(*Paper No. 3646.*)

"The Tredegar Dry Dock, Newport, Monmouth."

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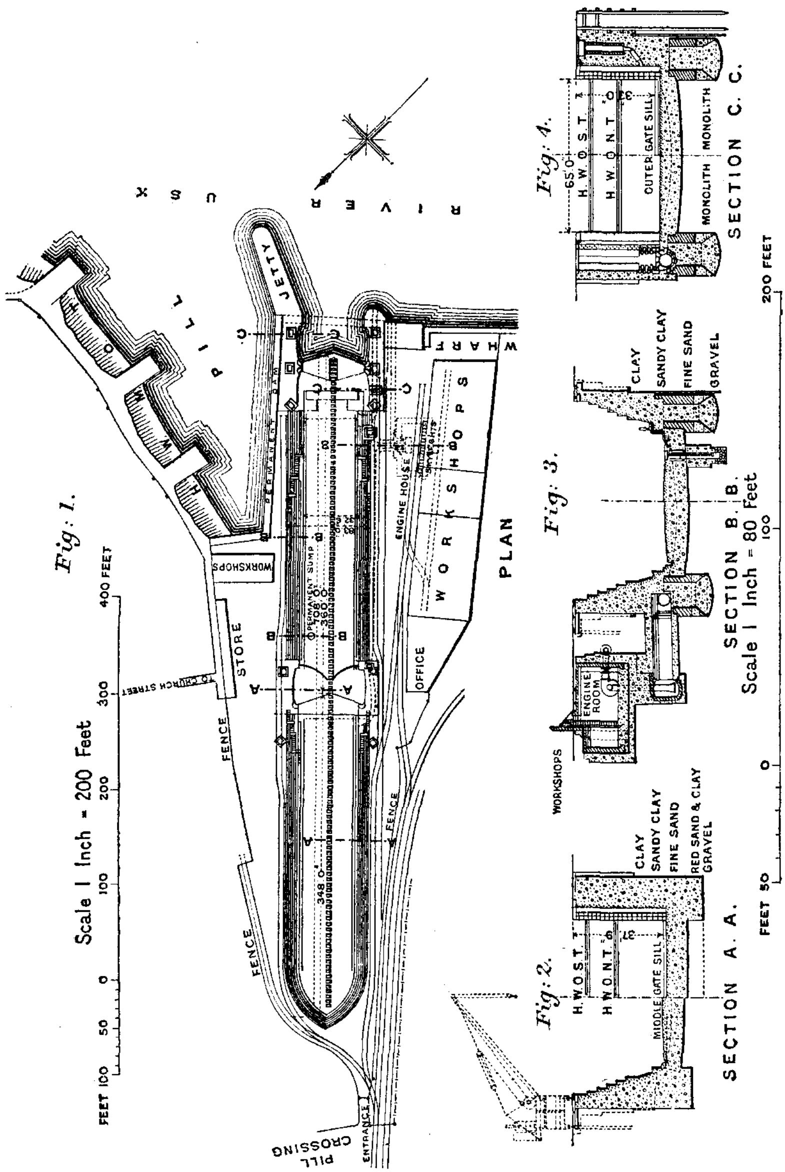
The Tredegar Dry Dock, at Newport, was built for a private Company, and is situated about midway between Alexandra Dock and the Old Dock, on the site of a creek known locally as "Gwenlly Pill," on the western side of the River Usk, a line of rails connecting the Dock directly with the Great Western Railway and with the Alexandra Dock Company's line. The dry dock is 708 feet in length and 65 feet in width at the entrance, and is the largest in the port. It is capable of accommodating a ship of 12,000 tons, and is divisible into two sections by middle gates, so that two ships of 7,000 tons each can be docked at the same time, one in each section, *Figs. 1–4.*

The breadth of the river at the entrance to the dock is more than 1,000 feet at high-water of spring-tides.

Difficulties in Construction.—The principal difficulties encountered in the work of construction were:—(1) close pile-driving through fine and compact sand; (2) trenching in and excavating from tidal water and surface water-bearing strata; (3) collapse of the cofferdam and consequent damage to the foundations of a portion of the floor; (4) the economical removal of tidal slurry and mud from the dock; and (5) the construction of chambers for machines, engines and plant, under the surface of the quay below the level of high-water, necessitated by the limited space at disposal. The methods adopted to overcome these difficulties, and the general method of carrying out the works, are described in this Paper.

