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THE CONSTRUCTION OF A TIMBER DRY DOCK.

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To be read before the General Section, 20th April, 1905.

INTRODUCTION.

Among the pages of the Engineering News for Nov. 28th, 1901, there appeared the following brief note:—"The William Skinner Ship-Building & Dry Dock Co., of Baltimore, Md., formally opened the second largest dry-dock in this country on Nov. 25. The dock is built of timber carried on pile work and the entrance is granite masonry backed by concrete. The steel caisson-gate gives an opening 80 ft. wide at the top with 22½ ft. of water over the sill. The general dimensions of the dock are as follows: Length over all 628 ft., length on keel blocks, 600 ft., width of entrance at the bottom, 60 ft., at top, 80 ft., width of dock on the floor, 62 ft., width at coping, 125 ft., depth of water over sill at low water, 22½ ft.,"

The same journal in its issue of Jan. 9th, 1901 devoted one page to a more extended notice of this work.

In the present paper it is proposed to give a more detailed account of this dock as it actually is; the methods of construction employed; the contract prices, quantities of material and cost data; a comparison of this with the other large docks to be found along the eastern coast of North America; and in conclusion, to show what three years of operation has done to verify the judgment of the designers and builders in their solution of the various engineering problems which were presented to them.

GENERAL DESCRIPTION.

The ship-building plant of the Wm. Skinner & Sons Co., is located at the foot of East Cross St., in Baltimore, Md. At the time of building the new dry dock, this plant consisted of several work shops equipped with compressed air machinery, and a marine railway for the docking of small vessels.

The port of Baltimore could boast of several such plants and in addition a timber dry-dock of small size, constructed some 20 years ago and at this time in a bad state of repair.

The size and tonnage of the larger vessels entering this port had long since exceeded the limits of its docking facilities, and whenever repairs were needed upon such ships they were compelled to seek the larger docks at Newport News, or New York.

The "William Skinner & Sons Ship-Building & Dry Dock Co, of Baltimore Md.," was organized. The newly organized company then secured additional property adjoining that of the old company, and had plans prepared for a modern timber dry dock of large dimensions. The proposed site of the new dock was covered by old brick warehouses and an old pier. It was impossible to secure sufficient property so that the proposed dock could be constructed within the then existing shore line, and it was therefore necessary to plan for building the entrance and about 175 ft., of the dock body, in the open waters of the harbor. The average rise and fall of the tides at this point is about 18 inches, though the maximum has been known to greatly exceed this amount, when both tide and wind are favorable for exreme conditions. The water is brackish.

Borings were made to ascertain the probable character of the foundations, and soundings taken in the harbor, after which the plans and specifications were prepared by Messrs. Ritchie & Ruple, Consulting Engineers of Cleveland, O. As finally agreed upon, the plans called for a dock body built of timber, supported upon piles, an entrance composed of concrete faced with granite masonry, and a steel caisson gate.

The work was divided into four parts as regards the letting of contracts as follows: 1st. Dredging and removing the old structures and piers. 2nd. Construction of the protection bulkheads and cofferdam. 3rd. Construction of the concrete and masonry of the entrance and power house foundations. 4th. Construction of the timber work and the main body of the dock.

A contract was signed on June 30th, 1899, with the Delaware Construction Co., of Wilmington, Del., covering all the work in parts 1 to 4, and they commenced operations a few days later. The mechanical equipment, the caisson gate and the superstructure of the power house were arranged for by special contracts to be noted later.

Detailed Description.

Foundations.

The nature of the soil upon which the dock was built varied considerably as shown by the materials encountered during construction. In excavating one of the bulkheads, after the river mud had been removed, there followed a layer of yellow clay some 8 or 10 inches in thickness; a few inches of vegetable matter resembling peat; a stratum 4 feet thick, composed of coarse quartzite pebbles and fine red sand merging into densely compacted layers of pure sand; and beneath all extending to some undetermined depth, a pure white clay. Before water had reached it, this clay was exceedingly hard, would take on some polish when rubbed, and was sometimes used by the carpenters to chalk lines. After standing some time in contact with water it became softer, resembling somewhat the texture of castile soap.

The concrete work about the dock entrance was in all cases placed directly upon this clay. It is doubtful if any of the piles or sheet piles ever penetrated this material to any extent. In fact those of the temporary work which were afterward pulled, appeared as if they had landed upon a rock, and the whiteness of their points was evidence enough as to what they had landed upon. No actual rock was however, encountered at any point.

Protection Work.

The safety and efficiency of a timber dry dock depends in a large measure upon the possibility of keeping water away from the piles and foundations. In the work under consideration this was a very important matter, for as has been mentioned above, over 200 feet of the structure was situated in the waters of the harbor.

It was proposed to surround the entire dock, (excepting of course the entrance way) with a single line of sheet piling. Commencing back some 65 feet from the shore line and extending outward to the limits of the dock, this line was to be doubled, the two lines being spaced 16 ft., apart. Round piles of yellow pine were driven every ten ft. upon the outer sides of these were drift-bolted two parallel lines of 12 by 12 inch Southern pine waling strips. One strip being placed at the level of the bulkhead top, and the other below low water line. The lower waling strip was omitted from the sheet piling within the shore lines.

Timber braces, 12 by 12 inch Southern pine were placed across this bulkhead at every pair of the guide piles and a 1¾ inch iron tie-rod beside each brace. The piles were slightly notched to keep the braces in position.

Along these guide wales was driven a continuous wall of Southern pine sheet piles, tongue and grooved, and mostly 40 feet in length. The sheet piles were 10 by 12 inches with a white pine tongue 4 inches square. Each pile was secured to the waling strips by ⅞ inch machine bolts.

Between the outer ends of these permanent bulkheads, a temporary one of like character was driven, which formed the cofferdam, and two single lines of temporary sheet piles were driven from bulkhead to bulkhead, enclosing that portion destined to be excavated for the entrance foundations, and the pump well.

Entrance.

The entrance proper of the dock, is concrete foundations and backing, faced with heavy granite masonry. The outer apron is 12 feet wide, the middle apron 12, and the inner 20 ft., The surface of each is level with the exception of the inner, which for a distance of 12 feet slopes downward to the cross drain in the main body of the dock.

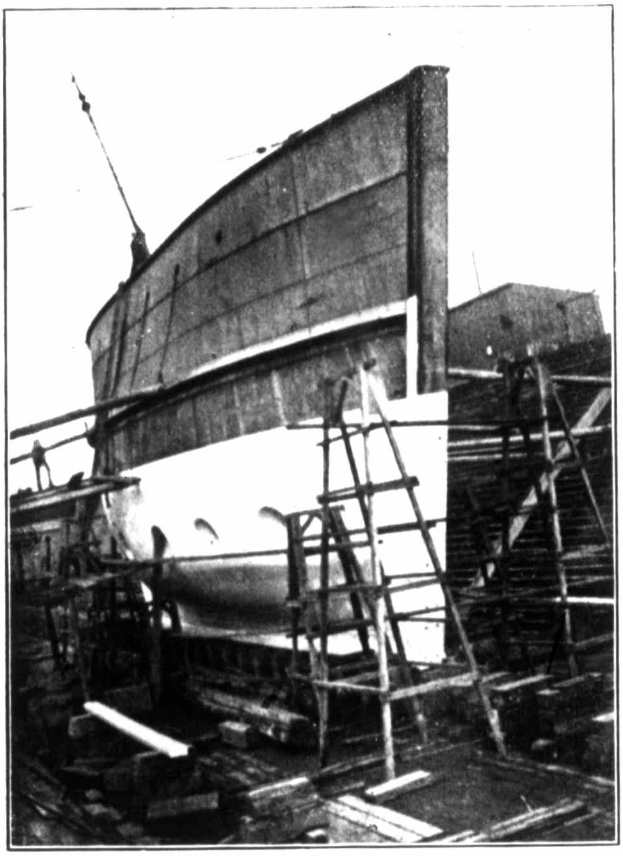
The entire surface is bush-hammered to a smooth finish. The sills, two in number, rise vertically from the aprons a height of 18 inches. The minimum width of entrance at the top of the inner sill is 60 ft.

The granite abutments are rock faced, with the exception of the bush-hammered jambs. They rise vertically from the inner sill level a height of 29 feet and recede 10, thus making the width of entrance at the coping level, 80 feet.

Each stone in course is doweled to the stones below, with two iron pins, each 1 inch square and 4 inches long.

Beneath the aprons are 11 steel bands, 10 by ½ inch, by 22 feet, bent upward at the ends, which serve to bind the sill stones together.

Behind the north abutment, the concrete backing is carried in a solid mass to the protection bulkhead, and in the concrete back-



The Caisson-Gate (Completed).

ing behind the south abutment, are formed the pump well, and engine pit, and drainage tunnel from the main dock body.

Gate.

When the dock is in use the entrance is closed by a steel caisson gate whose general dimensions and construction are shown upon the drawings accompanying this paper and the two photographs here shown.

The material specified was medium, open hearth, acid steel, testing from 54 to 62,000 number in tension, per sq. in., and containing not more than .08% of phosphorus and not more than .04% of sulphur.

A 4" by 12" oak strip is fastened along each face of the keel, stem and stern posts, to which is attached a 10" by ½" gum gasket. It carries a permanent ballast of concrete.

For filling the dock, it is provided with six 36" valves, and for water ballast, four, 6" valves and one 8" centrifugal pump with steam engine. Steam is supplied from the boilers in the main power house.

The gate draws 13"-8" of water when carrying only permanent ballast, and at such times its displacement is 212 tons. It was built under special contract, by the Spedden Ship Building Co., of Baltimore.

Main Body of the Dock.

The bottom of the dock is supported by 13 longitudinal rows of 20 ft., piles. The five center rows are spaced 4 ft. c. to c. longitudinally and 3 ft., c. to c. transversely. Upon these comes more directly the weight upon the keel blocks. The other 8 rows are spaced 8 ft., c. to c. longitudinally and transversely as shown on the "Half Midship Section" on the drawings. The sides of the dock are supported by rows of 25, 30, 35 and 40 ft., piles, spaced 4 and 8 ft., on centers. The piles are capped by 12" by 12" yellow pine timbers, secured to each pile with 1" by 20" drift bolts. The main cross timbers are spaced 8 ft., c. to c. They consist of Oregon (Douglas) Fir, 16" by 18" by 70 in length. Midway between each of these on the center line of the dock, is a similar piece, 14 ft., in length. They are secured to the pile capping with 1" by 30" drift bolts. Along the sides of the cross timbers are spiked 4" by 10" floor joists, and from the ends of the 14 ft. cross timbers, 6" by 10" floor joists extend to the foot of the side slopes. Upon these is spiked a flooring of 4" white oak plank. The first 80 feet of dock floor adjacent to the entrance and the last 40 next the head, is on a level with the tops of the cross timbers. The balance is 4" below the level at the center line and slopes uniformly toward the sides, on a grade of 3" in 30 ft. The floor rises toward the head of the dock on a grade of 6" per hundred feet. The slope timbers are spaced 4 ft., c. to c., being alternately 12" by 14" and 8" by 14" yellow pine timber. They are framed into the cross timbers at the bottom of the slopes, and secured to the slope pile capping by 7/8" machine bolts. The yellow pine altars were cut from a timber 10" by 14", so that when placed in position they would have a rise and tread of ten inches.

