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(Paper No. 2455.)

“The Barry Dock Works, including the Hydraulic Machinery and the Mode of Tipping Coal.”

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SITE.

BARRY DOCK is situated on the north shore of the Bristol Channel, between Barry Island and the mainland, 7 miles south-west of Cardiff, and 31 miles east of Swansea. The dock occupies the eastern portion of the Channel, which formerly ran between the Island and the mainland, about $\frac{1}{4}$ mile in width. The western portion of the Channel has been reserved as a harbour for pilot-boats and small coasting craft. The greater portion of the dock area consisted of mud and silt, with some sand and a few thin layers of peat; but the eastern end was composed of rocky marl and magnesian limestone. Deers' antlers, trunks of trees, human remains, fishermen's bone netting-needles, &c., were found in the excavations. The strata are broken up by numerous faults, the principal one running from Warren Tump, across the eastern end of the dock, to the north-west corner of Barry Island, and to Coldknapp Point.

HISTORICAL NOTICE.

In 1865 a railway was promoted by an independent company to run from the Great Western Railway at Peterston to Barry, and from Barry to Sully. In the following year an Act was passed for the formation of shipping places and a tidal harbour at Barry. Owing, however, to the commercial crisis of 1866 the promoters were unable to obtain the necessary funds, and these schemes were never carried out.

A Bill for the construction of the dock and railways was submitted to Parliament in 1883, when it passed through the House of Commons, but was thrown out by a Committee of the House of Lords. In August, 1884, however, an Act authorizing the works was obtained. The first sod was cut by Lord Windsor in November, 1884; the work was then carried on uninterruptedly, and the dock was opened for traffic on the 18th of July, 1889.

GENERAL DESCRIPTION.

The works (Plate 7, Fig. 2) comprise a tidal basin of 7 acres, a dock of 73 acres at the top of the slopes, and 62 acres at their toe, and a timber pond of 24 acres. There is also a graving-dock belonging to a private company. The dock, as originally designed, had a water-area of 40 acres; but the foundations for the south wall were set further back, in order to obtain firm ground, and the area thus increased.

The Barry Dock is designed to afford efficient accommodation for the shipment of coal from South Wales, the annual exportation of which, from Cardiff and Penarth alone during the past twenty years, has risen from 3,000,000 to 11,000,000 tons. Barry Island is about 1 mile in length, by $\frac{1}{2}$ mile in width, and rises 120 feet above mean sea-level; and the mainland north of the dock also rises considerably. The site is therefore well sheltered, particularly from south-westerly winds, which, together with easterly winds, are the strongest in the Bristol Channel. The entrance to the dock is at the eastern end of the island under the high land of Nell's Point, which excellent natural shelter is supplemented by two outlying converging breakwaters; these protect the entrance to the south, where the "fetch" is 14 miles, and to the south-east with a fetch of 16 miles. The approach to the breakwaters is free from rocks and shoals, and is also efficiently lighted. Between the heads of the breakwaters there is an opening of 350 feet, which is

close to deep water. There is good anchorage ground for the largest vessels to the east of the dock, between Barry and Sully Islands, a distance of 3 miles. The tidal range is 36 feet at ordinary spring-tides, increasing to 40 feet at extraordinary springs; and $19\frac{1}{2}$ feet at ordinary neap-tides, diminishing to 16 feet at extraordinary neaps. The dock is not fed with water from any river. A channel has been dredged between the breakwater heads and the entrance to the dock to a depth of 1 foot below the lowest part of the sills. On the seaward side of the entrance are two timber jetties, 200 feet long, with horizontal fenders along the face (Plate 7, Figs. 7, 8, and 11). The entrance is 80 feet wide, with a single pair of wrought-iron gates, and gives access to a basin 500 feet wide and 600 feet long. Between the basin and the dock is the passage, having also a width of 80 feet. The sides of the entrance and passage have two horizontal elm fenders for the protection of ships. The depth of water on the working part of the sills, which are curved, is as follows :—

High-water ordinary spring-tides	37·7 feet
Low-water ordinary spring-tides	1·6 „
High-water ordinary neap-tides	29·3 „
Low-water ordinary neap-tides	9·7 „

The available depths, however, at the centre of the invert are 3 feet more. On the west side of the entrance is a culvert having a minimum width of 10 feet, with a pair of greenheart sluices, raised and lowered by direct-acting hydraulic cylinders and pistons. There are no sluice-ways through the walls of the entrance or passage; but twelve sluices, having an area of 200 square feet, are provided in the gates. In the passage is a pair of wrought-iron gates; and there is a culvert on the west side 8 feet in diameter. The culverts serve to draw down rapidly the water when the flow of water through the gate sluices becomes slow from the decreasing head. The basin is used as a large lock, by lowering its water-level to the level of the water outside; and, as a rule, the dock is worked to the tide of the day, but at low neaps the basin is used wholly as a lock. As the middle of the sills is lower than the bottom of the basin, a channel has been made along the basin, between the entrance and passage, 1 foot deeper than the lowest part of the sills, so that vessels which can pass over the sills can enter the basin. The dock is 3,400 feet in length, the maximum width being 1,100 feet, divided into two arms at the western end by a mole. The northern arm is 1,500 feet long and 500 feet wide, and the southern arm 1,200 feet long

and 300 feet wide. The full width is left at the eastern end, for a length of 1,600 feet, where the largest vessels can swing, even when all the berths at the tips and quays are occupied. The bottom of the dock (which is not puddled) is 20 feet below mean sea-level, and the quay roads are $26\frac{1}{2}$ feet above the same level.

Along the northern side of the dock are eleven high-level fixed tips, resting on masonry foundation towers, from 174 to 300 feet from each other, so as to suit the hatchways of different ships. At four places on the north side, provision is made for movable tips, in order that coal may be put into two hatchways of a ship at one time. Where the fixed and movable tips stand, upright walls are built; and between these are slopes, $1\frac{3}{4}$ to 1, protected by pitching laid on a bed of 15 inches of broken stone. These slopes have been made, not only with a view to economy in construction and working, but also for convenience in coal shipping, as they allow vessels lying at the tips to overlap each other. To get the same number of vessels alongside a wall as can be accommodated at the sloping sides would necessitate an increased length of quay berths. Slopes also impound more water for locking and sluicing operations.

The mole is 1,300 feet long and 200 feet wide, with pitched slopes, $1\frac{3}{4}$ to 1 on the north side, and 2 to 1 on the south side. On the northern side of the mole are three low-level fixed tips, 300 feet apart; and masonry towers for two others have been built, one on the north side, and one to the eastward of the mole.

An upright wall is built along the south side of the dock, on which two low-level fixed tips have been erected, and two or three movable tips will be added. At the western end a low-level coal-tip is erected, similar to those on the mole, but with a timber substructure. Thus provision has been made for nineteen fixed coal-tips and seven movable tips. At the eastern end of the dock are three timber jetties with movable hydraulic cranes for unloading ballast, timber, pit-props, &c. Movable hydraulic cranes are erected along the quay on the south side, at the eastern end (Appendix VIII).

The foundations of the entrance walls rest on magnesian limestone and soft marl. Across the entrance is a minor fault, compact clayey marl being on the sea side, and rocky marl and limestone on the other side of the fault (Plate 7, Fig. 7). Under the sill, at the basin end of the entrance, is a wall of 3 to 1 fine Portland cement concrete, which has been faced with brickwork in cement mortar, to prevent the passage of water through the beds and fissures of the limestone and marl. Springs of salt water were met with, in which pipes were inserted, and carried to such a

height that the water did not overflow. They were then filled with cement grout and, after the cement had set, the projecting portion was cut off. Brickwork, in cement mortar, has been used for the invert, the upper two rings being blue bricks. Under the invert, 3 to 1 Portland cement concrete has been laid; elsewhere, 6 to 1. The pointing sills are inverted, and straight on plan, and are granite ashlar, from Cornwall. The hollow quoins and heel-post stones are also granite ashlar. The side walls have no batter, except near the bottom. They are constructed with mountain limestone, from near Wenvoe (about $4\frac{1}{2}$ miles north of the dock), and faced with hard red sandstone, procured from the shore at Sully, much of which was quarried below high-water of spring-tides. The walls surrounding the basin are founded on rock, benched to receive them; they are built of large blocks of mountain limestone, faced with hard red sandstone, squared, but not in courses. They are 50 feet in height, and have a vertical face, but with a curved batter at the base. They are 7 feet thick at the top, and 17 feet where they begin to curve. The cross section of the wall is varied in different places, to suit the nature of the ground upheld by them. Granite coping, $3\frac{1}{2}$ feet wide and $1\frac{1}{2}$ foot thick, with Portland cement dowels in the vertical joints, is laid on the basin and dock walls. The top of the coping is $6\frac{3}{4}$ feet above high-water of spring-tides. The space between the toe and the excavation in front is filled with 9 to 1 cement concrete. The south dock wall is similar to the basin walls, with the upper portion a little thicker; the top is dressed for 20 feet on the face, and projects 3 inches beyond the lower portion, which is left rough, so that vessels may not rub against the latter when the water falls in the dock. At the eastern end, the foundations are on rock, and elsewhere on marl or shale. The masonry was set by steam derrick-cranes, and also by steam travelling-cranes. Cast-iron 4-inch pipes were placed through the walls; and rubble-drains, 2 feet square, were built at the back. In the mouths of the pipes brass valves were inserted, to relieve the pressure at the back of the walls during construction, and in the basin when the water is lowered. Dry material was used for filling behind the walls; and any mud was cut away in long benched slopes, and dry materials substituted (Plate 7, Figs. 4 and 5, and Plate 9, Fig. 6).

