(*Students' Paper No. 134.*)

"Caissons for Dock Entrances."[1]

By Daniel Macalister, Stud. Inst. C.E.

In this Paper some of the different types of caissons at present in use, and their external and internal arrangements, are described and illustrated by practical examples.

Caissons are constructed of timber and also of iron, and may be divided into three classes, viz., floating, sliding, and rolling caissons. Floating caissons are of two types; one of a rectangular or box form, fitting into a berth or recess in the dock entrance, and having meeting faces on its sides; and the other like a ship, having a keel and stem, with meeting faces secured to them, which fit into a groove in the dock entrance.

Iron Box Caissons (Plate 6, Figs. 1, 2 and 3).

Box Caissons are constructed of wrought-iron plating and angle-iron framing, stiffened by stringers, decks, and diagonal bracing. A little above the level of low water, a watertight deck divides the caisson into two compartments, the lower one being an air chamber of sufficient capacity, or displacement, to bring the caisson almost into a state of flotation when the water is at the level of the watertight deck, the upper compartment being for the purpose of floating the caisson when it is desired to open the dock. When the dock is closed, water is allowed to flow into the upper compartment through valves, to prevent the caisson from floating when the water in the dock is above the level of the watertight deck. To open the dock, the valves are closed before the tide rises to the level of the watertight deck, and as it rises above that level the caisson gradually floats out of its berth and is then hauled by tackle to one side of the dock entrance, out of the way of ships entering, or leaving, the dock. To close the dock again, the caisson is hauled into position across the entrance, the valves in the upper compartment are opened,

[1] This communication was read and discussed at a meeting of the Students on the 11th of March, 1881, and has been awarded a Miller Prize.

and as the water flows in, the caisson gradually sinks into its berth and the dock is closed. To ensure regularity in sinking, the upper compartment is often divided by bulkheads into three divisions, with sluices to each, by regulating which, any tendency of one end to sink before the other may be counteracted. A sufficient quantity of ballast is placed in the bottom of the air chamber, to give the caisson stability during the operation of floating it into, or out of, its berth. The upper deck forms a roadway or bridge, to carry locomotive, or ordinary carriage and foot traffic across the dock.

Timber box caissons are divided into compartments and worked in a similar manner to those constructed of iron, but they may be of almost any form; as an example, the caisson at the Regent graving dock, designed by Mr. W. R. Kinipple, M. Inst. C.E., is horizontally of a crescent shape, thus giving a greater length of floor of dock in the centre.

Ship Caissons.

Ship caissons are constructed with wrought-iron keels and stems, angle- or T-iron frames, plated sides, and timber or iron decks, like an ordinary sailing ship.[1] The sides of the dock entrance and the stems of the caisson are battered to enable the caisson, when floating at the draught line, to clear the entrance. The caisson is floated out of and into its berth in the entrance like a box caisson.

Another form of caisson is that designed by Mr. David Cunningham, M. Inst. C.E., which might, however, be more correctly classed as a gate, because it is fastened at one end to the masonry of the dock entrance, and on being opened is swung round into a recess in the side wall in a similar manner to one leaf of an ordinary dock gate. It is constructed like a dock gate with the addition of a special pneumatic chamber or reservoir. When in position closing the dock, the caisson is suspended by projecting brackets secured to its ends, resting on corbels in the masonry of the entrance. To open the dock, air is pumped into the pneumatic reservoir, which causes the caisson to float off the corbels, and it is then swung round into the recess. To close the gate, the caisson is swung back into position across the entrance, the air is allowed to escape from the reservoir, and the caisson sinks until the brackets rest on the corbels.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lxiv., plate 7.

Sliding Caissons.

A sliding caisson is a box caisson, which, instead of being floated out of its berth on the dock being opened, is hauled endways into a recess in the side of the dock entrance. To do this, keels or rubbing-plates are fixed to the bottom of the caisson, which rest on sliding ways in the floor of the caisson berth and chamber, and when the hauling machinery is set in motion the caisson is hauled along the sliding ways into the chamber, leaving the dock entrance clear for the passage of ships, while the caisson is in a position of safety.

Rolling Caissons (Plate 7, Figs. 1, 2 and 3).

A rolling caisson is a box caisson, which is also drawn into a recess or chamber when the dock is opened. It is mounted on rollers which run on paths in the floor of the caisson berth and chamber (or the rollers may be placed on the floor and the keels on the caisson), and if it be desired to have a roadway over the caisson, the deck is mounted on levers which automatically lower as the caisson is drawn into the recess, to allow the platform to pass under the covering of the recess (Plate 8, Figs. 1 and 2).

The machinery for hauling the caisson into and out of the chamber may be a crab winch at the end of the chamber, and another on the opposite side of the entrance, with chains to each end of the caisson; or it may consist of an endless chain on each side of the chamber attached to a yoke and hauling bar projecting from the end of the caisson; the chains pass round a loose sheave on each side of the entrance to the chamber, and over two chain wheels keyed on to a shaft at the head of the chamber, which shaft may be worked by steam, hydraulic, or other power.

Iron Floating Box Caisson.

Figs. 1, 2 and 3, Plate 6, show the elevation, plan, and cross-section of the caisson at Messrs. R. and H. Green's new graving dock, Blackwall, designed by Messrs. Kinipple and Morris, MM. Inst. C.E. It is a box caisson 67 feet 3 inches in length, 10 feet in width, and 28 feet 9 inches in depth, having the outer corners rounded.