They are secured to the slope timbers by 12 inch boat spikes, and abutting ends are doweled with 1 inch by 6 inch iron pins. They are laid with the treads horizontal, which causes the lowest course to disappear about every 170 feet, owing to the rise in the dock floor.

Four chutes are provided on each side for the delivery of material. At these points the altars are omitted and 6 inch oak plank spiked upon the slope timbers.

Across the ends of the long floor timbers and along the piles in the slope rows are placed 6 by 12 inch yellow pine waling strips, bolted to the piles with 7/8 inch machine bolts. Between these waling strips are placed 12 by 12 inch braces, making a continuous line of bracing from the outer row of piles to the foot of the slopes. Another 12 by 12 inch brace extends from the waling on the outer row of piles to the capping of the third row, and a 1¾ inch iron tie rod is placed beside it. This combination of braces and rod forms a truss as shown on the drawing.

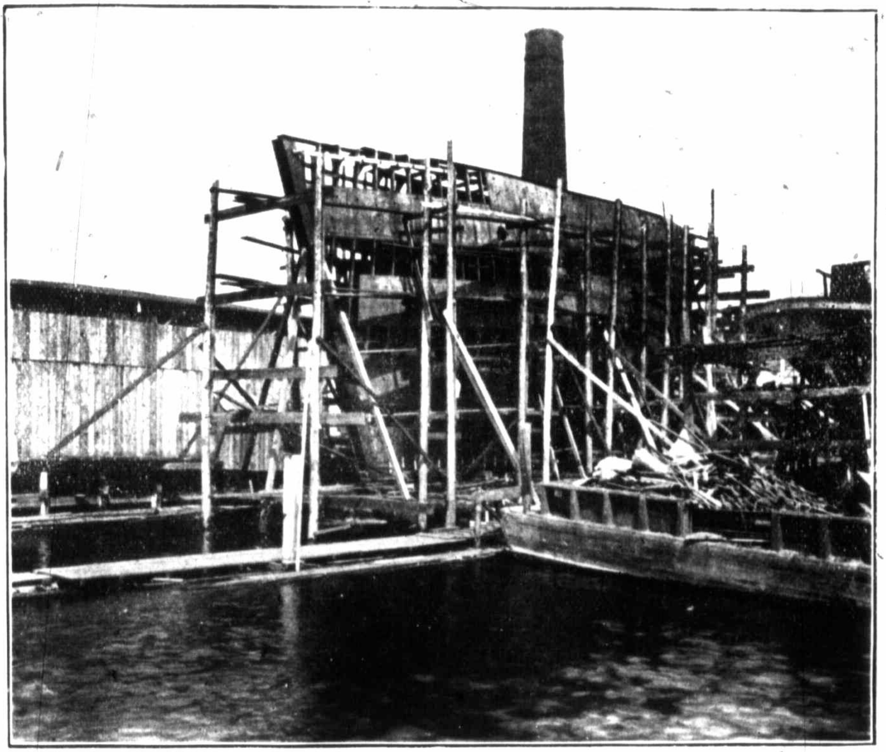
The head of the dock was originally designed to be similar to the sides, that is approximately, a 45 degree slope. During construction, however, an extension was built into this slope, forming a box with vertical sides, thus gaining over 24 ft., in total docking length.

Drainage System.

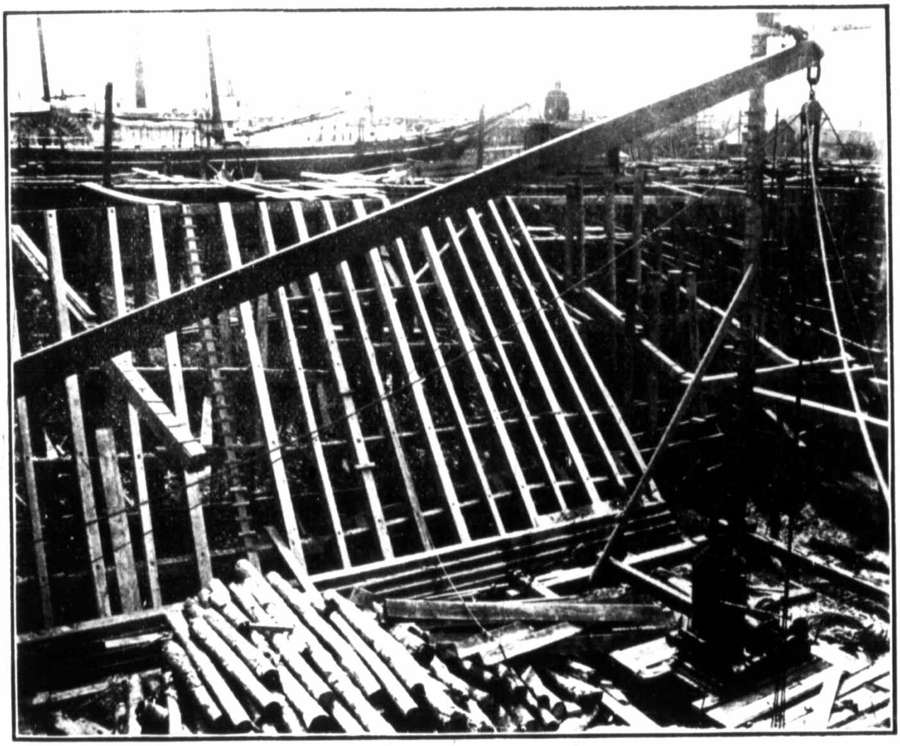
From the masonry of the entrance to the head of the dock, the floor rises uniformly 6 inches per 100 feet. From the center line to the foot of the side slopes the floor falls uniformly 3 inches in 30 feet. This causes the water to flow toward the sides and entrance of the dock. Along each side the dock, for its entire floor length, extends a drain some 5 feet wide and 3 feet deep, built of 3 inch plank spiked to the piling as shown on the detail drawings.

The oak flooring covers this drain but is not spiked down and the pieces are not fitted so closely together.

Adjacent to the masonry is a 6 foot cross drain, into which the side drains empty. The plans show this to be of a similar plank



The Caisson-Gate (Shewing Construction).



Shewing the side slope timbering.

construction, but as actually constructed, the foundations of the masonry aprons were extended into the body of the dock far enough to build this cross drain in concrete.

From the cross drain, a 6 foot square tunnel formed in the concrete foundations, runs beneath the south masonry abutment to the pump well below the engine pit.

This pump well is 23 feet 9 inches long by 6 feet deep and its roof is composed of a layer of concrete 10 feet 6 inches thich. In its centre is a 6 foot square pier to which run 12 inch I-beams from the side walls, as a support to the concrete roof and the machinery. Into this well extend the suction pipes from the centrifugal pumps.

Mechanical Equipment.

For the emptying of the dock there are provided three 36 inch, double section, centrifugal pumps, directly connected to simple, vertical, non-condensing engines. To take care of the leakage during use, an additional centrifugal pump, with 12 inch discharge, is connected to a small vertical simple engine. This machinery is located in a "pit" formed in the concrete which backs up the south abutment. The floor of this pit is 22 feet below the level of the top of the dock, or 15 feet 6 inches below mean low water line. From each of the large pumps, two 28 inch suction pipes pass vertically downward through the 10 feet 6 inches of concrete into the pump well below. There is one 42 inch, horizontal discharge pipe for each pump.

Steam is supplied from the boiler house at 125 lbs pressure. Three 350 H.P. Heine Safety Water Tube boilers, an auxiliary vertical boiler, two fire pumps, and fan and engine for forcing the draft, complete the equipment of the boiler house.

On actual test after completion, the average efficiency of each main pump was 38,250 gallons per minute. The indicated horse-power of the engines varied from 185 at starting to about 300 at the finish, giving an average efficiency for the pumps of 58%. The maximum efficiency noted at any time during the test was 72½%. These pumps and engines were built and installed by the Morris Machine Works of Baldwinsville, N.Y.

CONSTRUCTION.

General Scheme.

Broadly speaking the proposed plan of operation was as follows: After clearing off the existing structures and old wharves, to dredge away the material to the approximate lines of the dock bottom and side slopes; to drive the permanent protection work while this dredging was in progress; to drive the temporary cofferdam across the ends of the bulkheads, immediately the dredging was completed; to pump out the water and mud from the basin thus enclosed; to drive a line of 20" permanent sheet piles along the outer and inner face of the aprons; to further excavate within this box to the white clay stratum and upon it start the concrete foundations for the masonry; to build the masonry abutments, pump well, engine pit, powerhouse and main body of the dock.

This plan was modified considerably as will appear from the description to follow.

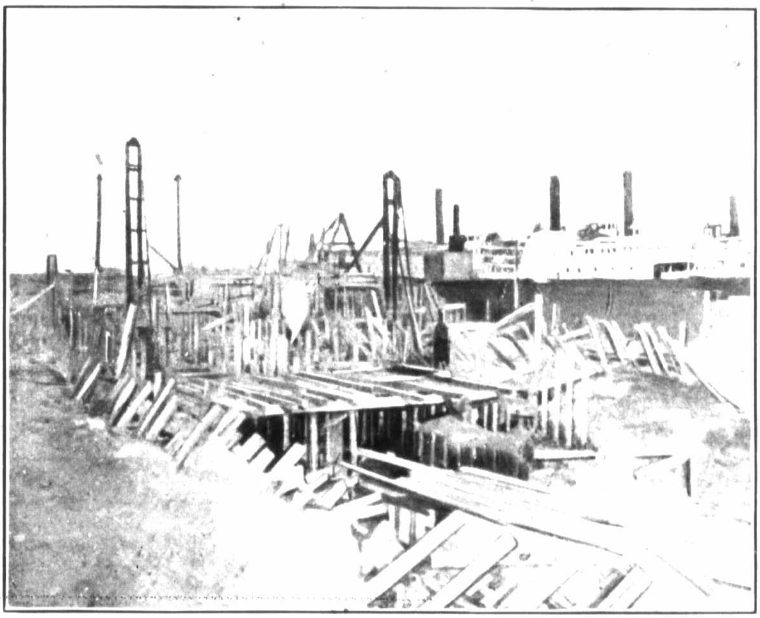
Contracts were signed in June 1899, and the contractors went to work almost immediately. By the following Spring the dock site had been cleared and dredged out to the required lines, and the permanent protection work finished, except that portion about the head of the dock which was never completed. This will be noted later when we come to consider the changes made from the original plans, when constructing the head of the dock.