The masonry towers for coal-tips on the north side of the mole are founded on a bed of 7 to 1 cement concrete, 5 feet thick, resting on mud. Previous to commencing these coal-tips, experiments were made to ascertain the bearing power of the mud, by building three brick piers thereon, forming a triangle, which

were weighted with rails. The mud bore a weight of 2 tons per square foot, when it suddenly yielded. The foundations of the coal-tips on the mole are therefore given an area over which the distributed weight is only 1 ton per square foot. On the west slope of the dock, a timber coal-tip is built, resting on piles driven into the mud, surrounded with concrete just below the dock bottom. On the north side of the dock, the masonry tower for No. 11 coal-tip rests also on bearing-piles driven through the mud, with raking-piles in front, the hard substratum below being inclined towards the dock. All the heads of the piles are surrounded with Portland cement concrete.

While sinking for the foundations of No. 10 coal-tip, some strong springs of fresh water were met with, and were conveyed from the foundations, through earthenware pipes, into a cast-iron cylinder, sunk at the south-east corner of the masonry tower. This water was pumped into tanks for the locomotives, and into a reservoir for the supply of the new town of Barry during the construction of the works.

The masonry is set in blue-lias lime-mortar, made from stone excavated on the site of the works, the strata being the same as those yielding the well-known lias stone of Aberthaw, a few miles distant (Appendix I).

The dock is connected with the coalfields by a railway, which joins the Rhondda Fawr branch of the Taff Vale Railway near Hafod (Plate 7, Fig. 1). The ruling gradient against the load is 1 in 400 to the dock, and for the return empty wagons 1 in 120. Branch lines connect the railway with the Taff Vale Railway at Treforest, and with the Great Western Railway at Peterston and St. Fagan's. A branch line, chiefly useful for passenger traffic, connects Barry with the Taff Vale Railway near the Penarth Dock station.¹

Various levels of the chief parts of the works are given in Appendix II, and details of the quays, mooring-posts, and rings in Appendix III.

Since the opening of the dock, a dam has been constructed east

	Miles.	Chains.
¹ Length of main line to Hafod	18	69
Length of Peterston Branch	1	79
Length of St. Fagan's Branch	1	9
Length of Treforest Branch	1	54
Length of Penarth Branch	3	60
Total length	27	31

of the entrance channel to enclose the foreshore, and also to prevent vessels being affected by the current flowing and ebbing to and from the foreshore inside the eastern breakwater.

At the entrance, 10- and 5-ton, and 5- and 2½-ton double-power hydraulic capstans are provided on each side; similar capstans are fixed on each side of the passage, and also snatch-heads. On the south quay are four hydraulic wagon capstans; and two hydraulic capstans are fixed at each coal-tip. Details relating to the hydraulic engines, pumps, and accumulators are given in Appendix IV.

The construction of a lock to the east of the basin, with deep sills, is contemplated, so that vessels may enter and depart at almost all states of the tide, in connection with which a channel will be dredged, extending to deep water, a little beyond the breakwater heads.

METHOD OF EXECUTING THE WORKS.

The tide had first to be excluded from the site of the dock and quays, upwards of 200 acres in extent, a somewhat difficult proceeding on account of the great tidal range in the Bristol Channel. This was done by putting three dams across the channel between the mainland and Barry Island, the two outer dams including the whole of the site required for the actual dock works. The intermediate dam was the first to be closed; and the only trouble experienced was the sinking of the earth into the mud, necessitating the frequent raising of the embankment tips. The closing of the second dam, at the western end of the dock, was very difficult, owing to its resting on mud varying in depth from a few feet to upwards of 40 feet. The first portions were made at each end, by tipping earth from wagons run out from the mainland and island; but, on reaching the deep mud, owing to the earth sinking into and sliding away with it, a timber pile viaduct was constructed across the gap, on to which the loaded trucks were run and the earth cast out, thus forming the dams in layers. This method was persevered in until, as the two ends approached each other, the tidal current became too rapid. Two unsuccessful attempts were then made by the contractor to close the gap with earth at low-water neap-tide, the intention being to exclude the tide of the day at low neaps, and then to raise the bank each day above the increase in height of the tide. In spite of every effort, the water gradually gained upon the work, and washed the earth inwards, leaving a gap 80 feet wide, through which the speed of the tide

was nearly 5 miles an hour. The method, originally proposed by the engineers, of dropping down shutters between walings, securely fastened to the viaduct piles, after the tide had receded, was now resorted to. The shutters were backed up with a large quantity of stone, together with earth, as rapidly as all the available trucks and wagons, which were standing full, could be brought forward. In this manner the tide was excluded from the western portion of the dock works in July, 1885. A 40-inch cast-iron pipe had been laid through the dam, and rested on a timber platform on the mud. A flap on the outside was closed against the rising tide, and opened when it receded, thus allowing the water left inside to be gradually lowered to the level of the sluice, and the excavation above that level to be proceeded with. The remainder of the water below the pipe was removed by pumping.

The eastern dam remaining to be closed had been made partly of permanent, and partly of temporary, masonry, founded on marl and backed up with earth. To close it, piers of masonry were built, leaving four 15 feet openings, through which the tide flowed, until the openings were rapidly closed with planks, backed with concrete made with blue-lias lime and Portland cement, in March, 1886. The planks were afterwards removed, and the concrete was faced with brickwork in cement mortar. To drain away any water accumulating at this end of the dock, three 12-inch pipes, with valves, had been laid through the bottom of the concrete wall, at its lowest part. Excavation was then proceeded with inside this dam, above the level of the three sluices. To drain the water from the excavation for the dock below the level of the temporary sluices, a sump, 20 feet in diameter, was sunk 10 feet below the bottom of the dock at the north-west end. From the sump a heading was driven, 160 yards in length, into the corner of the dock. All the water which accumulated between the intermediate and western dams flowed along channels to the corner of the dock, thence through the heading to the large sump, and was pumped by a Cornish engine along a wooden shoot, over the western dam, into the harbour. The engine had been removed from the Severn Tunnel works, and was capable of lifting 270,000 gallons per hour; but 150,000 gallons was about the average pumping required. To drain the excavation between the eastern and intermediate dam, another sump was sunk near the entrance, in which were placed two T bob pumps, which discharged the water over the eastern dam into the sea.

When the water was excluded from the site of the dock, between

the western and central dams, borings were made to ascertain the exact nature of the strata underlying the dock, which had already been found to be disturbed by faults. These indicated the necessity of setting back the south side of the dock, and of altering the position of the entrance.

The excavation for the dock was carried out in various ways, steam-navvies and grabs being extensively employed. The steam-navvies, when in regular work, excavated, in a day of ten hours, 500 cubic yards of marl, loosened with powder, and in softer material, such as stiff mud or clay, 1,000 cubic yards. For excavating mud from trenches in which water lay, steam-grabs proved the most useful; for lifting rock, portable steam-cranes, with iron skips, were employed. All hard materials for the excavation were utilized for embankments and quay roads round the dock; and the mud was deposited at the back of these, and in trenches for making the works watertight. Special side-tipping wagons, designed by the contractor, were used for tipping the mud and silt. The earthwork being well advanced, masonry was commenced in the dock. The lower portions of the basin walls were built in trenches, cut in the marl and magnesian limestone, before the completion of the excavation forming the basin. For transporting the material, there were thirty locomotives, exclusive of those working on the railways north of the dock. When the work was in full progress, about three thousand men were engaged. During the summer and autumn, the work was carried on also at night, temporary electric and Wells' lights proving extremely useful. The dredged material from the entrance channel was carried out several miles to sea, in hopper barges.

A caisson was erected at the sea face of the entrance, inside the temporary stone dam. It fitted against the quoins of the entrance, and enabled the temporary stone dam to be removed before the works were wholly completed. On the 29th of June, 1889, water was first admitted into the basin and dock by opening the sluices in the 10-foot culvert at the entrance, on a rising tide, the outer gates being closed, and the caisson, in position, resting on the keel-blocks against the quoins. The sluices in the culvert at the west end of the dock were also opened. At that tide the basin and dock were covered with 5 feet of water; at the next, with 18 feet; and at the following tide with 23 feet. The water between the entrance gates and caisson was allowed to flow inwards and outwards at each tide, through the sluices in the caisson; but as soon as the height of the tide exceeded the water in the dock, the caisson sluices were closed, and opened again when the tide receded. On the 13th of July,

1889, the caisson was floated with a draught of $18\frac{1}{2}$ feet of water, and was taken into the basin by a tug, and the tide admitted freely to the dock.

BREAKWATERS. (Plate 7, Fig. 6.)

The breakwaters are formed of rubble, excavated from the basin and railway cuttings; and the sea slope is protected by blocks of mountain limestone, of from 4 to 7 tons. The eastern breakwater is 2,600 feet long; the western breakwater, 700 feet long, is connected with the island by a light timber viaduct. The sea slope of the breakwater varies from $3\frac{1}{2}$ to 1 at the toe, to 1 to 1 at the top; and the inner slope is $1\frac{1}{2}$ to 1. The width of the breakwaters, 8 feet above high-water of spring-tides, is 20 feet; and above this is a rough parapet, 12 feet wide and 5 feet high. The great rise of tide renders it necessary that the breakwaters should be substantial works; they are, at the deepest part, 46 feet in height, and 200 feet in width at the base. The rubble hearting was deposited from wagons; and the large blocks were brought in trucks from a quarry 5 miles away, and placed in position, on the eastern breakwater, by a 10-ton Scotch crane, and on the western breakwater, by a crane fixed on a floating barge. The ends of the breakwaters are vertical, and consist of creosoted timber pilework, 32 feet wide, the intervening space being filled with stones roughly packed by hand. There are seven compartments in each breakwater head, with vertical rubbing pieces on the inside, so as to permit the subsidence of the hearting without damage to the framing.

LIGHTHOUSE.

A cast-iron tower has been erected at the head of the west breakwater, 30 feet in height, having a diameter at the base of $7\frac{3}{4}$ feet, and at the top of $6\frac{1}{2}$ feet, and a spiral staircase inside. In the tower is placed a fourth order dioptric, occulting, white light, visible in clear weather at a distance of 10 miles. It is 40 feet above high-water of spring-tides, occulting in periods of five seconds (three and a half seconds light and one and a half second dark), worked by eight-day clock-work. The light is suitable for both petroleum and gas; petroleum is used, which necessitates the attendance of a keeper, night and morning, to extinguish the lamp. When gas is used, personal attendance will be required only once a week. On the head of the eastern breakwater is a fixed bright light, half the height of the light on the western breakwater.