The caisson has one meeting face of teak-wood, which is protected from injury while the caisson is being shifted in and out of the berth by horizontal and vertical fenders projecting beyond the face. The outer plating of the caisson is of wrought-iron plates $\frac{7}{16}$ inch in thickness up to the watertight deck, and above that level $\frac{3}{8}$ inch and $\frac{5}{16}$ inch in thickness; the plating runs horizontally in alternate inside and outside strakes, lap-jointed and single-riveted; the vertical butt joints have cover plates, double-riveted. The plating of the bottom of the caisson is $\frac{1}{2}$ inch in thickness, and is stiffened by the vertical floor-plates $\frac{1}{2}$ inch in thickness, riveted to the side and bottom angle-irons. The spaces between these floor-plates are filled in with cast-iron kentledge and Portland cement concrete as ballast, to give stability to the caisson when floating. The angle-irons forming the side framing are 3 inches by 3 inches by $\frac{3}{8}$ inch, and placed 18 inches apart; the cross-beams of angle-iron up to the level of high water are 4 inches by 4 inches by $\frac{1}{2}$ inch, and above that level are 3 inches by 3 inches by $\frac{3}{8}$ inch, fastened with gussets to the side angle-irons; the uprights in the centre of the caisson are 4 inches by 4 inches by $\frac{3}{8}$ inch, and 18 inches apart; the angle-irons under the watertight deck are 5 inches by 3 inches by $\frac{3}{8}$ inch, widened at the ends and secured to the side frames; the deck beams are 3 inches by 3 inches by $\frac{3}{8}$ inch, secured by gussets. Horizontal plate stringers, 15 inches in width and $\frac{1}{2}$ inch in thickness, below the second tier from the top, and above that, $\frac{3}{8}$ inch and $\frac{1}{4}$ inch in thickness, are riveted to the cross-beams and secured by angle-irons to the outside plating and frames. The upper portion of the caisson is divided by watertight bulkheads into three compartments, each provided with regulating valves for admitting the water in order to sink the caisson into its berth in the dock entrance. At each end of the upper portion a watertight bulkhead forms a ventilator and manhole for access to the air chamber below the watertight deck. The bulkheads are of plating $\frac{3}{8}$ inch thick, stiffened with angle-irons riveted to the frames and beams, and secured to the watertight deck by angle-irons, thus forming efficient cross-bracing to the caisson. The meeting face of the caisson is of teak 14 inches in width by 7 inches in thickness, scarfed at the junctions, bedded in red lead, and bolted to 6-inch by 6-inch by $\frac{1}{2}$-inch angle-irons riveted to the caisson and following the curve of the masonry invert and the batter of the stop quoins. The seams between the angle-irons and teak face are caulked with oakum and pitch. The fenders are of rock elm 10 inches by 10 inches, secured by wrought-iron clips or brackets to the caisson. The planking of the roadway deck is of English oak 3 inches thick, secured to the deck beams and made watertight by caulking. Manholes are provided for access to the three upper compartments and the ventilators. Loop bolts are fixed to the corners of the caisson for attaching tackle for hauling it into and out of its berth. A 2-inch brass cock is fixed near the bottom of the inside face of the caisson to run off the bilge water into the graving dock, and a hand pump is provided to pump out any water in the event of the caisson springing a leak while out of its berth. The sinking valves are conical spindle valves of gun-metal, with spindles carried up to the roadway deck; the cast-iron inlet pipes pass by bends through the watertight deck, and are secured to the outside skin, the mouths being protected by brass rose heads. There are three sluices through the air chamber for filling the dock with water; the valves are 3 feet in diameter, of cast iron faced on both sides with gun-metal, and enclosed in cast-iron covers with gun-metal faces, and connected to the sides of the caisson by cast-iron pipes 3 feet in diameter, supported by the floor plates. The spindles are of gun-metal, passing up through the watertight deck in gun-metal stuffing boxes and continued up to the roadway deck by wrought-iron rods, worked by wheels and screws provided with indicators.

The dock was opened on the 16th of May, 1878, and the caisson has worked satisfactorily from the date of opening to the present time.

Iron Floating Caisson.

Figs. 4, 5 and 6, Plate 6, show the plan, elevation and cross section of the caisson at the Limekiln new graving dock, designed in 1864 by Mr. W. R. Kinipple. It is a box caisson of unusual form, being on plan like the two leaves of an ordinary dock gate, and is divided into an upper and a lower compartment by a watertight deck, these compartments being sub-divided by two watertight bulkheads. The outer plating is of wrought iron, the three lowest strakes being $\frac{1}{2}$ inch in thickness; the three above are $\frac{7}{16}$ inch, and the two top strakes $\frac{3}{8}$ inch in thickness, in alternate inside and outside strakes, with single-riveted lap joints and vertical butt joints with cover straps. The upper edge of the top strake is finished off with an angle-iron, to which is bolted a timber handrail. The plating of the bottom is 1 inch in thickness, and stiffened by the angle-irons forming the floor beams. The plating of the watertight deck is $\frac{7}{16}$ inch in thickness, having butt joints and cover straps, and connected to the skin plating and framing by angle-irons 3 inches by 3 inches by $\frac{3}{8}$ inch. The side frames are formed of similar angle-irons, spaced 2 feet apart, and divided into two pieces by the watertight deck. The angle-iron cross beams are also of the same size, secured to the side frames with lugs. The upright angle-irons in the centre of the caisson are 4 inches by 4 inches by $\frac{1}{2}$ inch, riveted at the intersections to the longitudinal angle-irons and the cross beams. The horizontal stringers in the lower compartments are 15 inches in width and $\frac{1}{2}$ inch in thickness, secured to the cross beams and skin; the stringers in the upper compartments are 12 inches in width and $\frac{3}{8}$ inch in thickness, and are secured in the same manner. The two watertight bulkheads are formed of plating of the same thicknesses as the corresponding strakes of the skin plating, and stiffened by angle-irons, thus forming very efficient cross bracing. The roadway deck is of fir planking 3 inches in thickness, caulked and made watertight, and is 2 feet below the top of the caisson, the sides of which form the hand-rails. The meeting face of the caisson is of 6-inch by $\frac{3}{4}$-inch plate iron, and abuts against the timber meeting face of the dock. Ringbolts are fixed to the caisson for securing the tackle used in hauling the caisson into and out of the berth. The ends of the caisson are protected by fenders of teak, which abut against the skewbacks or abutments of the dock entrance. The caisson is provided with sinking valves, drainage cocks, and sluices similar to those previously described; and in addition there are two sluices, or mud ports, at the level of the dock sill for the escape of muddy water; each sluice is 18 inches by 9 inches, clear dimensions, formed of plate iron with a cast-iron flap valve on the outer end, worked by chains from the deck.

This caisson has been in use from 1865 to the present time.

Sliding Caissons.

The Author understands that sliding caissons were first used at the Somerset dock, Malta, and afterwards at Portsmouth dockyard. Particulars of these have already been given.[1]

A good example of a sliding caisson also occurs at the Haulbowline navy yard, Cork.[2]

Three other examples of wrought-iron sliding caissons occur at the Milford docks for the lock and graving dock.[3]

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxiii., p. 362; and vol. lxiv., p. 145.