The temporary cofferdam was driven into place and the basin was then ready for pumping out. Meanwhile a pile driving machine, mounted upon a scow, had been floating about within the enclosure and driving the outer row of slope piles along both sides of the dock. Why these piles were driven at this time is not quite clear to the writer, unless it was thought that they could be driven more easily then, than by using a land machine at a later period, or possibly because there was nothing else for the machine to do for the time being.

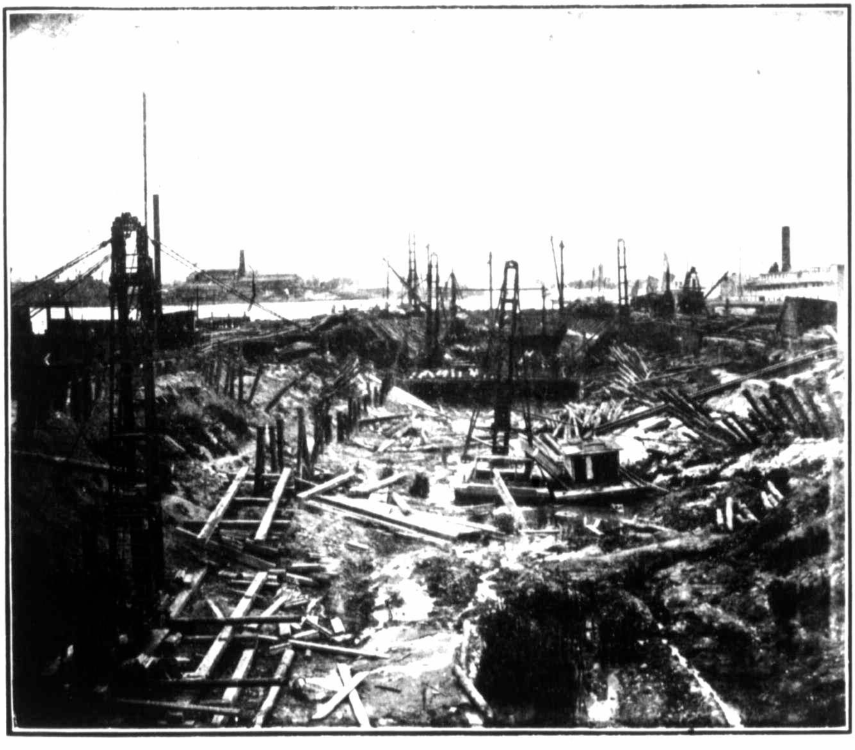
Afterward when the dock basin was pumped out, most of these piles slid into the bottom of the dock, along with the side slopes, or bent so far out of correct line that it was necessary to pull them out or saw them off and drive others. This gave rise to "extra" claims on the part of the Contractor, who maintained that having once driven them to the lines given by the Engineer, any necessary redriving should be paid for as extra work. If the writer's memory serves him correctly, the original driving was done under protest from the field Inspector, and the claims for extras were never entertained.

Pumping out the enclosure began. As the water level within sank a few feet, those portions of the permanent bulkheads extending beyond the original shore line, started inward toward the center of the basin, crowding before them the undredged slopes and the piles which had just been driven.

Pumping was hastily discontinued and the basin permitted to fill to the level of the water outside. The floating pile driving rig



Shewing progress of the work from June 1899, to the Spring of 1900.



Shewing condition of slope piles, driven before dock was pumped out. The sides slid into the dock bottom, carrying many of the piles with them.

mentioned above, which had been left inside, then drove more piles, upon which were placed the 70 foot Oregon Fir floor timbers, so as to form a transverse set of bracing from bulkhead to bulkhead across the dock. This system of bracing was continued shoreward, at 20 foot intervals, as far as any motion of the bulkheads had been noticed or could be expected. Then, where it had been planned to drive 20 foot sheet piles along the faces of the aprons (as mentioned above), after the dock should have been pumped out, the water machine drove rows of 34 foot piles, thus preventing what material was left about the foot of the cofferdam from moving into the dock.

Pumping was again started and continued until the bottom of the basin was laid bare. A small centrifugal pump and later a pulsometer, took care of the leakage, which was noticeably greater at high tides.

Entrance.

Excavation.

Within the box like enclosure formed by the bulkheads and the two rows of 34 foot sheet piles, excavation was started for the foundations of the masonry work and the engine pit. The more material removed, the greater became the need of temporary bracing to keep the sides of this box from collapsing. Complete sets of bracing were placed in position for every 6 or 8 feet of excavated depth and as the 12 by 14 and 8 by 14 inch slope timbers were used for this work it was important that they should be cut as little as possible.

Each set placed made it more difficult to place the next below, until the time came when the long timbers could not be landed in horizontal positions and had to be placed wherever a suitable opening could be found.

So thickly were these timbers placed, that at the time the first sill stones were lowered into the pit, there was but one opening to be found of size sufficient to admit them.

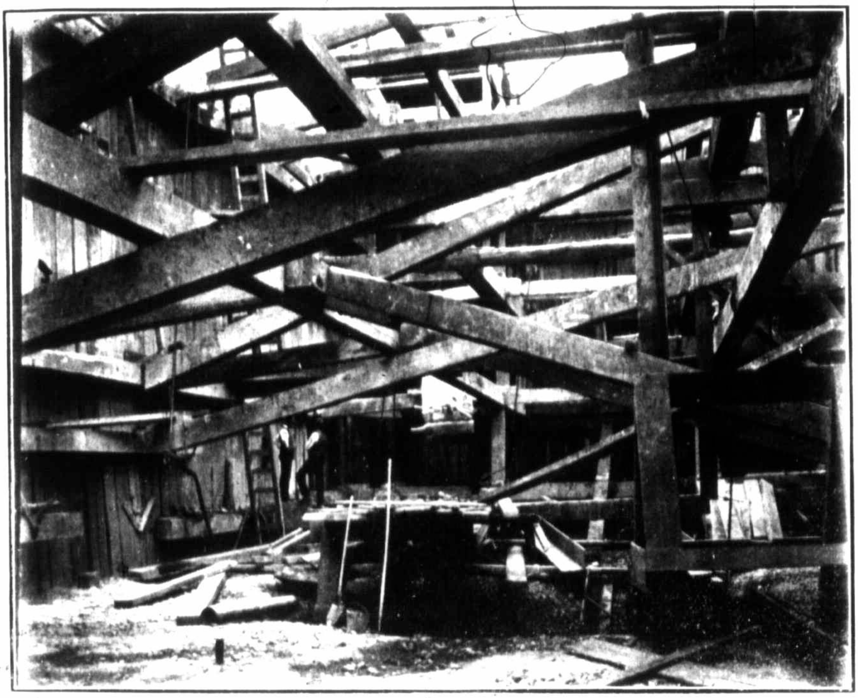
Excavation was carried to the stratum of hard white clay. In doing this it was found that the sheet pile protection had not penetrated this clay to any appreciable depth, as in many cases the excavation laid bare the points of the piles. More bracing was the order of the day, and that immediately.

Leaks at high tide had always necessitated regular pumping, but now the water began to find its way down the sides of the sheet piles and through the gravel stratum at their points, in quantities that became alarming. The original idea of driving a stop water cut off wall of 20 feet sheet piles along the front and rear edges of the pit was abandoned, as no pile could be forced into this hard layer of white clay. As a substitute measure a trench some 2 ft. wide and 4 ft. deep was dug in the clay parallel to the face of and at some distance in front of the outer sill of the aprons. This trench was filled with concrete which joined to the concrete foundation, formed a stop water as effective as the piles would have been.

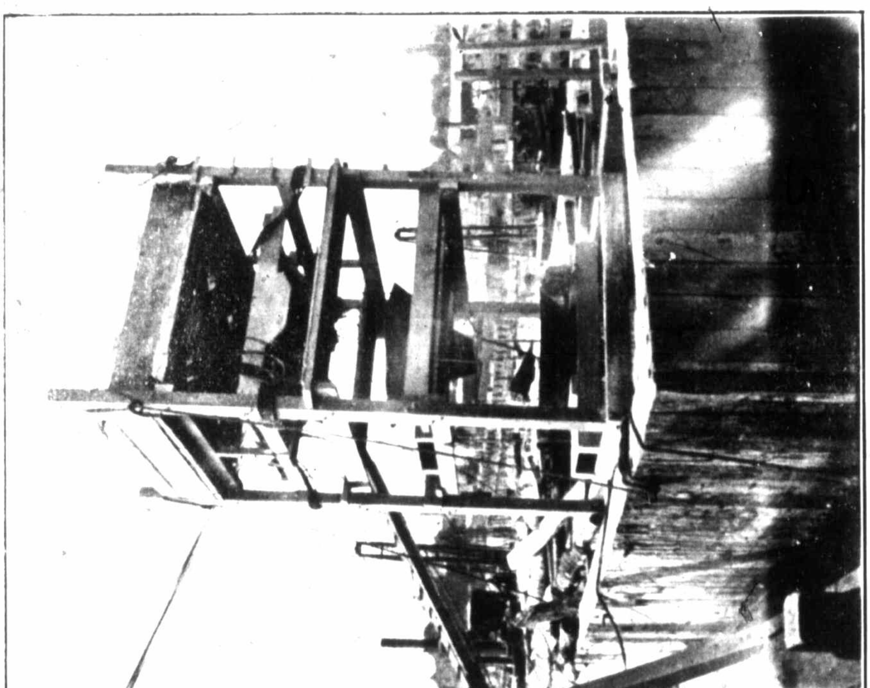
Concreting was started near the middle of the pit and the foundations raised several feet high. This was extended to within a few feet of the north bulkhead where the most serious leaks occured under the feet of the piles. At low tides these leaks were temporarily stopped, by driving inch boards along the outsides of the piles and dumping dredged material from the harbor into the bulkhead. Concrete was hurriedly placed along the feet of the piles and raised to the same level as that of the foundations previously placed. No further leakage of a serious nature was experienced in this direction. The concrete was then brought to the finished level of the lowest masonry course by removing the temporary braces as fast as a sufficient quantity of concrete could be placed about the bottom of the piles, to withstand the inward pressure.

Concrete.

The following extracts from the Specifications relating to the concrete work are noted. "One part of cement, two parts of sand and five parts of broken stone, to be throughly mixed, either by hand or suitable machinery, before being put in place, using only enought water to slightly moisten the mass. The several ingredients must be accurately measured for each and every batch of concrete, using suitable rectangular boxes holding not less than three cubic feet each." The cement used for concrete and mortar shall be a high grade of American Portland, uniform in quality, show good results by ordinary pat tests in air and in hot and cold water, (especially as to changes in volume), and be so finely ground, that at least 93% will pass through a sieve of 80 meshes to the inch, and 89% through a sieve of 100 meshes." "The cement must be slow setting and must not take on an initial set in less than 30 minutes; final set in not less than 3 and more than 6 hours." "Briquettes of neat cement must show a minimum tensile strength as follows: Samples kept in air one day and in water six days, 450 lbs per sq. in.; samples kept in air one day and in water 28 days, 575 lbs per sq. in." "Briquettes of 1 part cement and 2 parts sand, must show a minimum tensile strength as follows: Samples kept in air 1 day and in water 6 days, 150 lbs per sq. in. samples kept in air 1 day and in water 28 days, 200 lbs per sq. in." "Samples



Shewing temporary bracing required in foundation pit.