DOCK GATES. (Plate 8, Figs. 1 to 3.)

The entrance and the passage are each provided with a pair of wrought-iron gates, having a span of 80 feet, and a rise of 20 feet; they are 48 feet 10 inches deep at the mitre-post, and 42 feet 1 inch at the heel-post. Each gate is divided into fifteen watertight compartments, by decks and bulkheads. There are twelve decks, five of which are watertight; the greatest width of the decks is 8 feet, and the length along the centre line of the gate is 50 feet. Below deck No. 5 from the top, are air-chambers, which are almost sufficient to float the gates, leaving only a small weight to be carried by the roller and bottom pivot. Above deck No. 5, the interior of the gate is open at the back. Access to the air-chambers is obtained by a shaft leading from the top of the deck through this portion of the gate. Provision is made for draining the air-chambers at the bottom of the gates, whence the water can be pumped out. In each leaf there are six sluices, having a combined area of 100 square feet, worked by direct-acting hydraulic cylinders and pistons. The heel-posts, sills, and mitre-posts are of greenheart, the heel-posts having a radius of 15 inches. The heel-post rests on a cast-steel hemispherical pivot, with a cupped saddle, sufficient play being allowed to admit of the gate being thrown out slightly from the hollow quoins by relieving gear, to prevent the wearing of the heel-posts and hollow quoins when the gate is opened and closed. Oil-pipes are brought up to the top of the masonry of the gate recess, and a force-pump is attached to supply the oil for lubricating the pivot and relieving gear. The top anchorage consists of a circular collar, with a bush round an octagonal pin, fixed to the top of the heel-posts, sufficient play being allowed between the sides of the pin and the bush to admit of the free adjustment of the gates against the hollow quoins. The strain on the top pivot is taken by two strong wrought-iron ties, anchored to wrought-iron girders built into the masonry at the back. Forged-steel rollers are fitted to the gates, carried in a frame having a bearing under the gates, and supported behind by a spear, terminating with a screw for adjustment. The roller-paths, constructed of wrought-iron plates on edge, with a steel face on the top, have a radius of 43 feet. The rollers are provided with scrapers fitted close down to the roller-paths. Each leaf contains about 186 tons of wrought-iron, 22 tons of cast-iron and steel, and 1,400 cubic feet of timber. Each gate was erected near the position it had to

occupy, and each compartment tested with water. The gates are opened and closed by direct-acting hydraulic rams, a system which has proved very successful (Plate 7, Fig. 7; Plate 8, Figs. 6 and 7; and Appendix V).

To prevent the gates from floating, a cast-steel holding-down bracket is fastened at the top of each heel-post. For the protection of the gates from collision, stout chain cables and wrought-iron box booms are placed in front of the masonry. A combined regulating- and escape-valve has been fixed to each of the gate-machines at the entrance, in order to reduce the pressure from 700 lbs. per square inch to any degree between 500 and 100 lbs. The pressure usually employed for the entrance-gate rams is 250 lbs.; and the ordinary time occupied in opening the gates is one minute and a half, and the same in closing. At the passage, the full accumulator-pressure is admitted to the ram-cylinders; and the time occupied in opening is less than one minute, and the same in closing.

CAISSON. (Plate 8, Figs. 4 and 5.)

The caisson, made of wrought-iron and steel, is designed to suit its different positions, at the sea side of the entrance, basin side of the entrance, basin side of the passage, dock side of the passage, future lock, and future graving-dock. It has a length of 85 feet, and a beam, amidships, of 24 feet. The height, at the ends, is 42 feet, and at the centre $48\frac{3}{4}$ feet. The keel is formed to a radius of 137 feet, to correspond with the inverts; and the meeting faces are lined with greenheart, 15 inches by 7 inches. The caisson is ship-shaped on one side, and flat on the other, so as to enable it to fit against any of the faces now or hereafter to be made, and to be placed, when out of use, in the recess provided for it west of the entrance, where it will not project beyond the line of the wall. It is divided vertically by two watertight bulk-heads, and horizontally by eight decks, two of which are watertight, forming air and water chambers. The lower parts of the skin are of wrought-iron, and the upper 19 feet of steel. Immediately below the bottom deck, which is watertight, there are two sluices, each 4 feet by 2 feet, for lowering or raising the water-level on the two sides. Cast-iron kentledge is packed as ballast in the bottom of the caisson. The caisson contains about 328 tons of wrought-iron and steel, 22 tons of cast-iron, 354 tons of iron ballast, and 335 cubic feet of timber.

GRAVING-DOCK. (Plate 7, Fig. 2.)

The graving-dock is entered directly from the large dock, at the north-east corner, and has an entrance width of 60 feet, and a depth of water on the sill of 24 feet at high-water of spring-tides. The length of the graving-dock, from the entrance sill to the extreme end, is 724 feet, and is divided unequally, by a middle sill, into lengths of $372\frac{1}{2}$ feet and $351\frac{1}{2}$ feet, with a width of passage between the two portions of $58\frac{1}{2}$ feet. At floor-level, the dock has a width of 100 feet, and, at the top, of $113\frac{1}{3}$ feet. It has masonry side-walls, with granite altars and coping, and a cement-concrete floor. An open drain runs round the sides, and another one covered with stone slabs down the centre. The masonry of the walls and floor was not made of strength to resist outside water-pressure; but the walls and floor are provided with pipes and escape-valves to prevent pressure. The quantity of water finding its way into the dock is insignificant. Wrought-iron box caissons close both portions of the graving-dock. Four vessels, or even more according to size, may be accommodated at the same time; while by combining the two divisions, a ship of extraordinary length can be admitted. The graving-dock has a double line of keel-blocks. Two 40-inch centrifugal pumps empty either or both divisions of the dock, and are fixed in an engine-house 11 feet below high-water of spring-tides. The pumps can raise 62,000 tons of water in from three and three-quarters to four hours, and may be used separately or jointly as required. An hour and a half is occupied in emptying the inner dock at high-water of spring-tides when no vessels are in, and two hours and a quarter in emptying the outer dock. When vessels requiring their sides to be scraped and washed are in the dock, the water is pumped out gradually, so that the men may do the work as it subsides. When cleaning is not required, the docking is rapid; for instance, the surveyors were able to examine the bottom of a steamer of 1,198 tons in one hour and twenty-five minutes from commencing to haul it into the dock. Ships requiring heavy repairs are placed in the inner dock, and for light repairs in the outer dock. For driving the machinery in the workshops, three gas-engines are employed.

HYDRAULIC COAL-TIPS. (Plate 9.)

High-Level Tips (Plate 9, Figs. 5, 6 and 7).—Trains of from fifty to seventy wagons, mostly containing 10 tons each, are brought down

from the collieries. On the high-level, the trains are backed into curved sidings, with gradients of 1 in 233, intended for full wagons. In South Wales, the coal wagons are made with a door at one end only; and coal is not tipped through the bottom of the wagons. The loaded wagons are sent from the collieries with the doors up-hill, to prevent their opening on steep inclines, and, therefore, in most of the docks in South Wales, are turned for tipping. By the plan adopted at Barry, the wagons, when shunted into the sidings, have the doors at their right end for tipping. In case, however, a wagon is sent the wrong way, a table is provided in front of the weigh-bridge for turning it. The wagons are drawn forward, and are run one by one on to the weigh-bridge, and afterwards drawn on to the coal-tips by two hydraulic capstans. Masonry towers, 30 feet square, carry wrought-iron framing, with wrought-iron guides for the cradle. The cradle, which is moved up and down by direct-acting hydraulic rams, has a tip-up table, hinged in front, and worked by a hydraulic cylinder, hung on trunnions to girders underneath the cradle, which travel with it, and capable of tipping loads up to 19 tons. Four cast-iron rams attached to the underside of the cradle, for lifting and lowering, are $8\frac{3}{4}$ inches, $9\frac{3}{8}$ inches, $7\frac{1}{2}$ inches, and 8 inches in diameter respectively, and represent pressures of $18\frac{1}{2}$, $21\frac{1}{2}$, $13\frac{1}{2}$ and $15\frac{1}{2}$ tons on their respective areas. Waste of water is prevented by its being exhausted into the pressure, or into the return-mains. These descending loads (much of the coal from the high-level sidings having to be lowered for shipment) pump water back into the accumulators. The cradle has a maximum lift of 37 feet; and the tip can be used for balancing or bunkering by valves, which are worked by a man stationed in a cabin, containing the lever handles, at an elevation commanding a view of the deck of the vessel which is being loaded. The tips have coal-shoots, anti-breakage cranes, boxes, &c. A chain, fixed to the cradle, is hooked on to the tail end of the wagon, standing on the platform or cradle; and the catch, securing the hanging door at the other end of the wagon, is struck away. The cradle is lowered or raised, and tilted up, discharging the coal into an inclined iron shoot, extending over the ship's hatchway. At the commencement of shipping, an anti-breakage box is suspended at the end of the shoot from a hydraulic lifting and turning jib-crane, fixed near the top of the iron framing, at one corner next the dock. The coal drops into this box, which is lowered into the hold of the vessel, and emptied by the withdrawal of a bolt from a hinged flap at the bottom. To the bolt releasing the flap-door is