Tides.—The nearly uniform width of the River Usk from Newport Bridge to its mouth, and the great rise and fall of tides, afford excellent facilities for navigation of the river by craft of the largest tonnage. The entrance-sill of the dock is never submerged at low-water, but only a few neap-tides ebb to a lower level than the surface of the floor; ordinary tides rise to a level of about 21 feet above the sill. The height of the tides is much influenced by winds; on 12th February, 1899, the tide, aided by a strong south-westerly wind, exceeded its normal height by 3 feet $1\frac{1}{2}$ inch, flooding the low districts, and as it rose 8½ inches higher than the proposed coping-



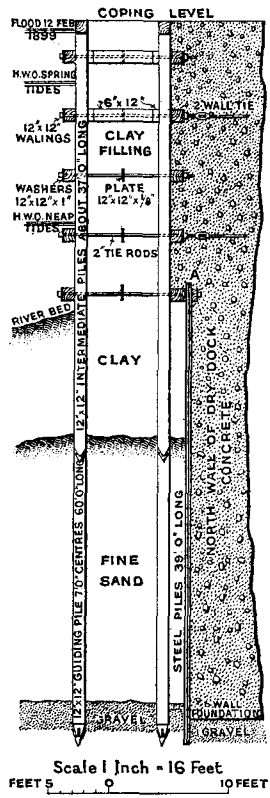
PLAN AND SECTIONS OF TREDEGAR DRY DOCK.

level of the dry dock it was decided to raise that level 1 foot 5½ inches, or 9 inches above the level reached by that tide.

Trial-Hole.—A trial-hole was made at a distance of about 80 feet from the existing river-wall, to ascertain the nature of the ground before digging the trenches, and was taken through clay and fine sand strata down to the gravel. As soon as sand was reached, water made its appearance and continued to increase in quantity until the gravel was reached, when the water began to rise and fall in the hole with the tide, proving direct communication with the river-water through the gravel stratum.

Cofferdam.—A cofferdam had to be formed on the foreshore to reclaim a considerable area of the site of the dry dock and to assist the contractors in its construction. The specification provided for an outer and an inner row of 12-inch by 12-inch close piling, in 60-foot lengths, spaced 7 feet apart, centre to centre, and braced together by five horizontal rows of 12-inch by 12-inch walings, spaced 5 feet apart, centre to centre, on the outer sides of the dam. The walings were bolted to the piles and were tied across the dam by 2-inch tie-rods at intervals of 7 feet. Two 12-inch by 6-inch inner walings, with 12-inch by 6-inch struts at each tie-rod, were also provided near the top.

Fig. 5.



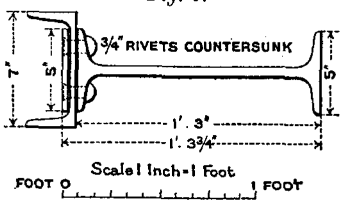
COFFERDAM.

It was intended to drive the piles down into the gravel to a depth of about 57 feet below the coping-level; the guiding-piles, 7 feet apart, centre to centre, were driven in the first instance without much difficulty, but the driving of the intermediate piles through the sand gave considerable trouble, more than 100 blows of a 25-cwt. ram falling 6 feet being required to drive the pile 1 inch, causing destruction of the heads of the piles. The water-jet method was tried, but without success, probably owing to the superincumbent bed of clay, and it was therefore found necessary to cut off the tops of the incompletely driven piles at coping-level, the piles not having reached the gravel.

As the purpose of the dam was not served by this piling, the design was altered as shown in *Fig. 5.* Short intermediate piles, about 37 feet in length, were driven, and as the difficulty to be overcome was apparently the displacement of sufficient sand to enable the piles to enter, it was decided to drive down into the gravel a row of close steel piling, against the lower waling on the dock side of the dam.

Steel Piling.—The sectional area of the steel piling per foot run of dam was about one-eighth of that of the adjoining row of timber piles, thus reducing the displacement of the material through which the piles were driven; and moreover the surface friction was also considerably reduced. Each pile was formed of a joist, a channel, and a plate, riveted together, *Fig. 6.* With the exception of those across the dock entrance, which were 28 feet in length, the piles were 39 feet in length and weighed on an average 25 cwt. each. The channel acted as a guide for the next pile, and the plate was added in order that the adjoining pile might be kept away from the rounded inner corners of the channel; the lower end of each pile was bevelled on one side.