Concrete Mixer.

will be taken from each lot of 100 bbls. to be selected by the Engineer."

"Sand must be clean, coarse and sharp, free from loam or earth matter, and screened or washed if required." "The stone used for concrete must be broken into pieces as nearly cubical as possible, and not more than 2½" in its longest dimensions; it must be kept free from dirt and rubbish of all kinds, and just before being used must be drenched with water." "Granite is to be preferred for this material."

The concrete was made in accordance with the specifications, using "Dragon" Portland cement and crushed granite, and was mostly machine mixed. The "machine" was of the gravity type, an invention of a local Engineer, who put it on the work as an experimental trial. The result was considered so satisfactory, that we believe this machine, or one along similar lines, can now be purchased in the open market as a patented invention.

As the accompanying photograph shows, the mixer consists of a light wooden frame work supporting two cone shaped hoppers, one vertically above the other, and above these, four pyramidal hoppers, the combined capacity of which, equalled either of the two cones, and at the top, bins for sand and broken stone.

For work in a pit this machine was exceedingly handy. It could be picked up by a dredge boom and placed in any desired location, and raised as the concrete work reached the lower hopper.

In operation it required the services of four men, two to fill the four upper hoppers, and a man at each of the others to regulate the gates. A scow load of sand and another of broken stone would be hauled along side the bulkhead and from this a bucket dredge would keep the sand and stone bins constantly filled.

The men at the upper hoppers would empty a sack of cement in each, and then by opening gates in the bottom of the bins above, allow the necessary amounts of sand and stone to flow in, marks having been previously made on the sides of the hoppers to show the correct proportion of each of the ingredients. The amount of water found by experience to be necessary, would then be dashed into the hoppers, and the charges allowed to run into the first cone hopper below.

Refilling would begin at the top while the men were caring for the first charge in the lower hoppers. The process was thus continuous, and the product as regards thorough mixing was first class, especially where the mixture was dropped from the lowest hopper directly into barrows. The capacity of a single charge was approximately 25 cubic feet of concrete, when rammed into place. The record for a days run (10 hours) was 110 batches, making about 35 cents as the labor charge for a cubic yard of concrete in place.

Masonry.

Upon a seven foot layer of this concrete as a foundation were erected the masonry aprons and abutments.

The stones were massive foliated granite from quarries near Port Deposit Md. The sill stones, 3 and 6 feet thick, were bound together with steel bands, set on beds of mortar and the joints flushed with Portland cement grout.

It required careful work to place these 15 ton blocks with their top surface truly level and their bush hammered faces to an exact transit line.

The course stones of the abutments are doweled on the beds with two iron pins, 1 inch square and 4 inches long. For setting the jamb stones a batter board was used which had been obtained from the ship building company who made the gate. Thus the gate and the recesses in the abutments were built to the same pattern, and there could be little chance of a misfit.

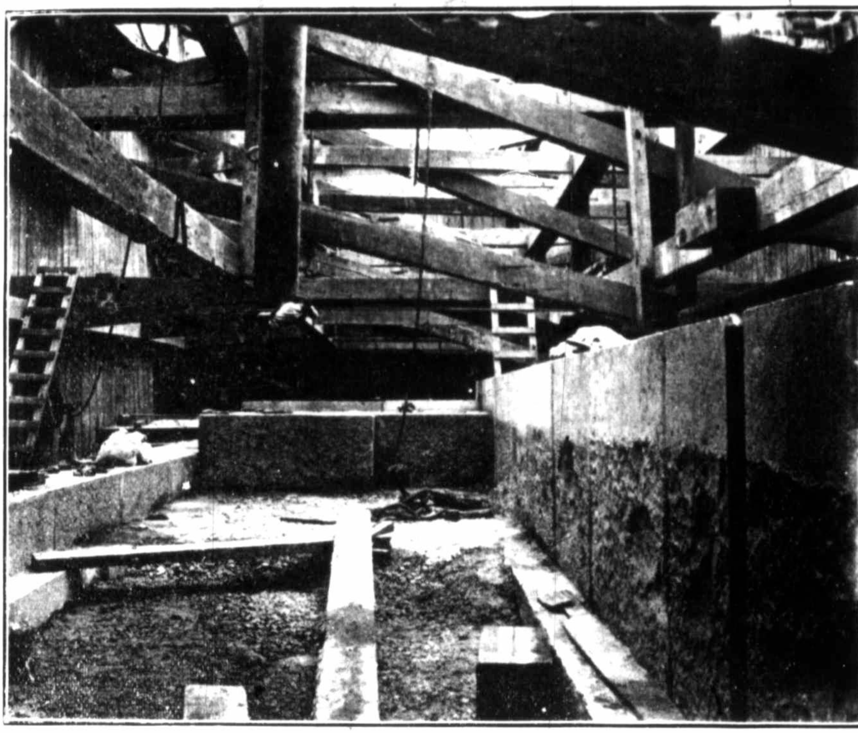
Behind the north abutment as the masonry work progressed the concrete backing was filled in solid to the bulkhead. Behind the south abutment, in the concrete backing, was formed the drainage tunnel from the dock, the pump well, and the engine pit.

Tunnel, Pump Well & Engine Pit.

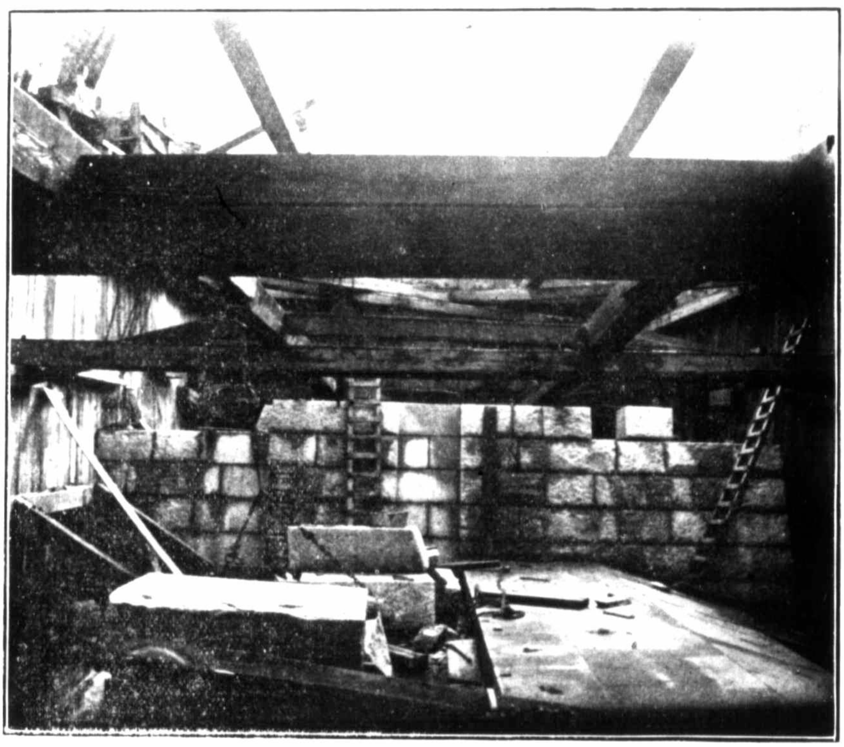
The tunnel from the main dock passes under the corner of the masonry and into the pump well behind the abutment. In cross section it is 6 feet square. At the point of junction with the pump well, a pump pit 6 by 6 feet and 2½ feet deep is constructed in the floor of the tunnel. Into this pump extends the suction pipe from the 12 inch centrifugal pump. It is the lowest point of the drainage system, intended to take care of leakage while the dock is in use. The pump well itself is 6 feet deep and has a floor area of approximately 300 square feet.

In the centre a 6 by 6 foot concrete pedestal serves as a support for the 12 inch I beams which are built into the roof as a support to the weight of the suction pipes, engines and pumps. Above the pump well is 10 feet 6 inches of concrete, which forms the foundation of the engine pit. The heavy suction pipes were supported on wooden blocking while the concrete was being placed about them and the blocking left until the completion of the work.

Anchor bolts for the engine bases were about 7 feet long, set within a length of 4 inch gas piping, with heavy cast iron base plates at the bottom.

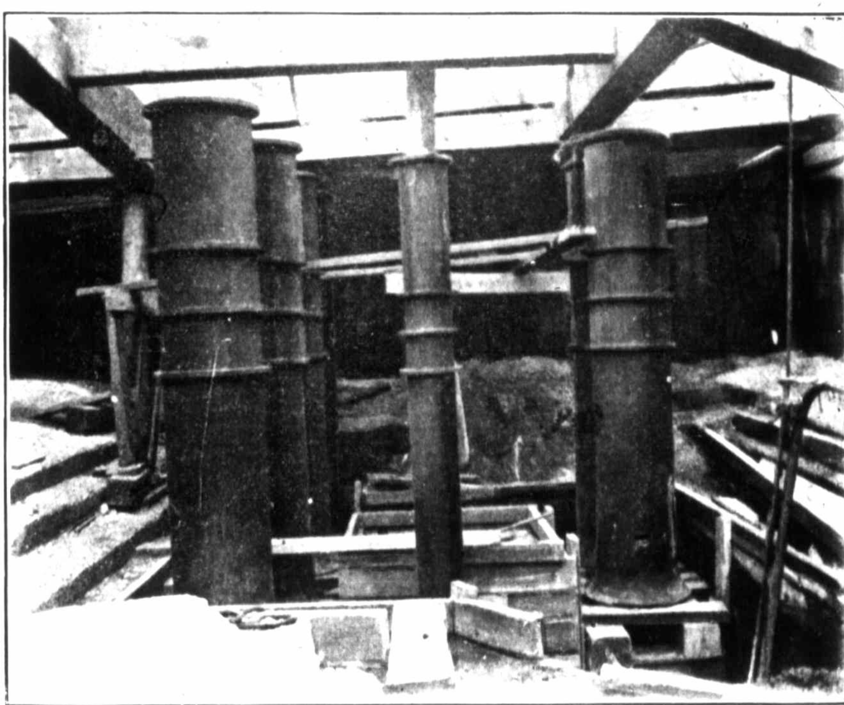


Shewing the 6 foot inner sill stones, and middle apron.