fastened a chain fixed on deck, thus making the discharge of the box self-acting. By means of the box, a cone of coal is formed as high as the point of the shoot, so as to avoid breaking the coal by dropping from the shoot into the hold of the vessel. The anti-breakage box is then swung out of the way, and the coal allowed to slide from the shoot on to the cone, and into the hold, where it is trimmed. The shoot is tapered towards the point, to check the sliding of the coal, and has a single door across, near the end, for regulating the same; and the butt end is pivoted under to give the shoot a somewhat greater range to the hatchway. For raising and lowering the shoot, and adjusting its level and inclination to suit the varying height of the deck, chains, pulleys, racks and pins are provided; and the shoot is also secured by safety chains. In the bottom plate of each shoot are two iron-bar screens for separating when required, the small coal which falls on to the vessel's deck, and is removed by an iron skip attached to the anti-breakage crane. The skip is raised and swung round at the same time, and then turned over into an iron spout, down which the screenings run into a wagon standing underneath the high-level viaduct, and clear of the cradle. On the underside of the shoots, immediately below the screens, are hinged doors to allow of single screening, double screening, or the coal to pass unscreened. As much as 400 tons have been shipped in one hour at one of the high-level tips, in the ordinary course of working. At all the high-level tips, vessels of any tonnage can be bunkered when light. After the coal has been tipped, and the cradle brought to its proper level, the empty wagon is pushed off the cradle, and runs down a road having an inclination of 1 in 80, on to a second weigh-bridge, where the tare is obtained. It is then pushed from this weigh-bridge, and runs down the siding used by empty wagons, which has a gradient of 1 in 70, on to a piece of level road. Here the empty wagons accumulate, and are drawn by the shunting-engine out of the tip siding, up a gradient of 1 in 45, and taken away to the sorting sidings. A difference of level at the crossing rails, of $4\frac{1}{2}$ inches between the lines for full and empty wagons, is met by a sliding rail which is closed by the wheels of the full wagon when passing, and opened again by a weighted crank-lever to allow the empty wagon to pass. Some of the tip sidings have two lines of way which, besides providing additional storage for coal of one quality, are also intended for wagons filled with coal from different pits, so that ships may be loaded with coal mixed in any proportion that may be desired.

Low-level Tips (Plate 9, Fig. 1).—The tips, or hoists, on the mole

and on the south side of the dock, differ from those on the north side, inasmuch as the loaded wagons are received into the hoists at the level of the quay, and the empty wagons are returned from the tip at the same level. The wagon has thus to be lifted the required height for tipping. When the wagons are brought from the collieries to the low-level, they are backed into sidings having first a rising gradient of 1 in 120 and then a falling gradient of 1 in 200, where the engine leaves them. They are afterwards pulled forward, down a gradient of 1 in 140, by a hydraulic capstan, on to a weigh-bridge; then on to a turn-table, whence they run on to the tipping-cradle. After being tipped, the wagons are run back on to another turn-table, where they are turned and pushed on to another weigh-bridge; from this they are pushed off, and run down a gradient of 1 in 70, on to a level piece of road, to be drawn away up a gradient of 1 in 45 by the shunting-engine to the sorting sidings. The turn-tables are so arranged as to avoid any fouling of wagons going to and leaving the tip. Each hoist has a substantial wrought-iron frame, 57 feet high, which supports the shoot for conveying the coal into the hold of the vessel, and guides the lifting-cradle during its ascent and descent. On one side of the upper part of the frame is a cabin, for the man who manipulates the valves. The hoist lifts wagons, of a gross weight of 19 tons, a clear height of 37 feet, and tilts them to an angle of 45° . The lifting of the cradle and loaded wagon is effected by two vertical direct-acting rams, of $11\frac{1}{2}$ and $6\frac{1}{2}$ inches diameter, with 37 feet stroke. In lifting the cradle, both these rams are exposed to the full hydraulic pressure; but, in lowering, the larger one is allowed to exhaust freely, while the smaller one returns the water to the accumulator under the influence of the descending weight of the cradle and empty wagon—a contrivance introduced some years ago by Sir W. G. Armstrong and Co. Each hoist is fitted with an anti-breakage shoot, in which the coal, in leaving the wagon, has its motion arrested by a sliding door across the shoot. As the coal slides from the wagon, this door is eased away down the shoot, until, when near the bottom, it opens a passage through which the coal can drop gently into the hold, thus leaving the shoot at a low speed. The sliding door is moved up and down the shoot by a hydraulic cylinder on the side, and is easily controlled by the man in the cabin, who works the hoist. When coaling into small bunker hatches, the shoot is prolonged by hanging a short tapered piece on to the end to contract its wide mouth. The hoist is fitted with a $4\frac{1}{2}$ -ton hydraulic crane, carrying an anti-breakage coal-box, holding 4 tons. When commencing to load a ship, the box is

filled with coal from the shoot, and lowered into the hold. A cone is thus formed, which both preserves the bottom of the ship from damage, and lessens the breakage of the coal. A hydraulic turn-over capstan for each hoist is provided for moving the coal-wagons, and working the turn-tables. With the exception of No. 12 tip, at the west end of the dock, all the wagons on the low-level lines require to be turned to get them into the hoist, a system necessitated by the limited space available; but at No. 12 tip, wagons run straight on to the tipping-cradle, as on the high-level tips. A movable tip, between tips Nos. 7 and 8, is in course of construction, for coal brought on to the high level; the mode of working to be adopted is given in Appendix VI. A movable tip is also being constructed for coal brought on to the low level (Appendix VI).

In all arrangements for tipping South Wales coal, it is most desirable to prevent rapid motion of the coal, or its being dropped from a height, as this description of coal is easily broken, causing considerable loss in its value.

ROLLING-BRIDGE.

The passage between the dock and basin is crossed by a rolling-bridge, worked by hydraulic power, carrying a single line of railway, and forming also a roadway. The bridge has two steel-plate main girders, with cross girders, and is counterpoised with kentledge at the tail end. The girders are $154\frac{2}{3}$ feet in length, $9\frac{1}{2}$ feet in depth, with a flange width of 2 feet, and they span an opening of 83 feet between the bearings. The bridge is carried on $2\frac{1}{2}$ -foot steel rollers, a pair close together, bicycle fashion, being fitted under each main girder; and they travel on level steel roller-paths, borne by girders. Two 6-foot trailing-wheels, at the tail end, run on bridge rails outside the main girders, and carry a weight just sufficient to overbalance the front part of the bridge. On one side of the bridge, the treads of the wheels are grooved; those of the rolling-carriage fit a projection on the roller-path, and that of the trailing-wheel fits the bridge rail. On the opposite side the wheels have flat treads. The bridge is moved by a three-cylinder hydraulic engine, placed underneath. When it is started forward, the front end stands slightly elevated, the rails of the trailing-wheels being at a slightly lower level for this purpose; but after the bridge has travelled forward $25\frac{1}{2}$ feet, the trailing-wheels ascend a gradient of 1 in 60 for 75 feet. This lowers the front part of the bridge, and brings it level. The rolling-carriage

is now over a table, under which is a large hydraulic cylinder, which pushes out two pairs of rollers, on each side, up inclined planes, and by this means the bridge is lowered or raised. There are two hydraulic buffers at each end to prevent the bridge over-running in either direction.

ELECTRIC LIGHT.

The dock, sidings, and buildings are lighted by electric light. The general illumination is effected by forty-one arc-lamps, of 3,000 candle-power nominal, each placed on poles, 40 feet above the level of the quay. There are two separate circuits on the north side, and two on the south side, the lamps being alternately arranged in each circuit, twenty and twenty-one lights each, so that, in the event of any accident, it is possible to use every alternate lamp throughout for lighting the dock. It has the further advantage that, when a reduced number of lights are sufficient, it is possible to throw every alternate light, over the whole dock, on to one machine. Glow-lamps light the interiors of the engine-houses, offices, coal-tips, weigh-houses, &c. It has been found necessary, however, on account of the wide distribution of the groups of these lights, and their distances from the engine-house, to use the alternating system, so that the energy may be carried in the mains at the pressure of 2,000 volts, and be transformed, on entering a building, or arriving at a place where the light is required, to the safe pressure of 110 volts. Two identical, vertical, compound engines, of 90 HP. each, with a steam-pressure of 80 lbs. per square inch, drive the dynamos placed between them, by belts direct from the fly-wheels. Two continuous-current machines for arc lighting, to give 1,350 volts, with 15 amperes current, are driven by one engine; and one alternator, to give 2,000 volts with 25 amperes current, is driven by the other engine. Either engine can, if necessary, drive any two dynamos, thus preventing a total breakdown to the lighting by either system.

The Engineers of the dock works were, Mr. John Wolfe Barry, Mr. T. Forster Brown, and Mr. H. M. Brunel, MM. Inst. C.E., the Author being the Resident Engineer.

Details of the quantities of the works are given in Appendix VII.

The Paper is accompanied by a number of drawings, tracings, and photographs, from which Plates 7, 8, and 9 have been prepared.

APPENDIXES.

I. MORTAR, CEMENT, AND BRICKS.

Previous to commencing the masonry, experiments were made in mortar-making, extending over several months, which showed the great danger in using improperly burnt and slacked lime. The lime, after being slacked, was kept in a shed for seven to fourteen days, and all hard pieces were removed before being ground in the mortar pans. Blue lias stone in this district weighs 168 lbs. per cubic foot, and, after burning, 100 lbs. The proportions adopted were 1 of lime, $1\frac{1}{2}$ of sand from the sea-shore, and $\frac{1}{4}$ of burnt ballast or ashes. Fresh water was used for slacking and mortar-making.

The analysis of an average sample of the cement used was:—

Silica	24·852
Alumina and Oxide of Iron	12·630
Lime	59·132
Magnesia	0·954
Sulphuric acid	1·590
Carbonic acid	0·470
Organic matter, &c., and loss	0·372
	<hr/>
	100·000

Bricks used in invert, arches, and tunnels were made from clay dug on Barry Island, dried in a shed, with flues under the floor, and burnt in Scotch kilns with projecting firing-places on the sides.