[2] *Vide* Spon's "Dictionary of Engineering."

[3] *Vide* "Engineering," vol. xxxi., p. 81.

Rolling Caissons.

Rolling caissons with horizontally bevelled ends have been introduced by Mr. W. R. Kinipple, and a Table is appended giving the principal dimensions of six caissons on this principle, either constructed or about to be constructed.

Cerro Graving Dock Caisson (Plate 7, Figs. 1, 2 and 3).

This caisson, designed for the Cerro graving dock, Monte Video, is a box caisson with keels attached to the bottom, which run on rollers placed on the floor of the caisson berth and the chamber in the side wall of the dock entrance. The caisson is similar in construction, internal fittings, and scantlings of framing and plating to the floating caisson at Blackwall graving dock previously described, with the exception that the ends are bevelled horizontally instead of being rounded.

The air chamber is of such capacity, and the caisson is so ballasted, as to bear on the keels with a pressure of about 5 tons when the tide is at the level of the watertight deck; and to keep this pressure uniform, adjusting valves are provided to allow the water to flow into the upper compartment as the tide rises above this deck. These valves are 8 inches in diameter, two on each side of the caisson, and of similar construction to those previously described. The keel rollers, set in the floor of the chamber, are of cast iron, with wrought-iron spindles lined with gun-metal, and working in gun-metal bearings in cast-iron frames. The rollers have flanges against which the spear ends of the keels press as the caisson is being drawn back into the chamber, thus causing the caisson to travel in the centre of the chamber, and so prevent abrasion of the timber meeting faces. Plate 7, Fig. 5, shows the form and dimensions of the keels, and the position of the rollers when the caisson is closing the dock entrance. The machinery for hauling the caisson into and out of the chamber consists of two endless chain cables, one on each side, attached to the ends of the yoke, which is fastened to the caisson by the hauling bar; these cables pass round loose sheaves at the entrance to the chamber, and over two chain-wheels keyed on to the driving shaft at the head of the chamber, the slack of the chains being carried by the chain rollers. The driving shaft is worked by a worm and spur wheel wrought off a capstan on the quay. Arrangements are made for keeping the caisson berth and chamber clear of mud, by placing the outlets of the filling and emptying culverts of the dock in the end walls of the berth and chamber. The chamber can be converted into a graving dock, for repairing and painting the caisson, by placing a temporary gate in a groove at the entrance to the chamber, and the water can be pumped out by a connection with the dock pumps. The caisson can also be floated out of its berth like an ordinary caisson, and placed against an outer meeting face, and so enable repairs and renewals of any work about the dock entrance and chamber to be effected without the aid of a cofferdam. When it is desired to do this the caisson is disconnected from the hauling machinery, the adjusting valves are closed at low water, and as the tide rises the caisson floats and is hauled back about 15 inches, so that one end clears the side of the dock entrance, and is then pulled round (Plate 7, Fig. 4) and sunk against the outer face in the position shown by dotted lines. The caisson has been constructed with bevelled instead of square ends, because with double-faced floating caissons of the ordinary types the side walls of dock entrances require to be built with a considerable batter, to enable the caisson to be floated in or out; and vessels entering, or leaving, a dock, with such an entrance, frequently have the paint or copper sheathing scraped off their bilges by rubbing against the sides of the entrance, under water. A case recently came under the notice of the Author, in which a large steamer had the grating over the injection pipe carried away as she was leaving a graving dock, by her bilge coming in contact with the battered side of the entrance under water. This accident would have been impossible in a dock entrance for a caisson with bevelled ends, as the side walls would be vertical.

Rolling Caisson at Garvel Graving Dock, Greenock (Plate 8).

This caisson was designed in 1871 by Mr. W. R. Kinipple. It carries a counterbalanced lowering bridge for foot, carriage, and railway traffic. The caisson is somewhat similar in construction to that at the Cerro dock, previously described, with the exception that the rollers are attached to the caisson and run upon plate rails laid on the floor of the chamber and berth, instead of the rollers being laid on the floor, and the keels secured to the bottom of the caisson.

The lowering bridge is mounted on the caisson (Plate 8, Figs. 1 and 2), the roadway being at the same level as the quay when the caisson is in position closing the entrance. When the caisson is drawn into the chamber, the bridge and the handrails are lowered sufficiently to allow them to pass under the covering of the chamber. It will be seen from Plate 8, Figs. 1 and 2, that the bridge roadway is carried by a series of levers or parallel bars, the upper ends of which are fixed to axles working in plummer blocks, secured to the bottom flanges of the girders of the bridge, and the lower ends to axles fixed in a similar manner to the cross girders of the caisson. The outside bars are secured to the ends of the axles, and are continued for 4 feet above the roadway to serve as railing standards, the whole forming a parallel motion like a pair of ordinary parallel rulers. To counterbalance the weight of the bridge the ends of two pairs of levers are extended downwards, and boxes containing ballast are attached to these. Plate 8, Fig. 1 shows the bridge "up" when the caisson is in position across the entrance, and the part elevation shows the bridge "down" when the caisson is in the chamber. Plate 8, Fig. 2, is an enlarged part cross section when the bridge is "up." The raising or lowering of the bridge platform is effected by rollers fixed on each end, which work against curved plates in the abutment and the curved girder or lowering plate across the entrance to the recess. In hauling the caisson into the chamber, in order to open the dock, these rollers (one of which is shown in Fig. 1) abut against the convex "lowering plate," causing the platform and the handrails to fall down automatically into the position shown by the full lines at the end of the elevation. To close the dock, the caisson is driven across the entrance, and the rollers on the other end of the platform come against a concave "raising plate" fixed in the opposite side wall of the entrance, causing the bridge platform to rise up to the level of the quay. When the bridge is "up" it is so locked between the abutments that it cannot fall down until the caisson is drawn back. The machinery for working the caisson consists of an oscillating three-cylinder hydraulic engine, driving the shaft with chain wheels and chains (Plate 7, Figs. 1 and 2). With this caisson the dock can be opened or closed, by the engine man, at any state of the tide, in three minutes, at a cost of about 3*d.*

To make the caisson scour out the berth and chamber every time the dock is opened or closed, the ends are close-plated, so that there is no opening through the body, as in the caissons at the Somerset dock, Malta, and at the Haulbowline dock, Cork. Thus, when the caisson is drawn back into the chamber, the whole of the water displaced by the advancing caisson rushes under it and past its sides, carrying along with it any mud which may have been deposited in the chamber or berth. The caisson has now been working for seven years, and the chamber has been kept quite free of mud or deposit, so that there has been no occasion to use a sluice for scouring purposes.