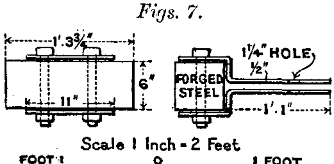
Fig. 6.



SECTION OF STEEL PILING.

The steel piling followed the contour of the dam and of the north wall of the outer dock, and proved most satisfactory, both in driving and in making a water-tight joint. A special forged-steel cap, *Figs. 7*, was fixed to the top of each pile during driving, asbestos cloth being placed over the cap to reduce vibration and to prevent the chipping of the edges of the ram. Of 281 steel piles driven, only three or four split at the top along the web, to depths varying between 5 inches and 3 feet. The driving of a pile without stoppage considerably reduced the resistance, the number of blows per foot being fairly uniform, whereas when the driving had been stopped for any appreciable time, as, for instance, for a night, the number of blows required to drive the pile 1 foot was increased by one-half. The ram used weighed 25 cwt. and was given a fall of 3 feet. To ensure plumb and close driving, five piles were usually pitched side by side at one time and driven a short distance; they were then driven separately to their full depth, with the exception of the outer pile, which was kept partly up to act as a guide for the

Figs. 7.

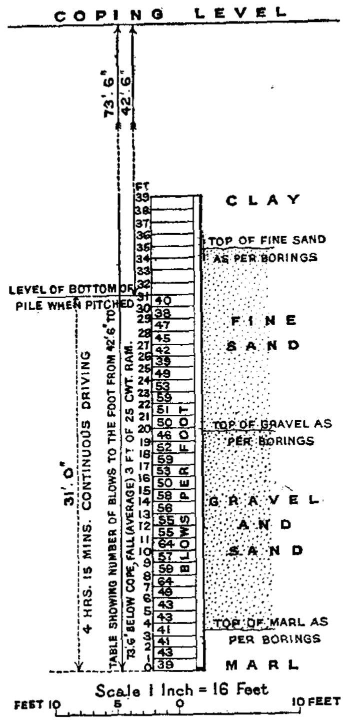


STEEL PILE-CAP.

next batch. The number of blows given to a steel pile for each foot driven, without stoppage, into the marl stratum underlying the gravel, is shown in *Fig. 8*.

Wherever practicable, the dam was anchored to the nearest wall of the dry dock by wrought-iron tie-rods, 2 inches in diameter, spaced 5 feet apart vertically and 7 feet apart horizontally. The area within the dam was excavated down to the surface of the existing clay bed, and was filled in with stiff puddle clay from the dock excavation. The dam was not, however, used to exclude the tidal water until the walls at the entrance had been built up sufficiently for the dam to be strutted against them. In order to avoid loss of time in waiting for the completion of the dam, a temporary puddled cross-dam was constructed, separating the upper from the outer dock site, thus enabling the contractors to proceed with the excavation for the upper dock.

Fig. 8.



Excavation.—A short length of the south wall of the upper dock was first excavated. Bore-holes made at the outset showed a marl foundation for the walls of this dock at an average depth of 51 feet below coping-level, and the contractors timbered their trench accordingly. After going through the clay, however, and whilst excavating the fine sand, some trouble was caused at a depth of 40 feet by water bringing sand through the gaps in the sheet-piling forming the bottom lining of the trench; and when the excavation reached a depth of about 48 feet, so much water carrying sand with it arose from the foundation that it was considered desirable to stop the excavation and to allow the water to rise in the trench, as settlement had taken place in the ground and timbering adjoining the trench. The Author then made a series of bore-holes over the site of the dry-dock walls and found that those which had been made at the outset

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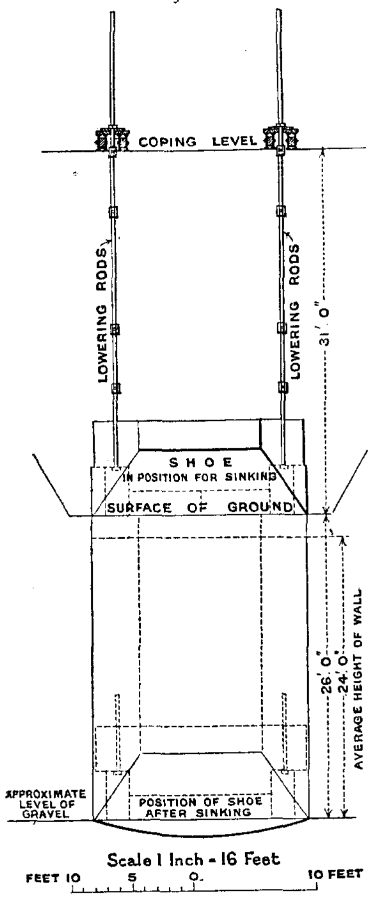
were not reliable for the upper dock, the supposed marl being in fact a stratum of red sand and clay under which there was a stratum of gravel of varying depth, rising towards the head of the dock. Below the gravel-bed red marl was found.