II. DOCK-LEVELS AND AREAS.

The following Table gives the levels of the more important parts of the dock above a datum line 50 feet below Ordnance datum:—

	Feet.
High-water ordinary spring-tides	69·70
Low-water ordinary spring-tides	33·60
High-water ordinary neap-tides	61·30
Low-water ordinary neap-tides	41·70
Mean sea-level at Barry	51·60
Entrance channel	28·00
Working height, sill of entrance	32·00
Working height, sill of passage	32·00
Centre part of sills	29·00
Sill of sluice in western dam	44·00
Bottom of basin	30·00
Bottom of channel in basin between entrance and passage	28·00
Bottom of dock	30·00
Bottom of timber pond	56·00
Sill of graving-dock at north-east corner of dock	45·00
Coping of basin and dock	76·50
Top of breakwater heads	78·50
Roads on tip on north side of dock	101·00
Depth of water in dock at high-water ordinary spring-tides	39·70
Depth of water in dock at high-water ordinary neap-tides	31·30

The areas of the dock and works are:—

	Acres.
Water surface	107
Quay roads and lands adjacent	242
Land covered by tide	208
	<hr/>
	557
	<hr/>

III. BUOYS, MOORING-POSTS AND RINGS.

Thirty wrought-iron buoys were placed in the dock, two in the basin, and two in the entrance channel. Holes were excavated below the bottom of the dock, 13 feet square and $7\frac{1}{2}$ feet in depth, which were filled with 7 to 1 Portland cement concrete, and four cast-iron washers 2 feet square were embedded therein. Two bent 3-inch anchor-bolts were fixed to these, linked together at the top, to which is shackled a stud-link mooring-chain with swivels 45 feet long. The other end is attached to the circular buoys, some of which are 11 feet in diameter and 5 feet 10 inches in depth, whilst others are 10 feet in diameter and 7 feet in depth. They have four watertight compartments with manholes and covers, and are surrounded with a fender of elm timber $1\frac{1}{2}$ foot by $\frac{1}{2}$ foot.

Cast-iron mooring-posts, embedded in cement concrete, are fixed at intervals all round the dock and basin. There are also mooring-rings along the quay wall, and at each of the coal-tips.

IV. HYDRAULIC ENGINES, PUMPS, AND ACCUMULATORS.

The hydraulic power is obtained by two pairs of compound horizontal condensing pumping-engines. These engines are of the tandem type, the cylinders being 16 inches and 28 inches in diameter, with a piston speed of 280 feet per minute. Both high- and low-pressure cylinders are steam-jacketed. The pressure-pumps are of Tannett, Walker and Co.'s differential ram principle, the diameter of the rams being $4\frac{1}{2}$ and $6\frac{1}{2}$ inches. The boiler-pressure is 80 lbs. per square inch; and at this pressure each pair of engines should be capable of delivering from the pumps into the accumulator 300 gallons of water per minute, at a minimum pressure of 700 lbs. per square inch, when running at the rate of 50 revolutions per minute. The crank-shaft of the engine is of forged steel, 8 inches in diameter. The pump-rams are of brass; and the engines are provided with surface-condensers, together with the necessary air- and circulating-pumps. Arrangements are provided for permitting either pair of engines to discharge exhaust steam into the atmosphere. Condensing water is obtained from and returned to the dock, through 15-inch pipes, by the circulating-pumps. The fresh water delivered into the mains is obtained from a well on the company's property. There are five accumulators in various positions. The diameter of the ram is 22 inches, having a thickness of metal of $2\frac{1}{2}$ inches and a stroke of 26 feet. The four Lancashire boilers are 28 feet long by 7 feet in diameter, and have two flues, each $2\frac{3}{4}$ feet in diameter. They are designed to evaporate $10\frac{1}{2}$ lbs. of water for every lb. of Welsh coal consumed in the furnaces, and $8\frac{1}{2}$ lbs. for small coal. The hourly consumption of steam per indicated HP. in the steam cylinders of the engine was guaranteed not to exceed 20 lbs., and the hourly consumption of best Welsh coal not to exceed 440 lbs., or $2\frac{1}{2}$ lbs. per

indicated HP. The engines, six boilers, three accumulators, and electric-light machinery are contained in a house erected on the south side of the dock. All round the dock are laid 7-inch pressure- and 8-inch return-mains, which are carried across the entrance and passage in grooves. From these mains there are branches to the different coal-tips, 3-inch pressure and 5-inch return. On the pressure-mains are expansion-joints and momentum-valves and stop-valves at convenient intervals; on the return-mains are relief-valves with springs and stop-valves.

Another hydraulic engine-house is being constructed at the north-west end of the dock, to contain engines, pumps, &c., of the same capacity as those in the existing engine-house.

V. GATE-MACHINERY.

In the case of the entrance gate-machinery, the water is admitted to a directing hydraulic cylinder, having a piston 2 feet 5 $\frac{1}{4}$ inches in diameter, and a 1 $\frac{3}{4}$ -foot ram, with a stroke of 25 $\frac{3}{4}$ feet, attached to the gate. The cast-steel cylinder is made in three parts, and tested to withstand a pressure of 3,000 lbs. on the square inch. The ram is of iron, cast vertically in one length, and is firmly guided and fixed to the gate by a forged steel cross-head and coupling-pin. Trunnions are cast on the cylinders, projecting above and below, and pivot in saddle-bearings, which also have trunnions on their sides, and these pivot in bearings fixed to the side walls of the ram chamber, thus permitting the cylinder to oscillate horizontally and vertically. The hydraulic rams are of sufficient strength to resist shocks of waves, and to hold the gates rigidly during movement. In the passage gates, the ram is attached to a radius arm near the top, with a slide against the back of the gate, the other end of the arm working on a pin in the holding-down bracket over the top of the heel-post. As the power required is less, the diameter of the piston is only 2 feet 1 $\frac{1}{2}$ inch, and that of the ram 1 $\frac{1}{2}$ foot, with a stroke of 16 feet 7 inches. The cylinder for the passage gate-machine is of iron, cast in one length, and tested to a pressure of 2,400 lbs. per square inch.

VI. MOVABLE TIPS—METHOD OF WORKING PROPOSED.

High Level (Plate 9, Figs. 3, 4, 5).—The full wagon runs on the line marked "Full," past the weigh-bridge and turn-table, on to the approach A to the bridge B, at the front end of which is the tipping-table E. The wagon is then tipped by means of the cylinder F into the shoot G, in the floor of which are two screens fitted with doors. These doors can be opened or closed, so as to obtain double or single screened coal; or, both screens being closed, the coal is delivered unscreened. The shoot is closed at the front end by a door H, worked by the cylinder K by means of chains. When the coal-box I is in position for filling, a grid L is drawn forward into the box by the small cylinder O, forming a continuation of the shoot-floor down to the bottom of the box. The grid consists of a series of 4 $\frac{1}{2}$ -by 3-inch joists, parallel to one another with 3-inch spaces between. The door H is then released, and the coal slides down the grid into the box, the smaller pieces falling between the spaces and forming a bed of small coal in the bottom of the box, the larger pieces resting on the grid. The grid is then withdrawn by the cylinder N, and the large coal falls down into the box and fills it. The box is then hoisted high

enough to clear the bulwarks of a ship by the cylinder P; and pressure being released from the jibbing cylinder Q, the jib falls outwards until the box is directly over the hatchway. The chains and pulleys for hoisting and jibbing are so arranged that the box is lowered 2 feet in running from its extreme position in to its extreme position out. The box is next lowered to within 2 or 3 feet of the bottom of the hold; and then pressure is introduced into the cylinder S, which is connected to the box by a $1\frac{1}{2}$ -inch chain, while the hoisting cylinder P is connected with the box-doors J, tending to keep them closed. When pressure is introduced into the cylinder S it lifts the box, while the coal, resting to a great extent on the doors, keeps them in their original position; the box, on being lifted, throws them open and discharges the coal. The box is then hoisted clear of the hatchway, and the jibbing cylinder brings the box back to its original position, and it is lowered on to a platform in readiness for another wagon load.

To provide for the various distances between the hatchways of ships, this tip is used in connection with a fixed tip. The ship is brought with one of its hatchways in front of the fixed tip, and the movable tip is then brought opposite one of the other hatchways by the following means. The tip runs on rails along the quay, about 50 feet each side of the centre of the approach: a connecting bridge is pivoted to the tip at U, and the back end runs on a pair of rails on an approach, curved in such a way that the tangent to the rails, at the point where the rollers on the bridge rest, is at right-angles to the centre line of the bridge in whatever position it may be. When the tip is moved, the bridge is drawn away from the approach, making an angle with it. The ends of the rails forming the line of way are made telescopic to allow of small variations in the position of the bridge. Greater variations are made up by loose sections of rails at G, which rest on girders pivoted on the bridge, and sliding on paths under the approach platform. The tip is moved by a hydraulic engine geared to the travelling wheels. The empty wagons are then run back from the tipping-table, past a pair of self-acting points at D, on to the line marked "Empty."

Water for the hydraulic power is taken from the main by a supply-pipe, through oscillating pipes at C, and along the bridge, through a swivel at U, to the valve cabin. The return-pipes run alongside the pressure, through the swivel and oscillating-pipes, which are made double for this purpose. The man in the cabin manipulates all the levers, except that for the tipping-valve, which is worked by the man who attends to the capstan for hauling the wagons on and off the table. The screenings fall into the hopper M, and thence into a wagon placed underneath to receive them.

Low-Level (Plate 9, Figs. 1 and 2).—The tipping-table for a movable tip for coal brought on to the low level has a lift of 30 feet, and is hoisted by four cylinders hung up in the framing of the tip. Two of these cylinders are of sufficient area to balance the moving parts, the other two lifting the load, thus saving water under pressure. The tipping is done by a horizontal cylinder, chains, and wire rope. The cylinder is placed on the top of the tip framing, and the chain passes round the pulleys at the head of the ram and back of the cylinder, and is fastened to a chain barrel keyed to a shaft, which is also fixed to the top of the tip framing. This shaft is keyed to two rope-drums, on each side of which a wire rope is attached, running over pulleys fixed to the cradle frame, and is secured to the bottom of the tip frame to allow of tipping being done at any point within the stroke of the lifting rams. The shoot is raised by two cylinders placed on the top of the tip framing, one for the heel of the shoot and the other for the nose. The shoot is

fitted with girders, pawls, and racks, and is so arranged that it will swing on one side should the rigging of a ship come in contact with it. On the top of the tip, a 6-ton crane is placed, which is run forwards and backwards by a hydraulic cylinder, and is withdrawn when a ship is being berthed, so as to be out of the way of the rigging. The hoisting is done by a hydraulic cylinder fixed at the back of the tip frame, to which is attached a small cylinder for releasing the coals from the anti-breakage box. This tip is also provided with an ordinary 2-ton anti-breakage crane.