This caisson was constructed in 1872 by Messrs. Hanna, Donald, and Wilson, of Paisley, N.B., at a cost of £7,797 complete, as follows:—

	£.
Cost of caisson	6,050
„ lowering bridge	1,450
„ hauling machinery	297
Total	7,797

The cost of a similar caisson at the present time would be much less, as the contract price of the plating was £34 per ton.

It is difficult but at the same time necessary to get a nearly perfect watertight joint between the meeting face of the caisson and the stone face of the entrance of a graving dock, because a few inches depth of water on the floor of the dock interferes to a serious extent with the comfort and convenience of the shipwrights and others engaged in repairing vessels, and involves a considerable expenditure for pumping. It may not be out of place here to describe shortly how a practically watertight joint was obtained at the first trial of the Garvel graving dock caisson without packing the joint with wedges, felt, leather, or india-rubber. The meeting faces of the caisson are of teak, and abut against the polished faces of the granite inverts and quoins of the dock entrance. In order to dress the faces of the granite quoins to a vertical plane, straightedges were erected, perfectly plumb, on each side and in the centre of the entrance. Fine wires were then stretched from one straightedge to the other, and offsets taken from the wires to the faces, by teak blocks 4 inches square, and the faces of the stone were fine axed and rubbed down until the offsets measured uniform distances from the wires to any part of the faces. After the faces of the inverts and stop quoins were dressed to vertical planes, they were finely polished with sandstone and emery, so as to present perfectly smooth surfaces to the teak faces of the caisson.

The teak faces of the caisson were dressed in a similar manner, straightedges being set up at the corners, and after the faces were dressed by hand planes, they were rubbed with sand-paper to remove any roughness.

Rolling Caisson for the new Graving Dock at Point Levis, Quebec.

This caisson is similar in construction to that shown in Plate 7, Figs. 1, 2, and 3, with the addition of the lowering bridge for foot and carriage traffic shown in Plate 8, Figs. 1 and 2, and was designed in 1878 by Messrs. Kinipple and Morris. Instead of the spindle valves for letting water into the upper compartment, it is provided with a pendulum valve which works automatically. It is also provided with stop valves, and in the event of an accident to the pendulum valve, the caisson may be worked by the outside valves in the ordinary manner. The pendulum valve is mounted on a frame, and can be raised out of its seat by a screw, so that it can easily be got at for repairs.

Messrs. Wigham Richardson and Co., Newcastle, constructed this caisson, and delivered it on board ship at Newcastle, for the sum of £5,700. The contract included fitting together and erecting in the contractors' yard, then taking down, packing, and delivering on board ship for Quebec.

A similar caisson was designed in 1877 for the Esquimalt graving dock, British Columbia, by Messrs. Kinipple and Morris, but it has not yet been constructed, the dock works not being sufficiently advanced for its reception.

Rolling Caissons at Garvel Wet Dock, Greenock.

Two caissons for the entrances of this dock, now in course of construction, have been designed by Mr. W. R. Kinipple, and are to be finished this year. Each caisson differs slightly in internal construction from those previously described, the bridge being intended for frequent and heavy railway traffic. The cross girders, which carry the lower axles of the bridge levers, are so spaced as to be vertically over the centres of the keel rollers on which the caisson rests when the dock is closed, and wrought-iron columns extend from the bottom of the cross girders down to the bottom of the caisson, to transmit the weight of the dead and live loads of the bridge direct on to the rollers, to prevent the caisson being strained by the exceptionally heavy loads which will pass over the bridge.

Concluding Remarks.

The first cost of a floating caisson is no doubt less than that of a rolling caisson, because of the extra cost of the caisson chamber in the side of the dock entrance for the latter; but in numerous cases this is more than counterbalanced by the fact that the cost of working rolling caissons is only a fraction of the cost of working floating caissons. A rolling caisson can be hauled into or out of its berth by simple machinery, under the control of one man, at any state of the tide, and with a considerable breeze and current through the entrance. On the other hand a floating caisson can only be floated out at, or about, high water, when it frequently becomes quite unmanageable on a breezy day, or in a strong tide, requiring a large number of men to work it, and frequently it sustains damage by being driven against the quay. It is urged in favour of sliding caissons that they possess the advantage over rolling caissons of having no submerged rollers, which are liable to get out of order and difficult to get at. Rollers, however, possess the advantage of acting as guides to keep the rolling caisson in the centre of the berth and chamber while travelling, thus preventing abrasion of the meeting faces. Sliding caissons have no such guides, and if there is much clearance between the keels of the caisson and the sliding ways, there is a risk that the sliding caisson may jamb while travelling, as there is generally some current and frequently a strong breeze through a dock entrance, which, acting on the portion of the caisson, projecting beyond the chamber, while in motion, may cause one of the corners of the opposite end to come against the side of the caisson chamber. Possibly therefore the advantage rollers offer as guides may more than counterbalance any disadvantage they are said to possess.

The rolling caisson at the Garvel graving dock has now been in use since it was completed in January 1874, and there has never been any interruption to its working, although the rollers and paths have been submerged the whole time. From this it would appear that the objections commonly urged against submerged rollers and roller paths seem to be overstated, and further, if the rollers are placed in the floor of the chamber it is not a very difficult matter to remove them, or if they are placed on the bottom of the caisson they can be mounted in such a manner as to be easily removed.

A rolling caisson can be constructed with a lowering bridge to carry railway traffic across the dock entrance; and where it is necessary to retain water both inside and outside, as in a lock with double gates at its lower end, and to provide railway communication across, it possesses the advantages over double gates of shortening the length of the entrance, dispensing with a swing-bridge, and the cost of additional labour and machinery for working the gates and swing-bridge.

The contractors for the caisson for the new graving dock, Quebec, estimate the cost of a similar caisson, erected complete in a dock in the Thames, but with a lowering bridge for railway traffic, to be £8,000.