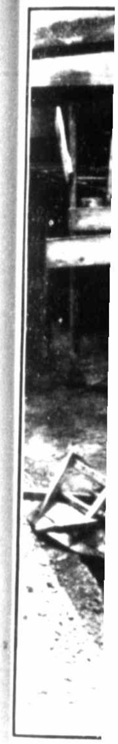


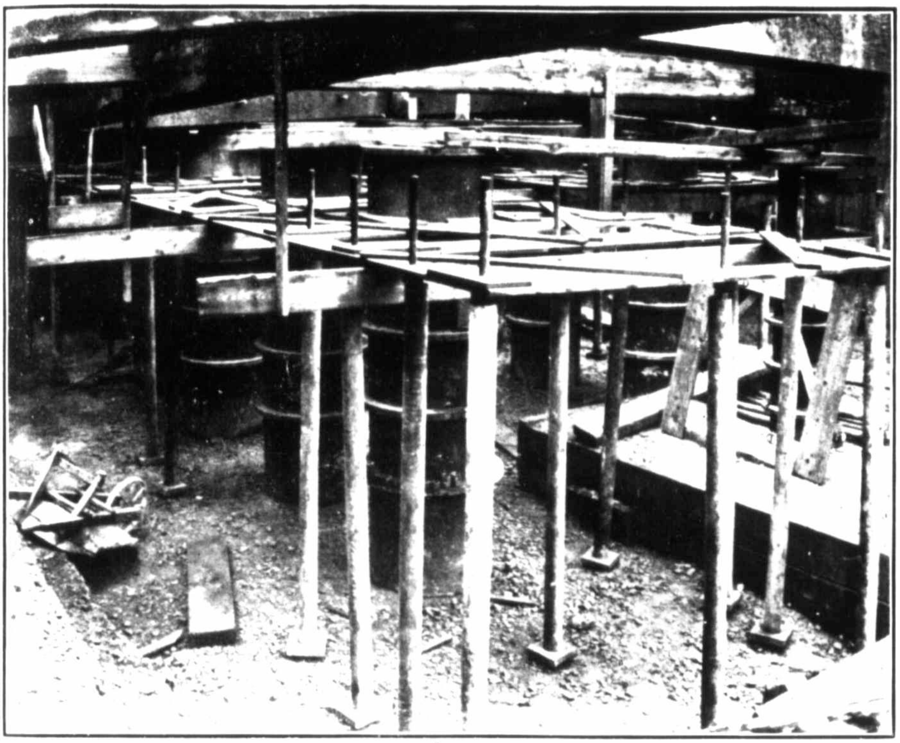
Shewing inner sill, and apron which slopes to cross drain.

The Completed Abutment.

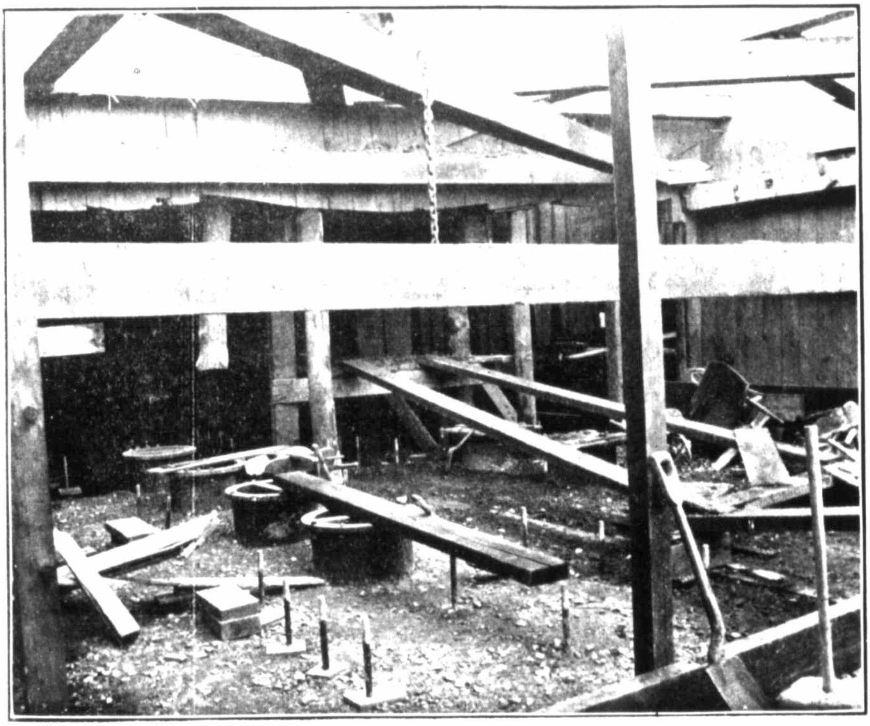


Shewing Pump Well, Suction Pipes and Pedestal.





Shewing method of setting anchor bolts for engine bases.



Shewing complete setting of Suction Pipes and Anchor bolts.

After the engines had been aligned these gas pipes were run full of cement grout.

There had been plenty of evidence at hand to conclusively demonstrate that a mixture of 1-2-5 concrete was not water proof when subjected to much hydraulic pressure.

As the roof of the pump well would be, at high tide, some 30 feet below the level of the water outside the dock, or subject to a pressure of some 1900 pounds per square foot, it was necessary to provide some means of preventing water leakage into the engine pit. When the concrete above the pump well had reached a point three feet below the finished level of the engine room floor, a 3 inch course of Portland cement mortar (cement 1 part, sand 2 parts) was spread evenly over the surface and extended on all sides a distance of 2 foot 6 inches beyond the finished wall lines of the pit. This 3 inch mortar course was carried up parallel with the walls of the pit to the top of the dock, being back in the concrete 2 feet from the face of the walls. Even with this precaution, the walls appeared to sweat at times, though the moisture did not accumulate in amounts sufficient to run.

This mortar course not having been specified or shown on the original plans became a subject for "extra" charge. It cost in labor and materials a total of $745.00 and the results obtained justified the extra expenidture.

The engine pit is 26 by 42 feet. It is provided at the top with a four foot wide platform, extending around the entire pit, from which stairways lead down to the engines and pumps.

Power House.

The power house is built of brick, set in Rosendale cement mortar. It was constructed under special contract by C. H. Fath & Son of Cleveland, O., for the sum of $5,750.00.

A 13 inch brick wall separates the boiler room from the engine pit, and is continued through the roof. Six, 36 inch steel plate girders, support the roof rafters, which are 2 by 6 inch timbers, spaced 18 inches on centers.

The roof covering is 1¼ inch matched lumber covered with tin. The total floor area figured from the outside dimensions of the stone footing course would be nearly 3274 square ft. which would make the contract cost of the building a little more than $1.75 per square foot of floor area. Figuring the cubic contents from the floor level to the underside of the roof boards, would give approximately 74685 cubic feet, and a contract cost of 7¾ cents per cubic foot.

The writers finds among his notes referring to the power house, that the cubic content of the walls was 7,000 cubic feet, the number of bricks used 116,000, which would give an average of 16½ bricks per cubic. foot.

That portion of power house covering the boilers is located within the lines of the main dock. For the foundations of this and the boilers, piles were driven and covered with a grillage of 10 by 12 inch timbers (old sheet piles removed from temporary work) upon which was placed a layer of concrete 9 feet thick. Air ducts were laid in the concrete for the forced draft.

Sluice Way.

It was originally planned to construct a buried sluice way in the outer end of the south bulkhead, through which the discharge from the pumps should flow into the harbor. The sluice way is shown on the general plan drawing accompanying this paper, but it was never constructed. Instead, the end of the bulkhead was never closed, and the pumps were allowed to discharge into it.

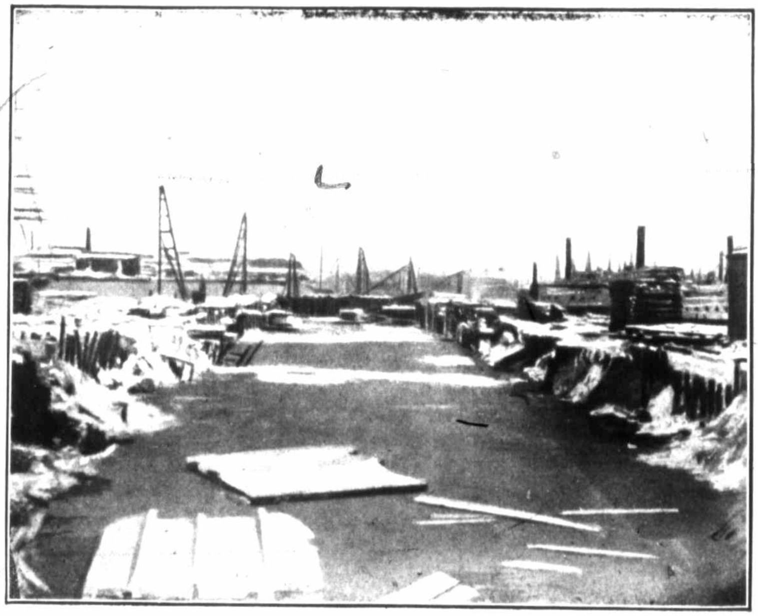
There was some question as to whether the rush of water from the discharge pipes would not scour out the material from around the feet of the sheet piles, and cause the destruction of the bulkhead. But at present writing, the evidence does not show that such action has taken place to any great extent.

Main Body of Dock.

The necessity of placing the transverse braces to keep the bulkheads in place, materially changed the general scheme of construction, in so far as it applied to the work on the main body of the dock. The presence of these braces made it impossible to use a pile driver on the dock floor level, and by the time work had actually strted here, there had accumulated from five to ten feet of mud, gravel and oyster shells in the bottom of the basin.

The pile drivers were placed on run-ways laid on top of these transverse braces, and from this elevation, the piles for the bottom and the side slopes of the first 200 feet of dock length, were driven.

Meanwhile excavation was being completed to the final elevation of pile cut-off, and as fast as a portion could be cleared, the piles would be cut and capped, and the 70 foot cross floor timbers placed in position. The piles driven from the elevation of the temporary braces, shown above, were found to be badly out of line at the point of cut-off, some so badly out, that it was necessary to cut them off a foot lower and cross cap them, in order to obtain any bearing.



Driving piles from the Temporary Braces.

Shewing feet of piles, driven from temporary bracing, before excavation had been completed to point of cut off.

The north bulkhead had given such evidence of instability that it was thought inadvisable to trust entirely to the earth back filling for security, so before the temporary bracing had been removed, a mass of concrete was packed in behind the altars and slope timbers, which, starting at the point of the first angle of the dock (80 feet from the abutments), was gradually increased in thickness, until it met the bulkhead some 20 feet back from the masonry, from which point the entire space behind the slopes was filled, until it reached the concrete backing of the masonry.

The cross drain was originally designed to be of plank construction similar in character to the side drains, but was constructed in concrete, the foundation work of the aprons being extended into the body of the dock for the purpose.

When sufficient flooring had been placed, a traveller was arranged, which had a derrick on the two forward corners, the booms of which could reach the surface level on either side of the dock. This was used in landing the heavy cross floor timbers and side slopes, and proved to be a very useful affair.