VII. QUANTITIES.

The quantities of the chief items of work comprised in the execution of the dock are:—

Excavation	5,000,000 cubic yards
Rubble masonry	200,000 „ „
Brickwork	10,000 „ „
Ashlar, chiefly granite	110,000 cubic feet
Timber work	220,000 „ „

VIII. TABLE OF THE MOVABLE HYDRAULIC PEDESTAL-CRANES, LIFTING THROUGH A CLEAR HEIGHT OF FROM 50 TO 56 FEET.

Description.	30 cwt.	2 tons.	30 cwt.	4 tons.
Radius	$\left. \begin{array}{l} 25 \text{ ft. min.} \\ 40 \text{ ft. max.} \end{array} \right\}$	29 feet	40 feet	29 feet
Diameter of lifting-cylinders	$7\frac{1}{2}$ inches	11 inches	$7\frac{3}{4}$ inches	$\left\{ \begin{array}{l} 11 \text{ inches small ram} \\ 15\frac{1}{2} \text{ „ large „} \end{array} \right.$
Diameter of turning-cylinder	$6\frac{1}{2}$ inches	$5\frac{3}{4}$ inches	$7\frac{1}{2}$ inches	8 inches
Stroke	10 feet	6 ft. 3 ins.	8 ft. 10 ins.	6 feet 3 inches
Multiplying power.	6 to 1	8 to 1	6 to 1	8 to 1

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PLATE . 5 .

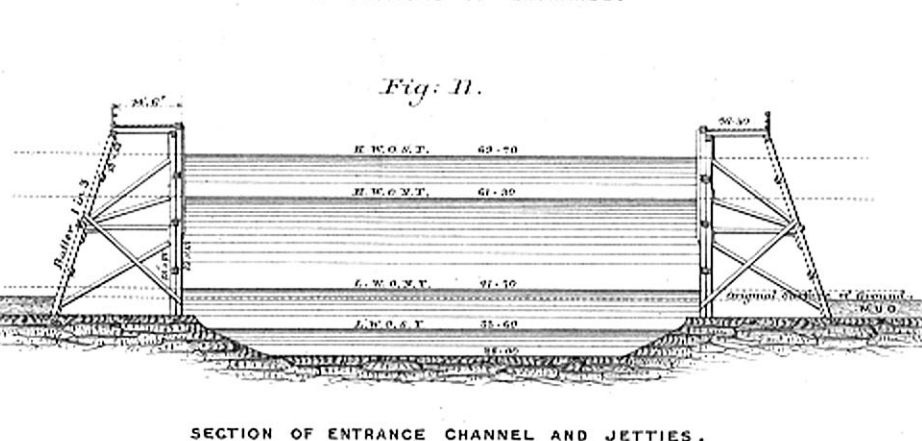


Fig: 1.

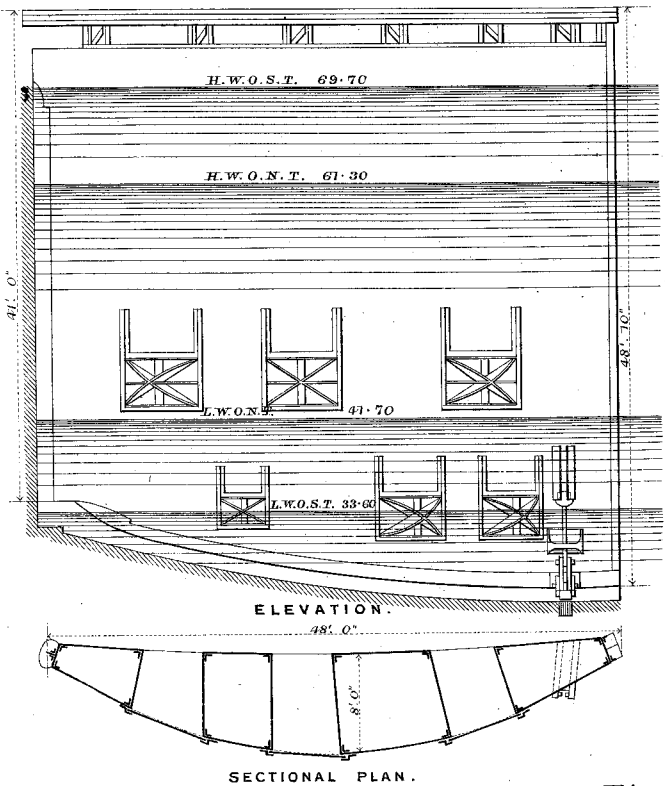


Fig: 2.

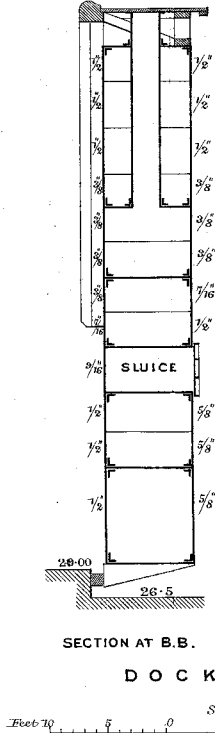


Fig: 3.

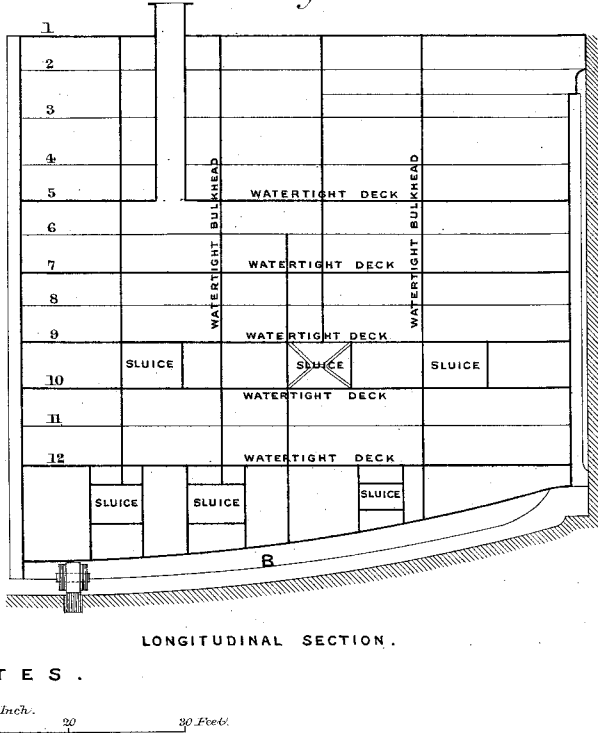


Fig: 6.

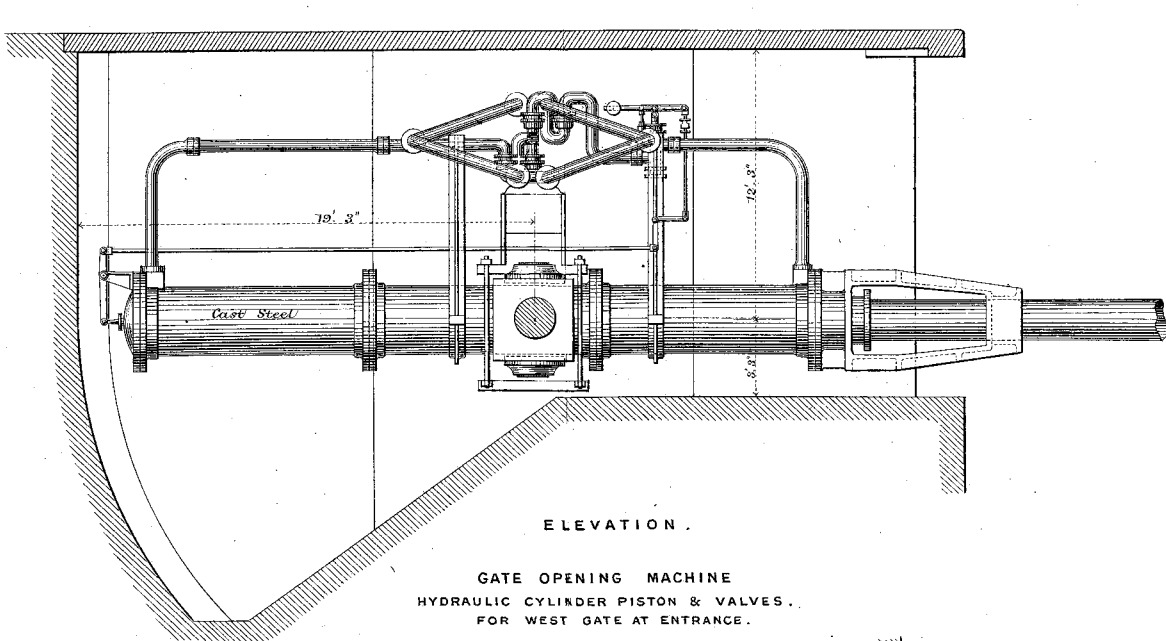


Fig: 4.