In order to drain the bed of fine sand, the contractors were instructed to sink a sump into the marl at the spot where the new bore-holes showed the greatest depth of gravel within the area protected by the cross-dam. The sump measured 14 feet by 14 feet at the surface, and three sets of runners were driven, reducing it at the bottom to 8 feet by 8 feet. Similar trouble was experienced in excavating the fine sand and the red sand, which quickened when charged with water; the pumps carried away a quantity of sand, which caused a settlement of the surrounding ground and timbering for a distance of 50 yards from the sump. The gaps in rear of the runners were filled in with clay, but the flow of water increased as the excavation proceeded. Eventually, however, gravel was reached at a depth of 53 feet, and was excavated within the sump; the pumps were worked at the lower level and the fine sand then gave no trouble and no further settlement took place. The runners through the gravel were then driven, wide apart, to give the surrounding water free access to the sump. The excavation within the sump was carried down to the red marl, reached at a depth of 68 feet 6 inches below coping-level, and a horizontal Tangye pump, capable of pumping 39,000 gallons per hour, was then fixed some distance down the sump, with a smaller relief-pump alongside. Pumping operations were then

Fig. 9.



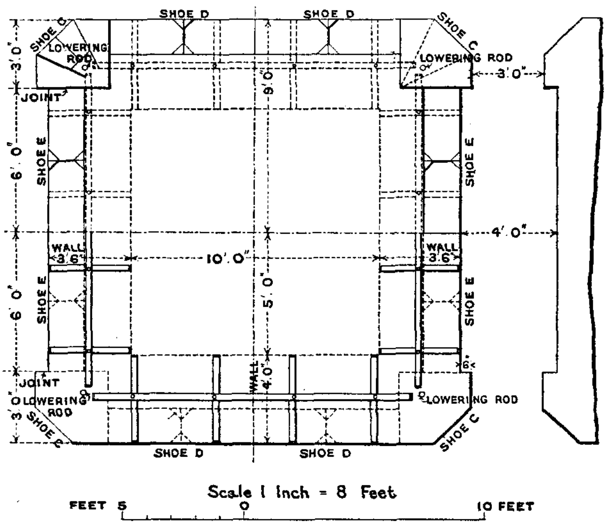
METHOD OF LOWERING MONOLITHS.

commenced and were continued night and day until the completion of the dock.

The bed of fine sand over the site of the upper dock having been successfully drained, the excavation of the trenches of this dock was proceeded with, the gravel being reached without further trouble. The stratum of gravel was found to be so very compact and homogeneous that it was not considered necessary to excavate further down to the marl for a foundation, and the walls were erected on the gravel. In order to enclose the fine sand upon which the floor of the upper dock had to be built, the foundation of part of the middle sill was taken down to the level of the gravel across the dock, and thus connected the side walls. The information obtained from the trial-holes and the difficulties hitherto encountered led to an alteration being made in the method of constructing the foundations of the walls of the outer dock beyond the cross-dam. As it was anticipated that worse difficulties would probably be met with in trenching in the deep stratum of fine sand so near to the river's edge, the trenches were dispensed with and monoliths were sunk through the upper strata to the gravel.