The width of the dock entrance is 62 feet, and as the overlap or width of the meeting face of the caisson is 1 foot on each side, the length of the caisson is 64 feet, and the depth is 31 feet 6 inches. A pair of dock gates having an overlap of 2 feet or a span of 66 feet, and having the ratio of rise to span 1 to 5, would be 71 feet in length, and 2,236 square feet in area. Mr. Harrison Hayter, M. Inst. C.E., estimates the cost of wrought-iron gates at from £1 10*s.* to £2 per foot super, when iron is about an average price.[1] The cost of gates of the above dimensions, at the average price of £1 15*s.* per foot super, would be £3,913, or very nearly half the cost of the caisson and folding bridge.

The Author believes that on comparing the cost of a lock fitted with a rolling caisson and folding bridge, with the cost of a lock with double gates and a swing-bridge, there will be, in the case of the former, a saving of about the cost of the swing-bridge. In the former, although there is the extra cost of the chamber, there is a considerable saving in the length of the entrance works over the latter, and these would probably counterbalance. The cost of two pairs of gates being about the cost of the caisson and folding bridge, the cost of the swing-bridge would be the excess of the latter, and to this must be added the cost of the machinery for working the dock gates and swing-bridge, together with the wages of men employed in addition to one man necessary to work the caisson.

The Paper is illustrated by several diagrams, from which Plates 6, 7, and 8 have been engraved.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lv., p. 72.

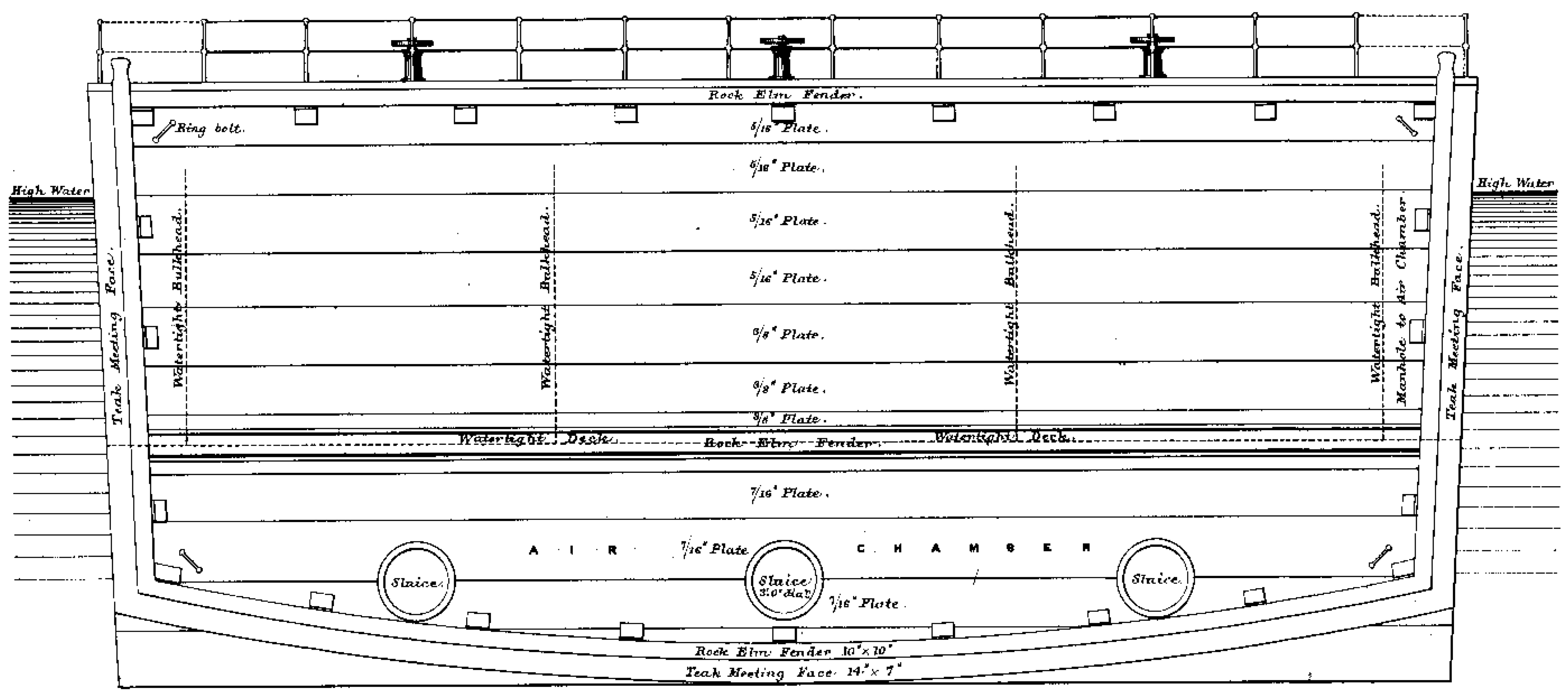
APPENDIX.

Particulars of Rolling Caissons.

Name of Dock.	Caisson. Length.	Caisson. Breadth.	Caisson. Depth from Roadway to Bottom of Caisson.	Caisson. Depth from Top to Bottom of Caisson.	Caisson. Width of Entrance.	Caisson. Depth of Water on Sill of Dock.	Folding Bridge. Length.	Folding Bridge. Breadth.	Folding Bridge. Nature of Traffic.
	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	
Garvel graving dock, Greenock, N.B. Opened 1874.	59 6	15 11	28 0	25 6	60 6	20 0	60 5	12 10	Foot, cart and railway.
Cerro graving dock, Monte Video. Caisson constructed in 1876	61 0	9 6	30 9	29 0	54 6	24 0	..	..	Foot.
Esquimalt graving dock, British Columbia. Dock works in progress.	71 2	15 10	34 9	33 3	65 0	26 6	72 3	10 6	Foot and cart.
Point Levis graving dock, Quebec. Dock works in progress; caisson constructed.	68 0	15 10	34 0	32 0	62 0	25 6	69 8	10 6	,, ,,
Garvel wet dock, Greenock, N.B., caisson No. 1. Dock works in progress; caisson to be constructed this year.	74 0	15 10	41 0	38 6	70 0	32 0	77 9	13 0	Foot, cart and railway.
Garvel wet dock, Greenock, N.B., caisson No. 2. Dock works in progress; caisson to be constructed this year.	74 0	15 10	41 0	38 6	70 0	32 0	77 9	13 0	,, ,,