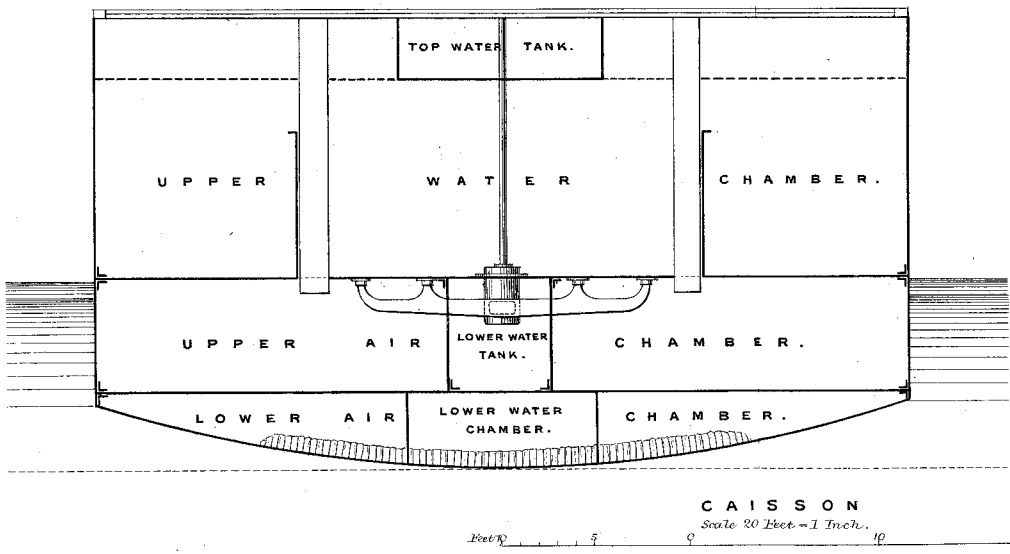


Fig: 5.

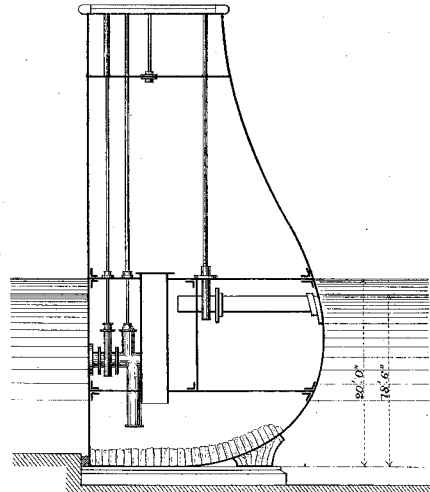


Fig: 7.

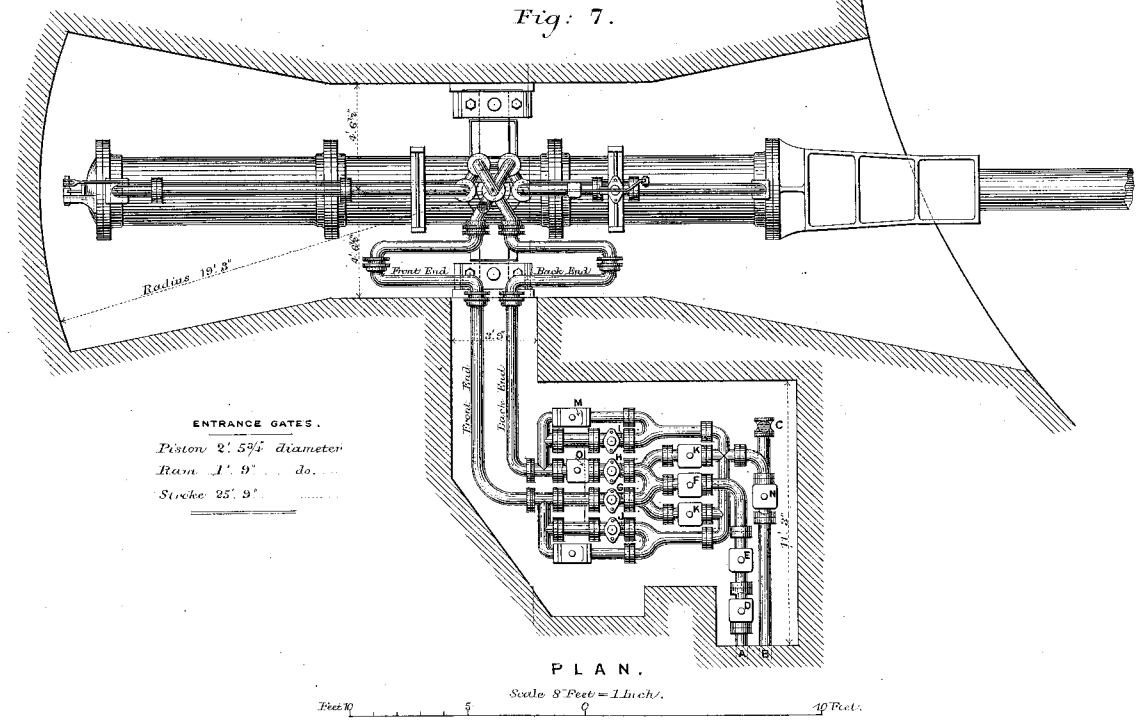


Fig. 1.

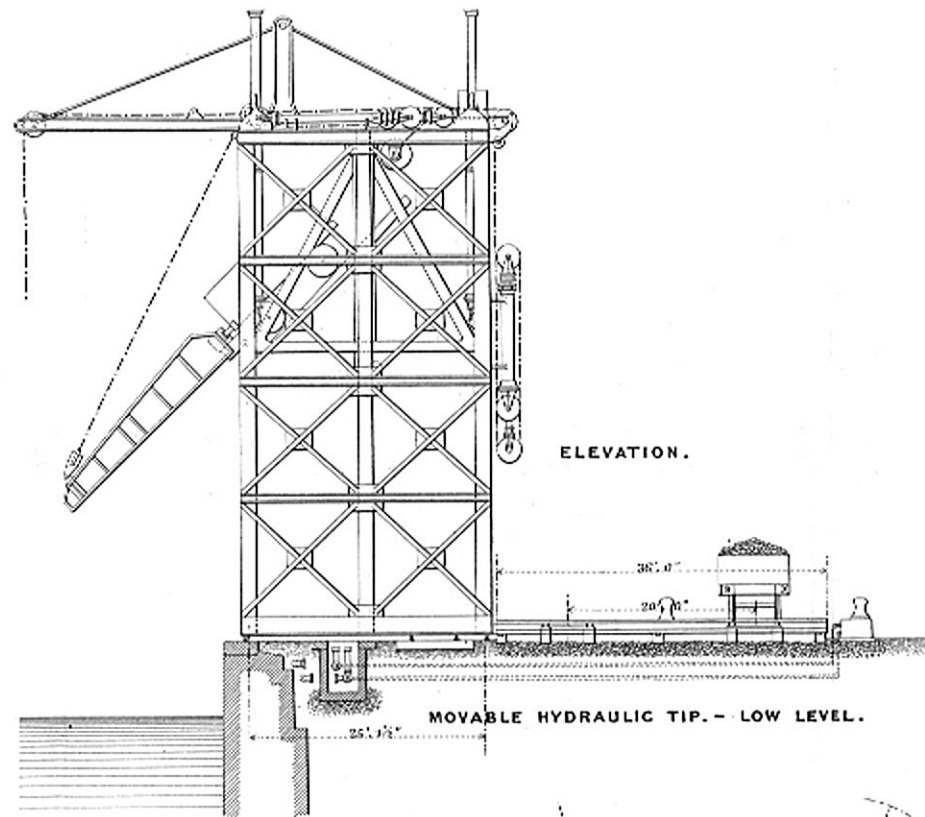


Fig. 3.

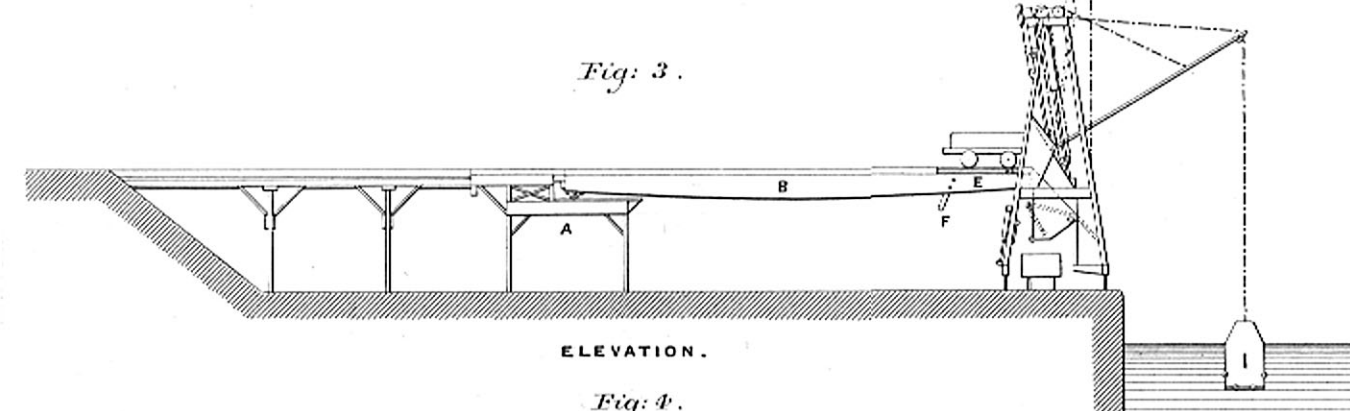


Fig. 4.