It was originally planned to face the side slope timbers with one inch white pine boards, over which the altars would be spiked, but after facing a small portion, these boards were entirely omitted from the remainder.

Their use necessitated hewing the entire back surface of the altars, in order to keep the front surfaces to the required lines, and it was also thought that these boards would serve to retain water behind the slopes, after the dock had been pumped out, and the gradual drainage of this into the slopes would keep the altars muddy and slippery most of the time.

The soft mud and gravel removed from the bottom of the dock, was placed or rather dropped from buckets behind the slopes, as fast as altars could be placed to retain it. It would have been much preferable to have carried this material entirely away, and provided a better kind. Many times this semi-liquid mass broke through temporary retaining walls and came pouring back onto the dock floor. Its use caused a considerable inward bow in the slope timbers at one point, and at another near the first angle in the south side, when the filling had reached nearly to the coping, the pressure was sufficient to force the slope timbers from the piles, and seriously threaten to overturn that portion of the slope. Heavy iron tie rods were immediately placed so as to fasten the slope timbers back to the bulkhead, and the addition of filling was stopped until that portion already placed had entirely dried out.

The north bulkhead at one point for a distance of some fifty feet had crowded so far into the dock that it was within the finished coping line. As it was impossible to get it back again, the top was sawed away and the finishing timbers laid upon it, instead of the pile capping. It seems to have kept to this position ever since, so no harm has resulted from the compromise.

When construction work had progressed to the point where the original shore line was located, the most difficult portion of the work was over. The hydraulic pressure against the bulkheads had no longer to be reckoned with, and the temporary braces having been taken down, a free field was left for the pile drivers and the traveller.

The drivers were now landed on the dock bottom, and the rows of piles from this point became more satisfactory.

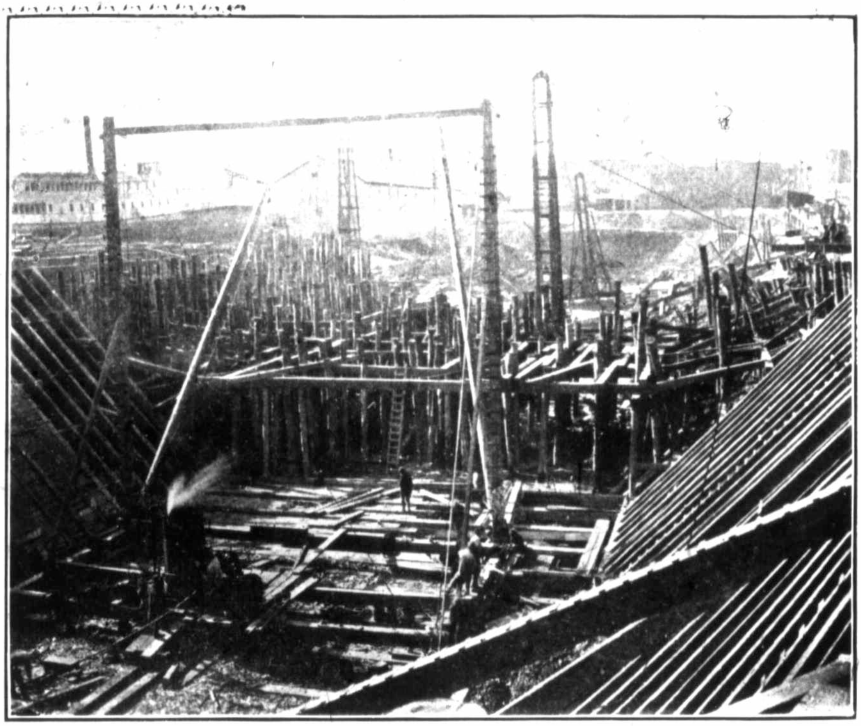
The excavation was mostly in the gravel strata above the white clay, and a number of springs were encountered, which for a time sent water and filling up through the crevices in the flooring, but gradually ceased to flow, or found their way into the lower level of the side drains.

At the extreme head of the dock, however, a very serious spring was encountered, which it was impossible to check. The flow from this source would approximate that from a 5 inch pipe under moderate head. After various attempts to choke it back with concrete and cement, all of which were unsuccessful, the stream was piped into the nearest side drain and allowed to run. This will be referred to a little later, as the owners of the dock, after they came to operate it, tried their hand at controlling this stream.

About the head of the dock, the sand and gravel soil became so compacted that it was practically impossible to drive the slope piles. The top row was driven, after a fashion, however, through the surface soil, and from this point to the foot of the slope, the banks were cut to slope of the side timbers. As the altars were placed, concrete was rammed between them and the bank, in place of earth filling.

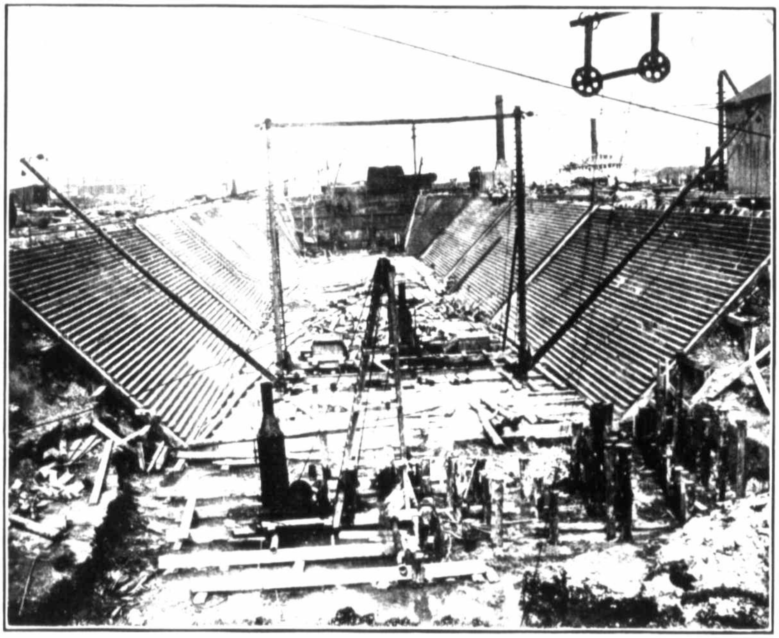
It was originally planned to have the head of the dock, a slope, similar to the sides, but this was modified in part, and a box like projection constructed, which gave an additional 24 feet 2 inches to the effective working length of the dock.

The driving of the protection sheet piling about the head of the dock was abandoned, owing to the hard subsoil, and in its place was constructed a masonry retaining wall, to support the city street which passes close to the head of the dock, but at a higher level.

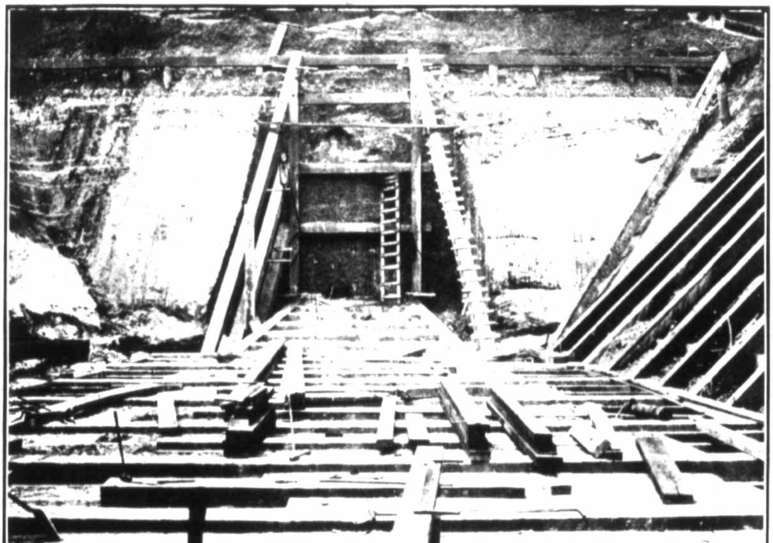


Shewing form of traveller used for handling heavy timbers.

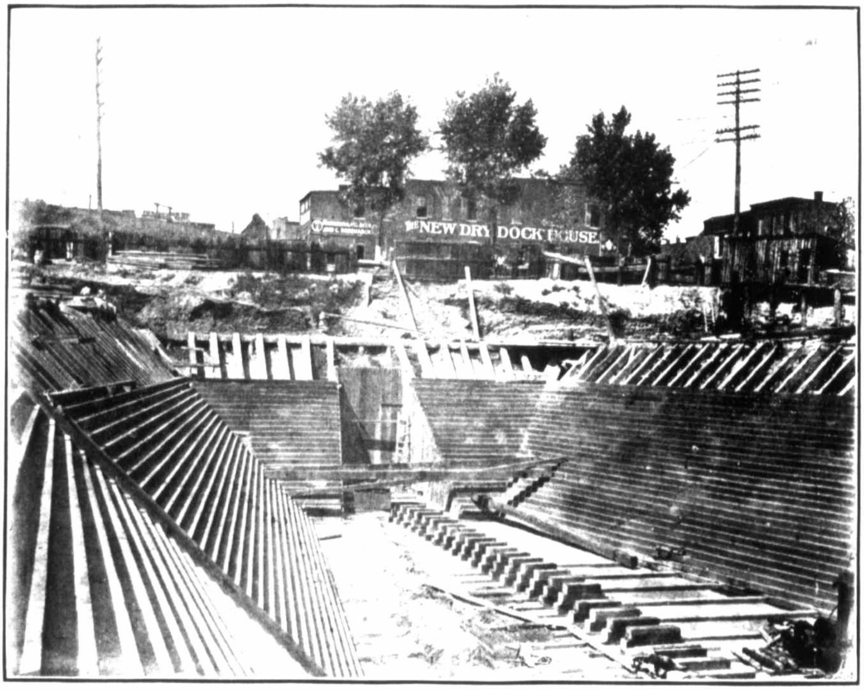
Shewing result of pressure, due to semi-liquid backfilling.