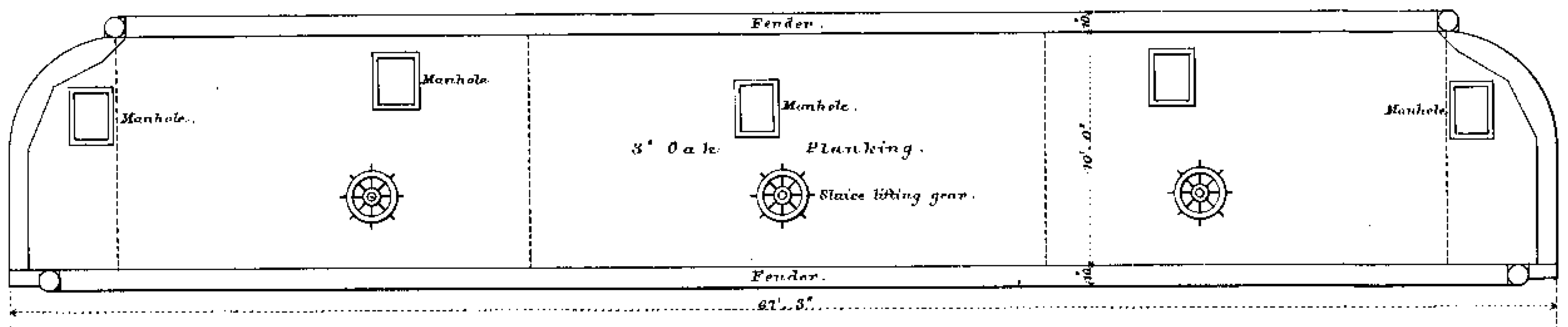
CAISSONS FOR DOCK ENTRANCES.

Fig: 1.



ELEVATION.

Fig: 2.

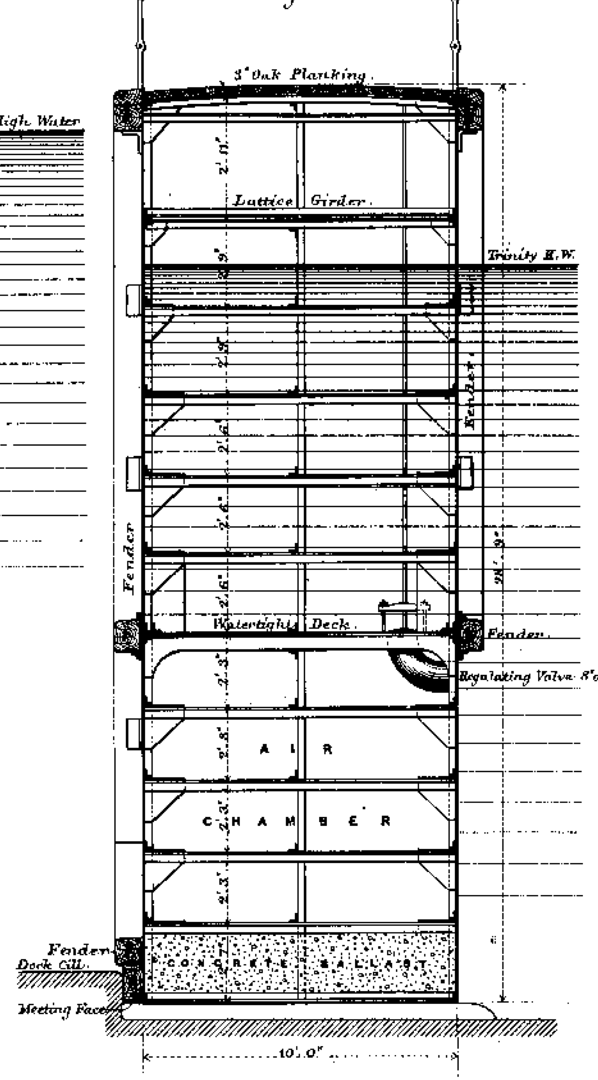


PLAN.

FLOATING BOX CAISSON AT MESSRS GREEN'S NEW GRAVING DOCK, BLACKWALL.

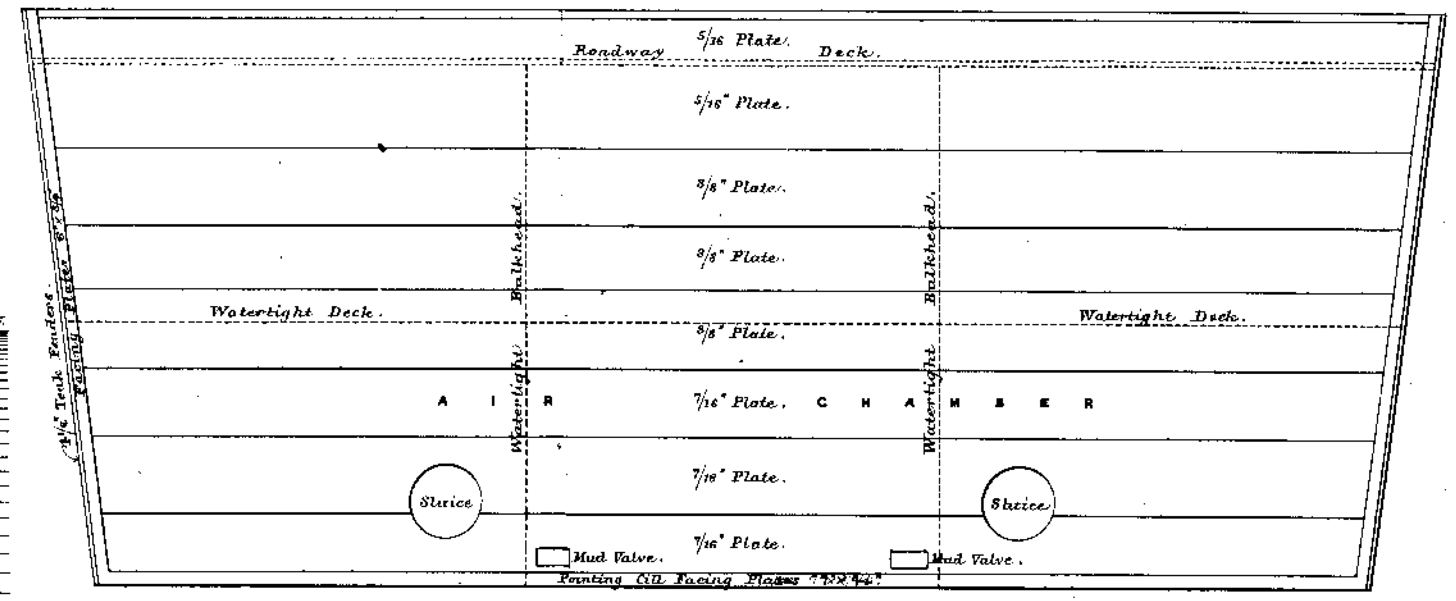
Scale for Figs 1, 2, 4 & 5.