Monoliths.—The monoliths for the entrance walls were 18 feet by 18 feet in horizontal dimensions, and those for the dock walls 15 feet by 18 feet. The cast-iron shoe for each monolith consisted of four corner and eight intermediate castings provided with a cutting edge, all bolted together. Frames of T-bars were bolted to the castings and connected at the top by a 3-inch strap. The lower ends of the lowering-rods were built into the shoe, one at each corner; two sets of 3-inch lowering-rods were provided, each set consisting of four 12-foot lengths fully threaded, and a number of 5-foot and 10-foot intermediate rods provided with couplings and steel tap-screws for connection to the rods built into the shoe, *Fig. 9.* The walls of the monoliths were approximately 4 feet in thickness, reduced to 3 feet 6 inches on the sides provided with a recess, *Fig. 10.* The rods were held up between two sets of girders at the coping level by large nuts and washers bearing on the girders, the ends of which rested on timber framing supported by short piles temporarily driven about 2 feet 6 inches from the corners of the monoliths. As the monolith sank it was guided into the material by means of the lowering-rods for a depth of about 10 feet, after which these guides were dispensed with. The monolith was then allowed to sink by its own weight, and if one side showed a tendency to lean outwards the excavation was temporarily stopped on that side and continued on the opposite side until the monolith righted itself. In this way twenty-three monoliths were sunk, the filling to the shoes and the walls up to the level of the T-bar framing being composed of concrete, as were also the upper walls of seven of them. The upper walls of the other sixteen monoliths were built of brickwork. The concrete used was gauged in the following proportions:—within the shoe-castings, 3 to 1; from the top of the castings to the top of the T-bar framing, 5 to 1; and in the main walls 6 to 1, except in the case of the sixteen monoliths having walls of brickwork. The level of the bottom of the superstructure to be placed on the monoliths was, in many cases, far below the natural level of the ground through which these had to be sunk, so that, in order temporarily to hold up the ground surrounding them, it was necessary to carry the walls up to

Fig. 10.



PLAN OF MONOLITH.

a higher level than was actually required for the works. In such cases the walls so carried up were reduced to a thickness sufficient merely to withstand the surrounding pressure, and were afterwards removed where no longer necessary.

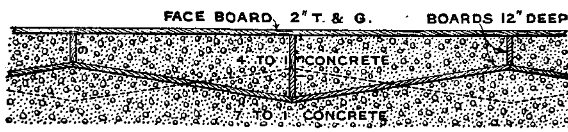
The work of excavating the material within a monolith was carried out between tides. Grabs of various patterns were tried, but were finally abandoned; either they could not bite the clay within the limited space, or they allowed the sandy material to run out with the water before it could be discharged. It was thus found more economical to excavate by hand, and, as the tidal water at times came over the top of the monolith and filled the hollow space, a small pulsometer pump was used to pump out the water as soon as the tide had receded sufficiently, and, when necessary, during the sinking operations. In general, five monoliths were in process of sinking at the same time. In a few cases, when a monolith refused to sink by its own weight, extra weight was added in the form of bundles of pig-iron weighing between 35 cwt. and 2 tons, as much as 100 tons additional weight being required in two instances to cause the monolith to resume its downward course. When the monolith had sunk about 1 foot into the gravel, as water kept coming up rapidly the bottom was at once filled in with a layer of dry concrete gauged 4 to 1; the remainder of the hollow core was then filled in with concrete, gauged 10 to 1, in which large stones were embedded. The 6-inch recess shown in *Fig. 10* on two opposite sides of the monolith was designed with the intention of driving piles in the gap between two monoliths for the purposes of excavating and subsequently concreting the enclosed space down to the gravel. This was, however, found to be inconvenient; the shoe being on a higher level on the recess-sides allowed sand to get within the monolith, notwithstanding the fact that the remainder of the shoe had already reached the gravel; it also complicated the shape of the walls. This recess was ultimately dispensed with by keeping the cutting edge of all the castings forming the shoe at the same level. When commencing operations, the bottom of the shoe was at an average depth of 33 feet below the coping level; the monoliths were sunk to an average depth of 57 feet, giving an average height of wall, including the shoe, of 24 feet. For bonding-purposes, bent rails were built in at the corners of the walls of the monoliths, and a groove was formed at the top of each layer of concrete, at the centre of the walls, to key it to the next layer. The monoliths were sunk about 21 feet apart, centre to centre, leaving a space of about 3 feet between each two monoliths; this space was then excavated to the gravel by driving two or three sets of runners at the ends, where necessary, or at one end where the steel sheeting could be utilized, and the material was extracted by hand in the usual way. The space was then filled in with concrete similar to that of the cores of the monoliths. The walls nearest the entrance were completed in the first instance, to receive the struts of the cofferdam across the entrance, which was then completed. The tidal water was thus kept out, and, the temporary cross-dam having been removed, the unfinished work of construction throughout the dock was completed in the dry.