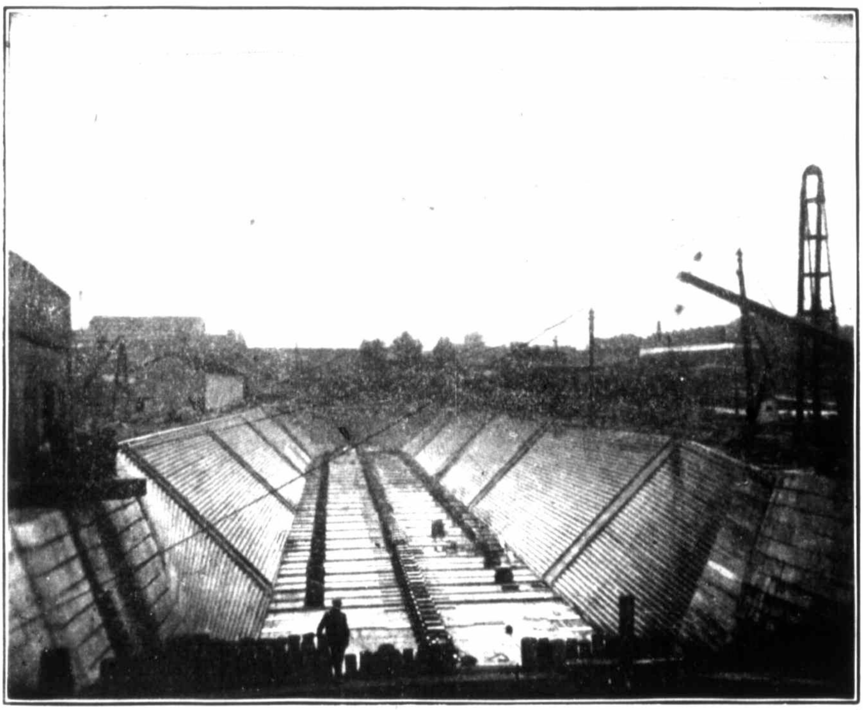
Shewing condition of work after reaching permanent shore line.



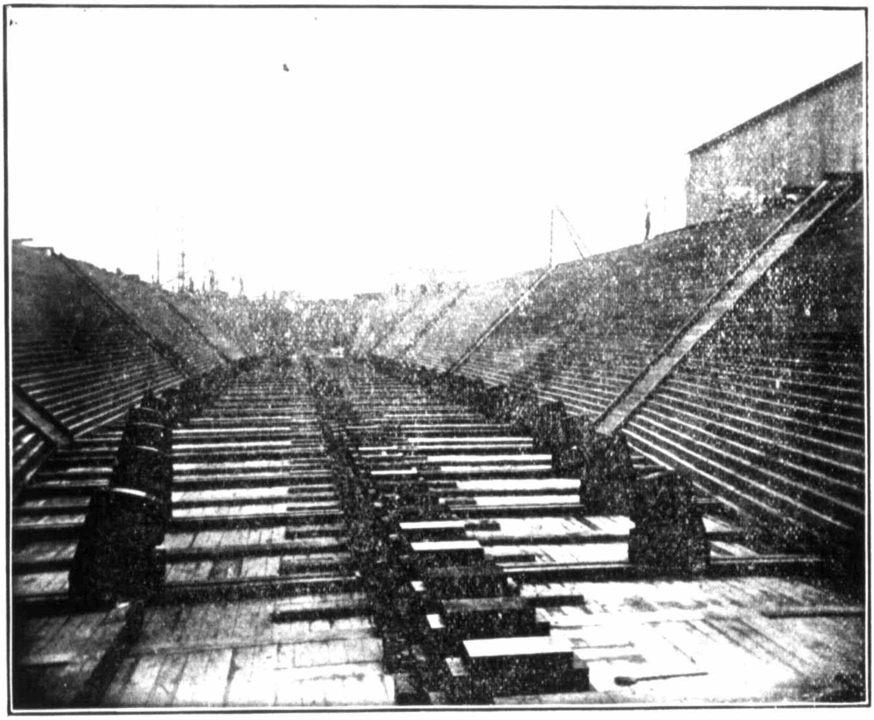
Shewing condition of foundation at head of dock, where it will be noticed that the soil stands a vertical cut.



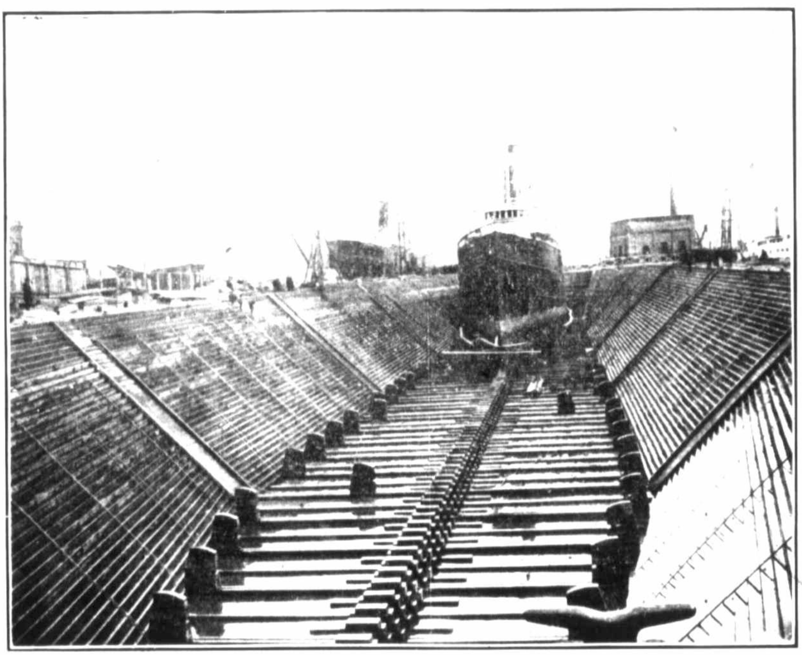
Shewing the box projection in the head of the dock.



Shewing main body of the dock looking from the cofferdam.



Shewing main body of dock, looking from box in the head.



The formal opening, November 25, 1901.
A 300 ft. steamer in dock.

By this time the keel and bilge blocks had been placed and the dock allowed to slowly fill by leakage. The cofferdam was pulled, and the entrance dredged out to the level of the aprons.

The dock was completed and formally opened on the 25th of November, 1901, thus making the total time of construction a trifle less then 2 years and 3 months. There had been used in the work an amount of material approximately as follows:

Yellow Pine Sheet Piling	1,100,000	ft. B.M.
Yellow Pine Timber	1,028,000	" " "
White Oak Planking	112,000	" " "
White Oak Timber	82,000	" " "
Oregon Fir Timber	114,000	" " "
White Pine Boards	4,600	" " "
Steel Bands	4,100	lbs.
Steel I beams	2,600	"
Iron Tie Rods	52,000	"
Cut Granite Masonry	22,000	cu. ft.
Concrete	180,000	" "
Round Piles	933,000	lin. "

And in addition there had been 30,000 cu. yds., of Excavation and 60,000 cu. yds., of Dredging.

Cost Data.

The contract for this work was let on the basis of unit prices for material in place, and labor performed, as per the following schedule:

Dredging	32c.	per cu. yd.
Excavation	37c.	" " "
Sheet Piling	$ 53,25	" M. bft.
Yellow Pine Timber	37.60	" " "
White Pine Boards	35.60	" " "
Oregon Fir Timber	26.00	" " "
White Oak Plant	38.00	" " "
Round Piles	15c.	" lin. ft.
Tie Rods	4c.	" lb.
Steel Bands	5c.	" "
I Beams	4 3/8 c.	" "
Concrete	21c.	" cu. ft.
Cut Granite	1.09	" " "

The total cost of the complete dock was $430,000.00.

Aside from the carpenter force which was more or less skilled labor, the working force consisted of negros and foreigners, principally Bohemians. It is the writer's opinion, that the ordinary colored gentlemen, when viewed from the standpoint of reliability as a workman, is a failure. Pay days on this job were twice a month, and after each one, the personnel of the laboring force would contain about 75% of unfamiliar faces. Two weeks steady work was about the limit.

Wages for a ten hour day's work were approximately as follows:

Foremen	$3.50
Carpenters	2.25
Carpenters' Helpers	1.75
Engineers	2.00
Firemen	1.75
Common Laborers	1.50

The contractor's claims for "extras" on this work reached an enormous total. Unfortunately, in the specifications, no provision had been made for the possible need of temporary bracing. When the protection bulkheads started into the dock, temporary bracing became absolutely necessary, the placing of which the contractor of course claimed to be outside the scope of his contract. A compromise was effected whereby the contractor was to place and remove all needful bracing, using therefor timbers that could later be placed permanently in the dock. For this labor the contractor was to charge extra time, and for the material be allowed a certain percentage of its contract value, until such time as it should be placed in final position in the work.

No one could have foreseen the great amount of time that would be necessary to accomplish this, or the consequent extra cost.

It is seldom that a work of this extent does not cost human life as well as money, and the writer would be pleased were it possible for him to state that this was an exception to the usual rule, but such was not the fact. Two workmen were killed. Of narrow escapes there were several, such as when a pile overturned, and a hoisting bucket full of mud fell back among a gang of shovellers. Of the less serious accidents, we might mention that of a member of the Engineering staff, who stepping off a timber one day, found himself up to his shoulders in the rich black ooze at the dock bottom.

Comparison With Other Large Docks.

It may now be of interest to record the finished dimensions of this dry dock, and compare it briefly with the other large structures of similar nature to be found along the North Atlantic seaboard.

In looking over the published literature bearing upon this subject, it is at once evident that there is needed a more systematic method of recording the dimensions of docks, whereby measurements may become directly comparable. One writer in describing a structure will note that "the length on the floor, head to inner abutment is 516 feet" while another states that "extreme length at bottom on keel blocks is 558 feet".

The purpose of a dry dock is to dock vessels, therefore the first principal dimension of a dock, should be given as that of the longest possible boat which the structure would be able to accommodate, or in other words, the greatest horizontal distance, measured along the level of the tops of the keel blocks, from a vertical line tangent to the inner face of the caisson gate, to the corresponding point in the head of the dock. Next in importance is the minimum depth of water over the entrance sills, after which should be given the width of entrance at the level of the top of the highest sill, the vertical distance from the top of this sill to the coping level, and the width of entrance at this level. In the body of the dock, dimensions should be given as follows: Maximum width on floor level and at the level of the top of the keel blocks, maximum width at coping level between the inside faces of the coping timbers, and horizontal distance at coping level from vertical tangent to inner face of caisson to the inner face of the coping timber at the head of the dock.

Following this method, the finished dimensions of the Baltimore dock are as follows:

The horizontal distance at level of keel blocks, from a vertical tangent to the inner side of the caisson, to the vertical face of the box in the head is 599 feet 4 inches. There is over the inner sill at any low tide, 22 feet of water, and at high tide, 25½ feet has been recorded. The width of entrance at the level of the top of the inner sill is 60 feet, and at the coping level, 80 feet. The top of the inner sill is 29 feet below the coping level. The maximum width of dock body is 60 ft. at the floor level, and 69 feet at level of tops of the keel blocks. The maximum width at coping level is 125 ft. between inner faces of the coping timbers. The over all dimension at coping level, from tangent to the caisson, to inner face of coping timbers at the dock head is 604 feet 7 inches.

The other large docks along the Atlantic seaboard are located at the following points: St. Johns, Nfld.,; Halifax, N.S.; Portsmouth, N.H.; Boston, Mass.; Brooklyn, N.Y.; League Island, Pa.; Newport News, Va.; Norfolk, Va.; and Port Royal, S.C.

In the following table, the writer has compiled, from various sources, the principal characteristics of these. The indefiniteness of the two leading dimensions will emphasize what has just been stated regarding the desirability of a more uniform system.