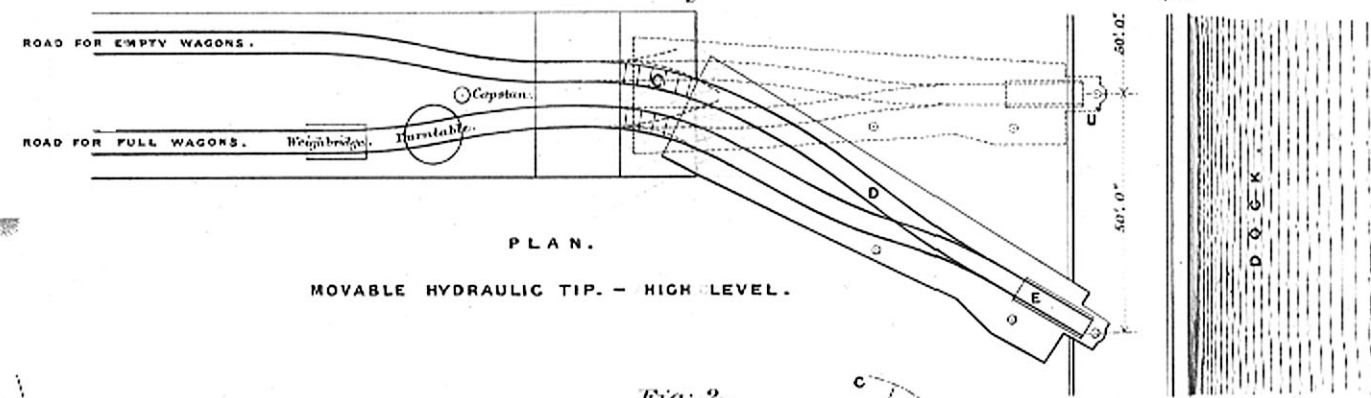


Fig. 2.

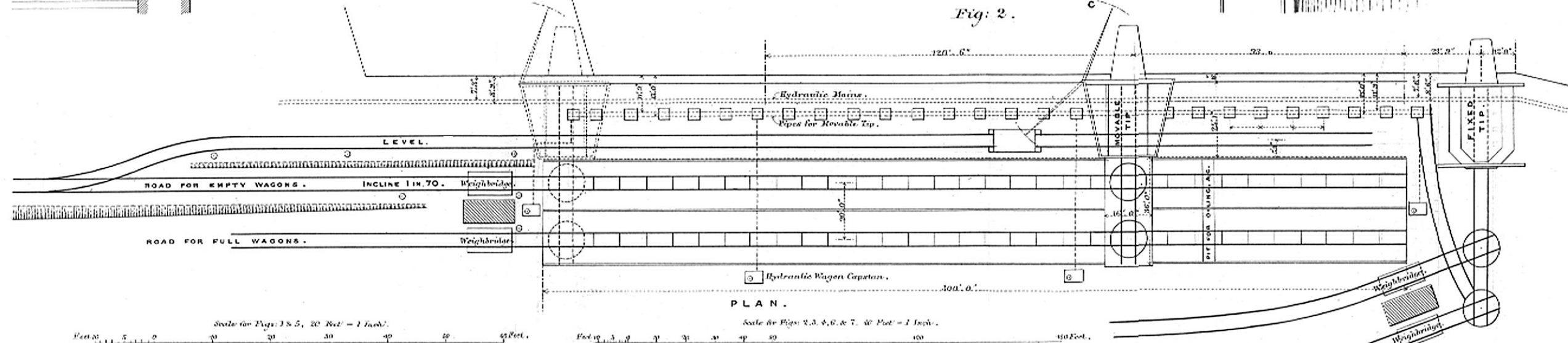


Fig. 5.

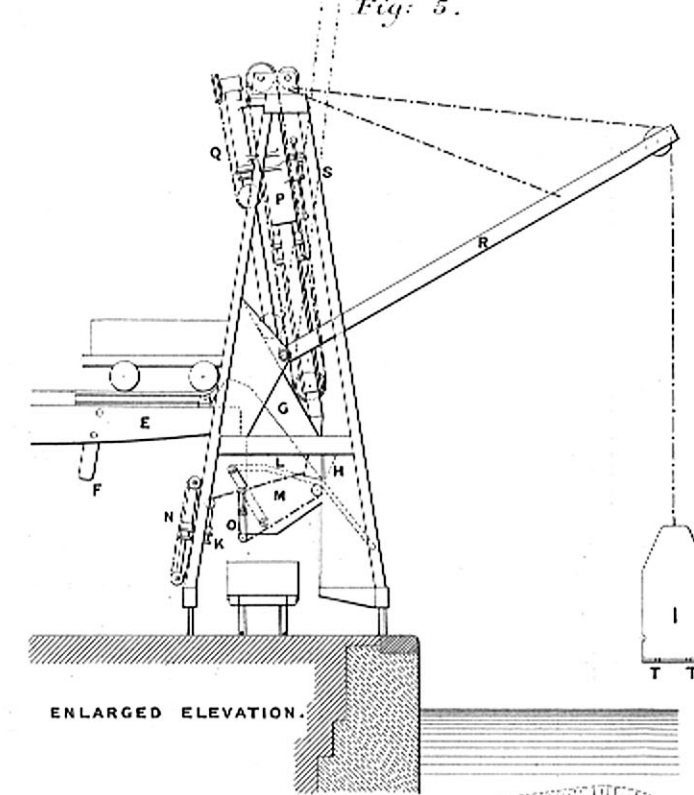


Fig. 6.

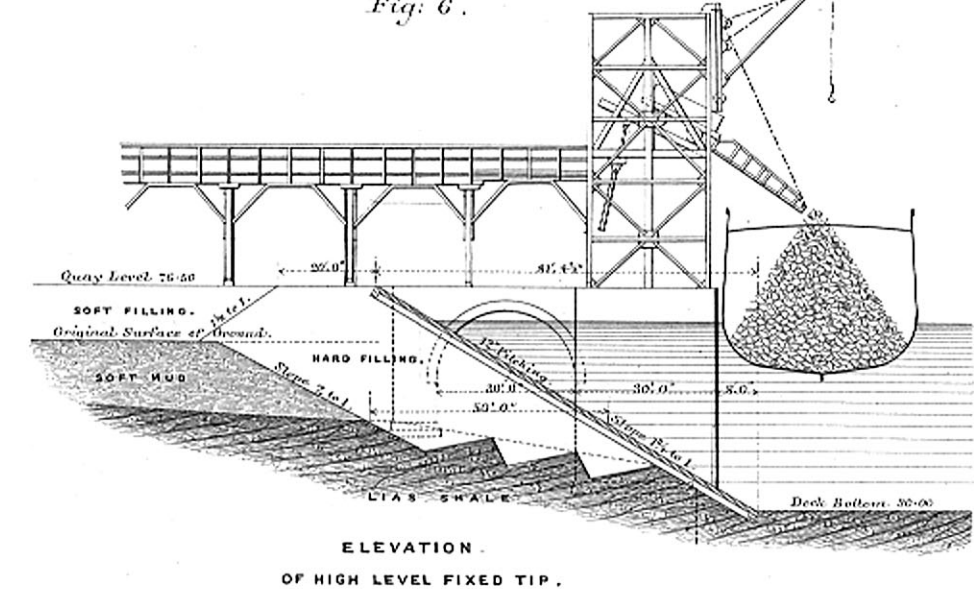
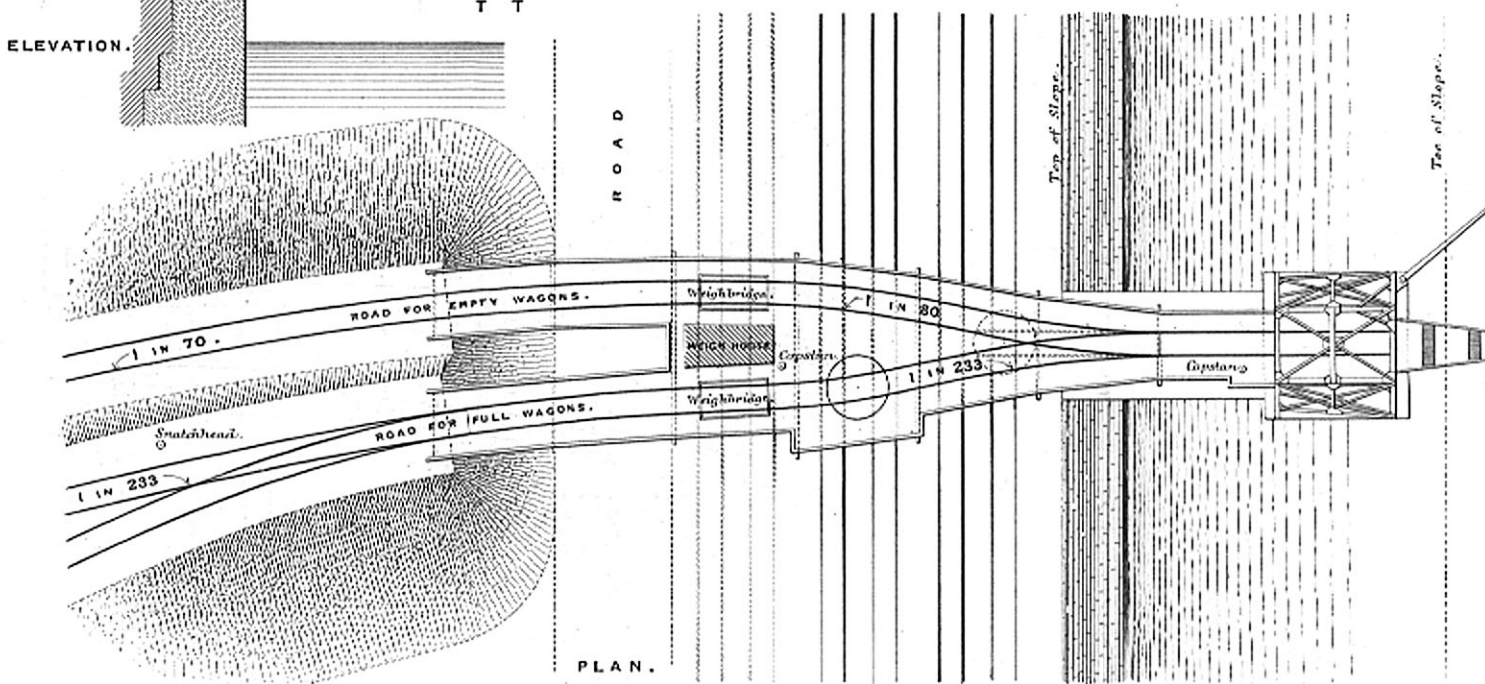


Fig. 7.



HIGH LEVEL FIXED TIP, SHEWING SECTION OF DOCK SLOPE IN HARD MATERIAL.

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