Fig: 3.



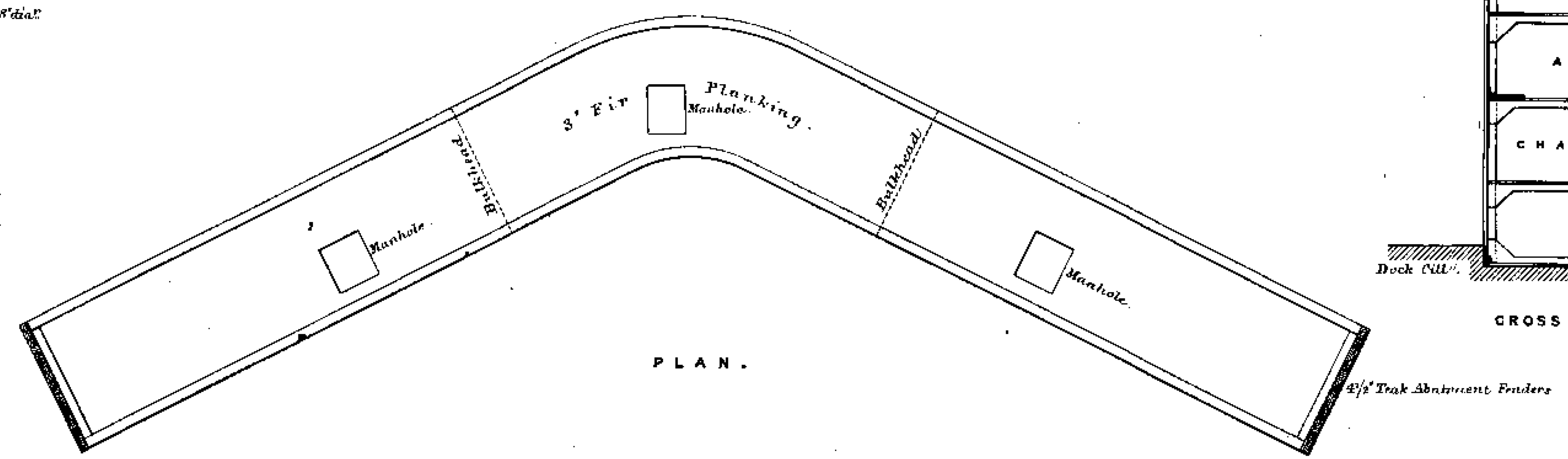
CROSS SECTION.

Fig: 4.



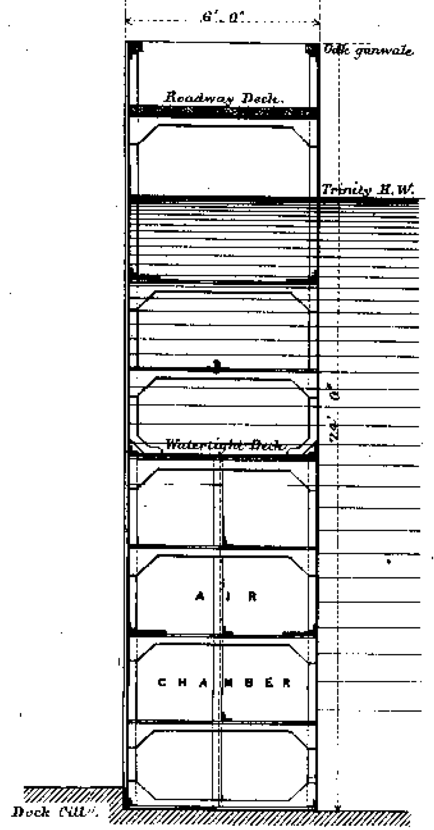
ELEVATION.

Fig: 5.



PLAN.

Fig: 6.



CROSS SECTION.

FLOATING CAISSON AT LIMEKILN NEW DOCK.

Scale for Figs 3 & 6.

CAISSONS FOR DOCK ENTRANCES.

