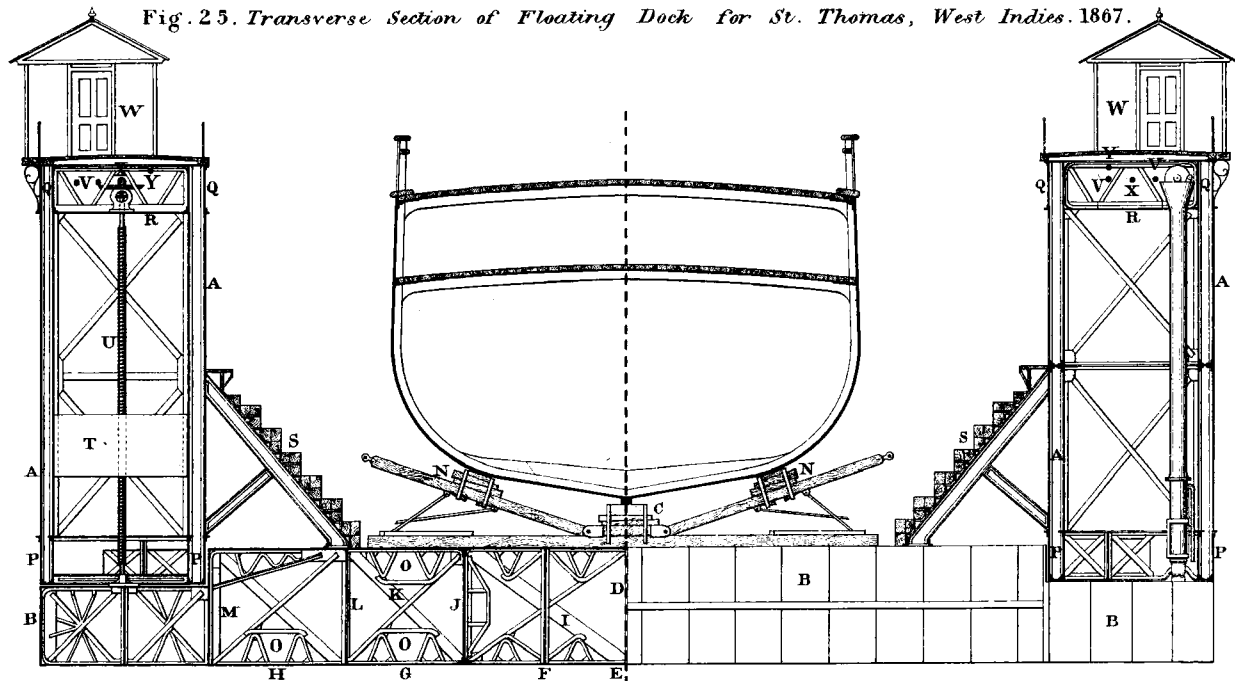


(*Proceedings Inst. M. E. 1867. Page 80.*)

FLOATING DOCKS.

Plate 21.

Fig. 25. Transverse Section of Floating Dock for St. Thomas, West Indies. 1867.



(Proceedings Inst. M. E. 1867. Page 80.) Scale $\frac{1}{200}$ 10 5 0 10 20 30 40 50 Feet.