Concrete.—The foundations of the side walls (with the exception of the monoliths) were composed of 8-to-1 concrete up to the level of the underside of the dock floor; the superstructure was formed of a hearting of 7-to-1 concrete with a facework of 4-to-1 concrete 12 inches in thickness, finished with a smooth and true face; large stone displacers or plums were embedded in the concrete, not exceeding in the aggregate 15 per cent. of the whole bulk; the facework was brought up simultaneously with the hearting, as far as possible, but to prevent the formation of a vertical joint between them the boards separating the two mixtures were placed so as to break joint at each layer as shown in *Fig. 11.*

The entrance and middle passage walls were backed with clay-puddle. The walls of the head of the dock, being on a curve, were faced with brickwork so as to dispense with curved shutters.

Culverts.—The culvert formed in the south wall is 5 feet in internal diameter; it extends from the upper dock to the end of the outer dock, and thence, enlarged to 6 feet in diameter, to the outfall and to the suction-well of the pumping-station. All exposed faces were made of 4-to-1 concrete to a depth of 12 inches. Three paddle-shafts are provided, the rubbing-stones of the paddle-grooves being

Fig. 11.



SECTIONAL PLAN OF SIDE WALL.

of Cornish granite, fine-axed perfectly smooth; the paddles are of teak and are raised and lowered by means of a vertical screw spindle.

Dock Floor.—The dumpling in both docks was excavated in the dry down to the fine sand foundation upon which the floor, 9 feet in thickness at the centre, was built. The inverted arched bottom of the floor, 4 feet in thickness at the centre and made of 6-to-1 concrete, was dished 2 feet on the underside and 4 feet on the upper side; the remainder of the floor, 5 feet in thickness at the centre, was made of 8-to-1 concrete, with the exception of the surface, which was made of 4-to-1 concrete to a depth of 1 foot, and was finished smooth on the top; a slightly richer concrete was used for the floor of the sills.

There is a longitudinal fall of 6 inches in the length of the floor and a lateral fall of 6 inches from the centre-line to the gutterway, formed in the floor alongside the lower altar on either side and connected to the main culvert. In order to relieve the floor of undue pressure from air and water below the foundations, two rows of vertical 4-inch drain-pipes were embedded in the concrete about 10 feet apart on either side of the centre-line; in the outer dock these pipes went down to the gravel. No trouble was experienced in the upper dock, but in the outer dock, in consequence of sand blowing up the pipes at high tides, a number of them had to be stopped. The pointing sills were made of greenheart timber, 12 inches by 12 inches, laid in blue brickwork and held in position vertically and horizontally by $1\frac{1}{4}$-inch Muntz-metal bolts. This method did not, however, provide a perfectly tight sill, as water under pressure followed the contour of the greenheart timbers and rose up in the dock, and caulking was found to be necessary.

Gates.—Three sets of gates were provided, namely, the outer or river gates and the inner or half-tide gates at the entrance, and the middle or partition gates at the middle passage, dividing the dock into two sections. The gates were supplied and erected by the Thames Ironworks Shipbuilding Company, Limited; they are single-skin gates and swing without rollers. The plates, ribs, tie-bars, angle-bars, etc., are of mild steel; the heel-posts and meeting-posts are of greenheart, the pintles of annealed cast steel and the anchor-rods and connections of forged steel. Gangways are provided over the river and middle gates; each leaf of the river gates is fitted with three sluices, 3 feet by 2 feet 9 inches, and of the half-tide gates with one sluice, 3 feet by 2 feet 9 inches.

The erection of the river gates was pushed ahead in the first instance, and this proved to be a wise precaution, for before the walls and the floor of the dock had been completed the entrance dam sprang a leak along some tie-straps at the north-east corner. Every effort was made to stop the leak, but it became worse, and shortly after high-water of the following tide the material within the dam collapsed and allowed the tidal water to flow in and fill the dock. The river gates being then nearly completed were requisitioned to act as a dam. At this stage the meeting-post timbers had not been dressed, nor were the anchorages available, and temporary measures had to be adopted to make the joints between the gates and the sill, and between the meeting-posts, water-tight. The gates, when thus temporarily placed, were about 1 inch away from the sill at the meeting-posts, and some trouble was experienced in keeping the water out at this opening. Finally a wooden rebated template wrapped in canvas was fitted over the sill and the opening, jointed with red lead, and strutted to the ribs of the gates, whilst on the other side and under the gates, clay-bags and clay were rammed tightly up to the sill. These measures proved effectual. The portion of the dam across the entrance was then removed down to the level of the apron, and the work of completing the dock and the other gates was resumed.