PLATE. 7

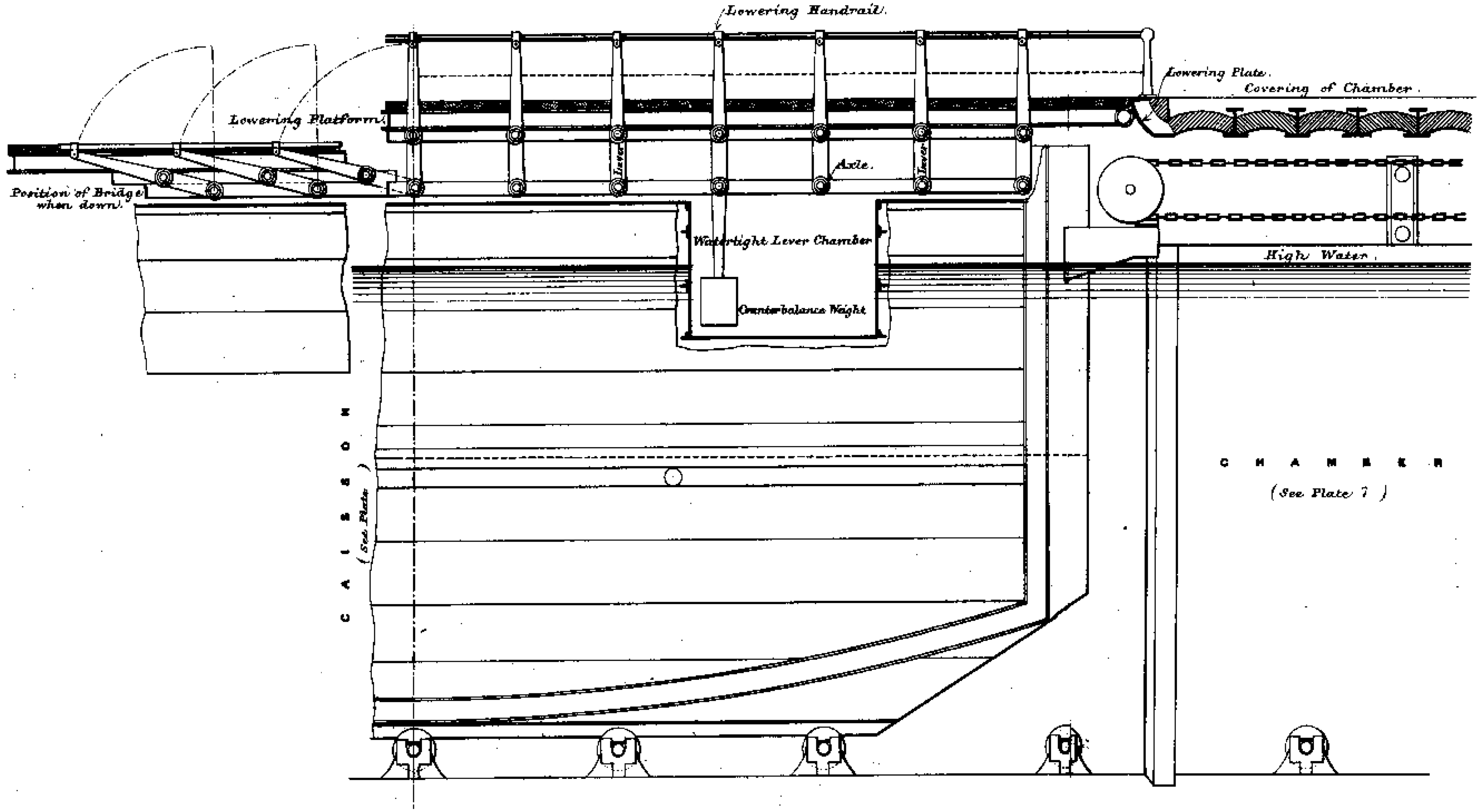
TRAVELLING CAISSON AT CERRO GRAVING DOCK, MONTE VIDEO.

THOS KELL & SON, LITH. 40, KING ST COVENT GARDEN.

CAISSONS FOR DOCK ENTRANCES.

PLATE. 8.

Fig: 1.



ELEVATION.

TRAVELLING CAISSON WITH FOLDING BRIDGE.

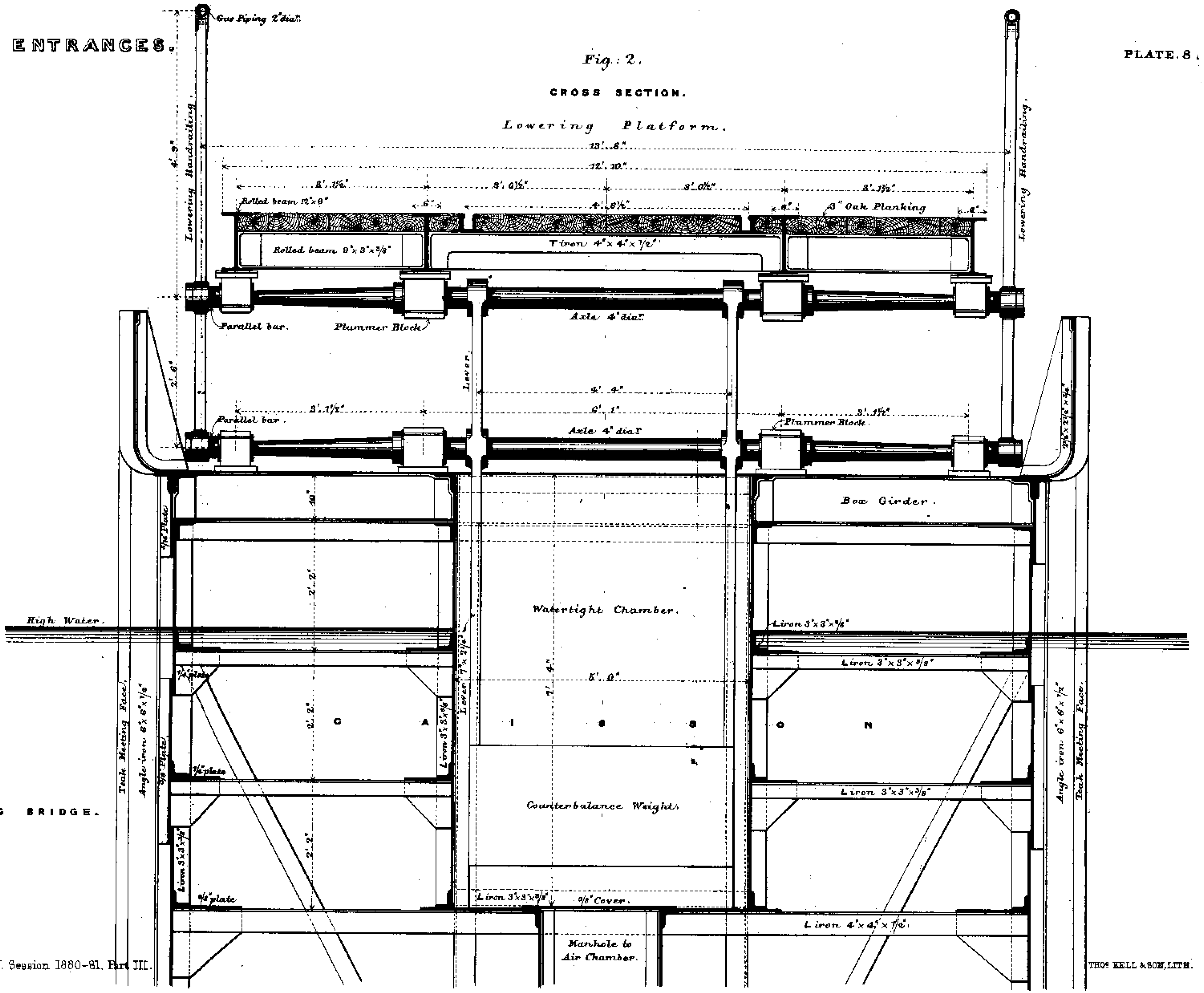
Scale for Fig: 1.

Scale for Fig: 2.

Fig: 2.

CROSS SECTION.

Lowering Platform.



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