The gates are operated by means of hand-winches and tackle; the winch, to which is geared a capstan-head with grooves for four removable handle-bars, is placed in a pit below the level of the quay. The handle-bars extend above the quay level and are worked by men from that level; the gates can thus be opened or closed in 5 minutes, one man at the brake being sufficient for slackening the tackle.

Pumping-Station.—As the water in the dock recedes to below the level of the entrance sill at the ebb of every tide, small drainage-pumps would be sufficient to drain the water remaining in the bottom of the dock. In many cases, however, a ship can be admitted to one section of the dock about 2½ hours before high-water, and by pumping the water out of this section immediately it may be possible to examine and repair the ship and undock it on the ebb of the same tide, and for this purpose large pumps became a necessary adjunct. The pumping-station is situated on the south side of the dry dock, close to the entrance. Owing to want of space at the level of the quay, the engine-room had to be built underground, with skylights, close against the wall of the adjoining workshops; artificial light is also provided in the engine-room. The floor is 19 feet below quay-level; the walls are of concrete, with a brick facing, lined throughout on the concrete side with asphalt; the roof consists of girders and brick arches, levelled over with concrete covered with a layer of asphalt. The suction-chamber is formed immediately below the floor of the engine-room.

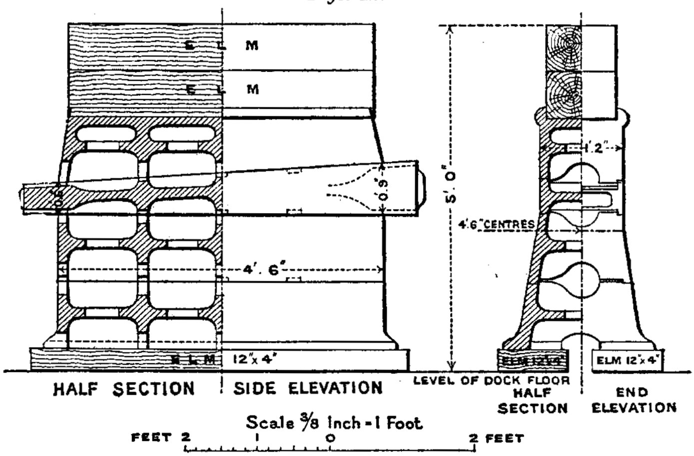
Pumping Machinery.—The pumping-plant was supplied and erected by Messrs. Tangyes, Limited, and consists of two 26-inch (suction and delivery) centrifugal pumps with closed-type disks 5 feet in diameter having a maximum peripheral speed of about 2,700 feet per minute. Each pump is driven directly by a horizontal gas-engine of 140 brake-HP. The suction-pipes, about 20 feet in length, provided with a bell-mouth, pass through the engine-room floor into the suction-chamber below; a 22-inch sluice-valve is fitted to the delivery-branch of each pump, and also a 22-inch non-return flap-valve, the shaft of which comes through a stuffing-box to the outside of the valve-casing and carries a lever and weight so regulated as to ensure the valve closing without shock when the pumps are stopped; the height of the lever also indicates to the attendant in the engine-room the quantity of water being pumped; water is kept circulating round the pistons, exhaust-valves and cylinders, to prevent overheating. In addition to the main engines and pumps, a 10-inch beltdriven centrifugal pump is provided, having an open-type disk, 18 inches in diameter, for dealing with mud and debris from the dock bottom. The pump is capable of pumping 1,300 gallons per minute with a lift of 40 feet, and is driven from a horizontal gas-engine of 19 brake-HP. It is also coupled to an air-pump, 10½ inches in diameter by 6 inches stroke, the duty of which is to charge the pumps. The air-pump has a separate system of suction- and delivery-pipes for keeping the engine-room dry, this being necessary when the dock is full, as ordinary drainage cannot be effected owing to the depth of the engine-room floor below the quay level. There is also included in the installation a 3-HP. horizontal gas-engine connected directly to a small air compressor for charging with air two cylindrical vessels, each 3 feet in diameter by 4 feet in length, to a pressure of 90 lbs. per square inch. The main engines and pumps are started by air-pressure from these vessels, and after they have made two revolutions the air-pressure is automatically cut off and the usual cycle of gas-engine operations begins.

Trial of Pumps.—The time taken by the pumps to empty the dock, containing 3,652,000 gallons of water, was 103 minutes, the maximum lift, including friction in the delivery-pipes, being 20 feet. Each engine developed at the maximum load 134 brake-HP., the power utilized in raising water being 80 HP., showing the combined efficiency of the engine and pump to be 60 per cent. The pumps started at 135 revolutions per minute and delivered 16,300 gallons each per minute; as the lift increased, the speed of the engines also automatically increased, reaching a maximum of 172 revolutions per minute when the dock was nearly empty, representing a delivery of 13,600 gallons per minute for each pump. The engines used 13½ cubic feet of town gas per brake-HP.-hour, and the equivalent of the friction in the delivery-mains and pumps varied between 20 inches and 16 inches head of water. The main delivery into the river consists of cast-iron pipes, 48 inches in diameter, jointed with lead and hemp, and is connected by a reducing-pipe to the two 26-inch and 9-inch delivery-pipes of the three engines. These pipes are laid on concrete seating-blocks with a fall to the river of 1 in 8.

Equipment.—The keel-blocks, 5 feet in height, are placed 4 feet 6 inches apart, centre to centre, and consist of two loose elm sleepers, 4 inches in thickness, on which are laid four cast-iron sliding frames, two of which are wedge-shaped on one side; two 8-inch elm blocks are placed on the top casting, being kept in place by a lip on either side of it, *Figs. 12.* A 20-ton locomotive steam-crane, capable of lifting a working load of 10 tons at the centre of the dock, runs along the edge of the quay on the south side, and travellingcranes of smaller capacity are also provided on either side of the dock.

Permanent Sump.—In order to save the cost of using the town water-supply for cleaning the deposit of slurry and mud from the altars and floor of the dock after each admission of tidal water, a permanent sump was made alongside the temporary drainage-sump, for the purpose of collecting water from the gravel stratum. The sump is formed of cylinders 3 feet in diameter, lined with concrete, which were taken down into the gravel to about 3 feet above the marl, the bottom being filled with large rubble to a depth of 3 feet. The water is raised by means of a horizontal pump fixed on the lower altar of the dock. The suction-pipe starts close to the

Figs. 12.



KEEL-BLOCK.

bottom of the sump and the delivery-pipe is carried up to the coping level on the south side and then around the coping to the north side, being provided at intervals with 3-inch nozzles for hose-connections; this service is also used for filling ships' ballast-tanks, and for general purposes.

Concluding Remarks.—After the river gates had been closed and the water over the floor had been pumped out, it was found that the collapse of the dam had caused damage to the floor of the dock, which at the time of the accident was not quite completed. The temporary drainage-sump was found to be choked up, and on the removal of the surface material a cavity was found under the concrete floor, adjoining it and extending partly round it; the cavity in the worst place measured 20 feet by 20 feet by 3 feet in depth; some fine sand below the floor had apparently found its way into the sump, choking it and leaving a portion of the floor suspended, and moreover a spring of water was discharging into the sump from within the cavity, carrying sand with it. The sump was carefully cleaned out to the bottom and the joints of the runners were packed with hay; the sump was then filled to a depth of 6 feet with rubble, and above this concrete walls were brought up, leaving a chamber in the middle of the sump for the suction-pipe of the pump. As the walls reached the level of the underside of the floor the chamber was reduced so as to leave only just sufficient opening for the suction-pipe to pass through; the cavity under the floor was then filled up with well-rammed sand, the suction-pipes were withdrawn and the sump itself was filled up with concrete and grout poured through the opening from a height sufficient to deal with the head of water during the setting of the concrete, and the floor was finally completed.

The contract was first let in March, 1898, to local contractors, who constructed the greater part of the dams and steel piling, but a dispute having arisen as to the interpretation of some clauses, the matter was referred to arbitration in London and the contract was terminated. Mr. J. C. Hawkshaw, Past-President Inst. C.E., was appointed Consulting Engineer, and a fresh contract was entered into in September, 1900, with Messrs. Price and Reeves of Westminster, who carried out the works to completion in March, 1903. The Engineers were Messrs. Jacobs and Barringer, London, and the Author acted as Resident Engineer.

The Paper is accompanied by six tracings, from which the Figures in the text have been prepared.