TABLE SHOWING CHARACTERISTICS OF THE PRINCIPAL DRY DOCKS TO BE FOUND ON THE NORTH ATLANTIC SEABOARD.

Location.	Character of the Structure.	Year when Completed.	Time spent in Construction.	Cost.	Length (coping level).	Length (on floor).	Width—body (coping level).	Width—body (floor level).	Width—entrance (coping level).	Width—entrance (sill level).	Depth of Sill below coping level.	Depth of Water over Sill.
St. Johns, Nfld.	Concrete & Timber	1884	2 years	$550,000 *b*	600' *c*	558' *k*	132' 4"	49' 10"				25 H.T.
Halifax, N.S.	Stone and Concrete	1889	3 years	$750,000	600' *d*	560' *l*	102	70	89' 6"	81'	34' 6"	30' H.T.
Portsmouth, N.H.	Granite & Concrete			$1,089,000 *b*	775 *f*	725'	130'	80'				30' H.T.
Boston, Mass, No. 1 ...	Granite	1833	5 years	$677,000	396' 5" *g*	367' 5" *m*	80'	30'	60'	44'	30'	25 H.T.
" " No. 2 ..	Granite & Concrete			$1,025,000 *b*	750' *h*	729' *h*	114'	72	101' 8⅝"		35' 2"	30 M. H. W.
Brooklyn, N.Y., No. 1..	Granite	1851	7 years	$2,241,000	369' 3" *g*	333' 3" *m*	100'	30	66'	48	30'	25' H.T.
" " No. 2..	Timber *a*	1890	3 years	$565,892 *b*	500' *i*		130' 4"	50'	85'		30' 6"	
" " No. 3..	Timber	1897			600' *h*	556' *h*	151'	64'	105	70	33'	28' M. H. W.
League Island, Pa.	Timber	1391			500' *g*	459' 8" *m*			85'			25' 5" H.T.
Baltimore, M.D.	Timber	1901	2 yrs. 3 mo.	$430,000	604' 7" *j*	599' 4" *n*	125' *o*	60'	80'	60	29'	25' 5" H.T.
Newport News, Va, No. 1	Timber				638' 6" *g*	573' *m*	130	49	96' 3"	50		24' 5"
" " " " No. 2	Timber	1901			860' 5" *g*	804' *m*	162'	80	114	84		30
Norfolk, Va., No. 1....	Granite	1833		$945,676	331' 8" *g*	302' 8" *m*	86'	30'	60'	44'	30	25' H.T.
" " " 2.....	Timber				500' *g*	459' 8" *m*			85			25' 5" H.T.
Port Royal, S.C.	Timber	1895	4 years	$418,915 *b*	496' *g*	459' *m*			97'			26' 0" H.T.

NOTES:
a. Rebuilt in granite and concrete in 1902.
b. Contract price.
c. "Head to caisson in outer sill."
d. "Head to outer groove."
e. "Head to gate in outer groove."
f. "Over all."
g. "Extreme length."
h. "Head to outer gate sill."
i. "Inside caisson."
j. From inner face of caisson, when in outer groove, to inner face of the coping timbers at dock head.
k. "On the keel blocks."
l. "On bottom, head to inner groove."
m. "On bottom."
n. "On the keel blocks from inner face of caisson when in outer groove, to vertical face of box in dock head.
o. Neat width between inner faces of coping timbers.

By a study of the table, it is seen that in maximum length of docking facility, the Baltimore dock is only exceeded by dock number 2 at Newport News, dock number 2 at Boston, and the United States government dock at Portsmouth.

The Portsmouth and Boston docks were still under construction at the time the Baltimore Dock was completed, so that at the time of opening, it could rank as the second largest dock on the coast.

When we consider the serious mishaps that have attended the construction of some of these docks, and the length of time required for their completion, we find that the Baltimore dock was built within a reasonable time, at a not excessive cost, and was practically free from misfortune.

The timber dock at Port Royal was under construction for a period of four years, during which time the cofferdam gave way, the dock floor was lifted by the hydraulic pressure, and the dock was flooded by the tidal wave of August 1893.

Though the contract price given in the table is only 418,915 dollars, it has been stated that the dock has cost the U.S. govt. upwards of one million dollars, including site and repairs, and a recent report states that it is to be abandoned entirely.

In the new Boston dock the cofferdam failed twice during construction, at one time a length of 200 feet giving way, and at another time the dock was flooded and all work stopped, due to a settlement and overflow of the clay banking at the sides.

The two timber docks at Brooklyn have been the cause of many anxious moments on the part of the officials in charge. There has been leaks which were estimated at 10,000 gallons per minute.

Dock number 2, after nine years or so of use, failed so seriously that in 1900 it was almost completely rebuilt in concrete and masonry, and can hardly be classed at this time as a timber dock.

Conclusion.

The Baltimore dock has now been in operation for nearly three and a half years, and it may be of interest, in conclusion, to see what the result has been.

Through the concrete backing and the joints of the granite abutments, at the time of completion, there were several places where small streams of water had found entrace into the dock. It was thought at the time, that these streams of muddy water would gradually deposit enough silt to choke back the flow, but such has not been the case. The leakage through the concrete, remains about the same, no worse than at first and no better.

The 3 inch mortar course about the engine pit has proved effective. There are several damp places, but at no point can running water be seen, and what dampness there is, shows in horizontal lines around the engine room, and is evidently caused by an incomplete bond between one day's work on this mortar course, and the next.

The concrete placed between the altars and the north bulkhead, has served to keep the bulkhead in place, but at this point there is more leakage through the altars than at others. Since the filling has become compacted, there have been no visible signs of movement either in the bulkheads or the slopes of the basin.

The large stream of water at the head of the dock, (mention of which has been previously made) gave considerable trouble, in that it brought with it quantities of fine sand which choked up the side drains. After various attempts to control it, a test well was drilled, which showed that at a depth of 65 to 80 feet below the coping level, there existed a stratum of coarse gravel, and rock at a depth of 132 feet. Three ten inch pipes were driven to the rock, and perforated where they passed through the gravel stratum.

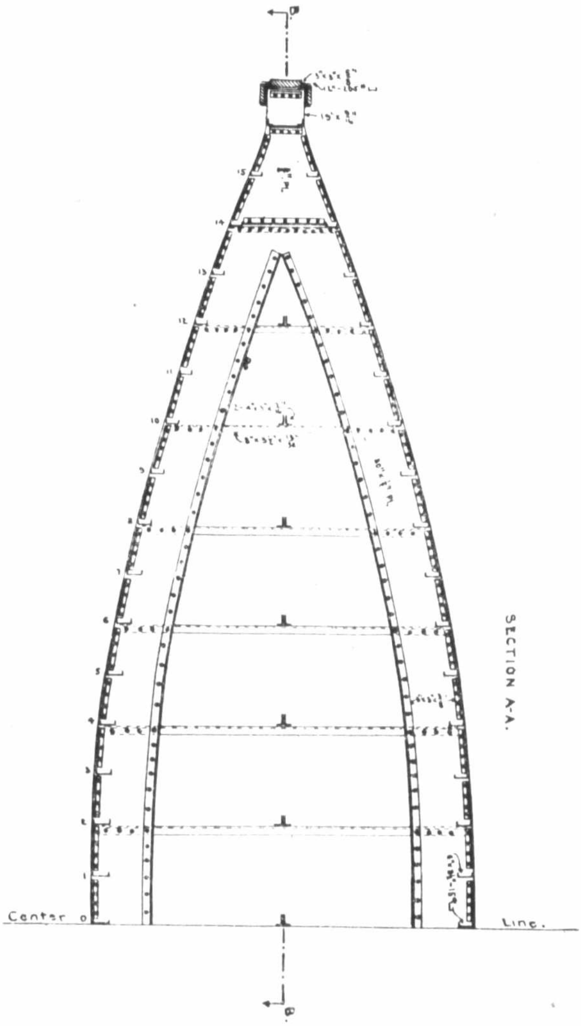
These wells are pumped by compressed air and the work has to go on constantly whenever the dock is being used.

At the outlet of the pumps, where the sluice way was omitted, there has been no evidence of scour about the feet of the sheet piles. The drainage system has proved of ample size for the work intended.

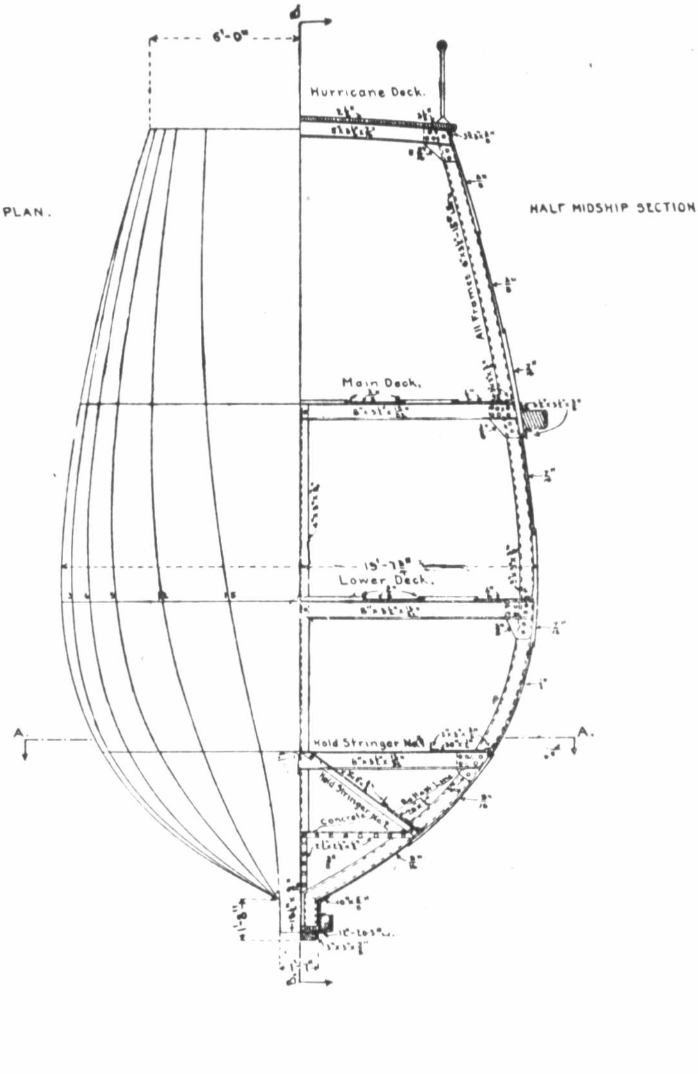
The shortest time in which the dock has ever been pumped out with all three pumps running, is 70 minutes. With two pumps going, as is usually done, it can be emptied in 90 minutes.

There is no doubt that in the designing and building of this dock, many things would have been done otherwise, could foresight only have been as keen as hindsight. But after all is said and done, can there be a better test of the success of an engineering work, than that it satisfactorily performs the functions for which it was designed?

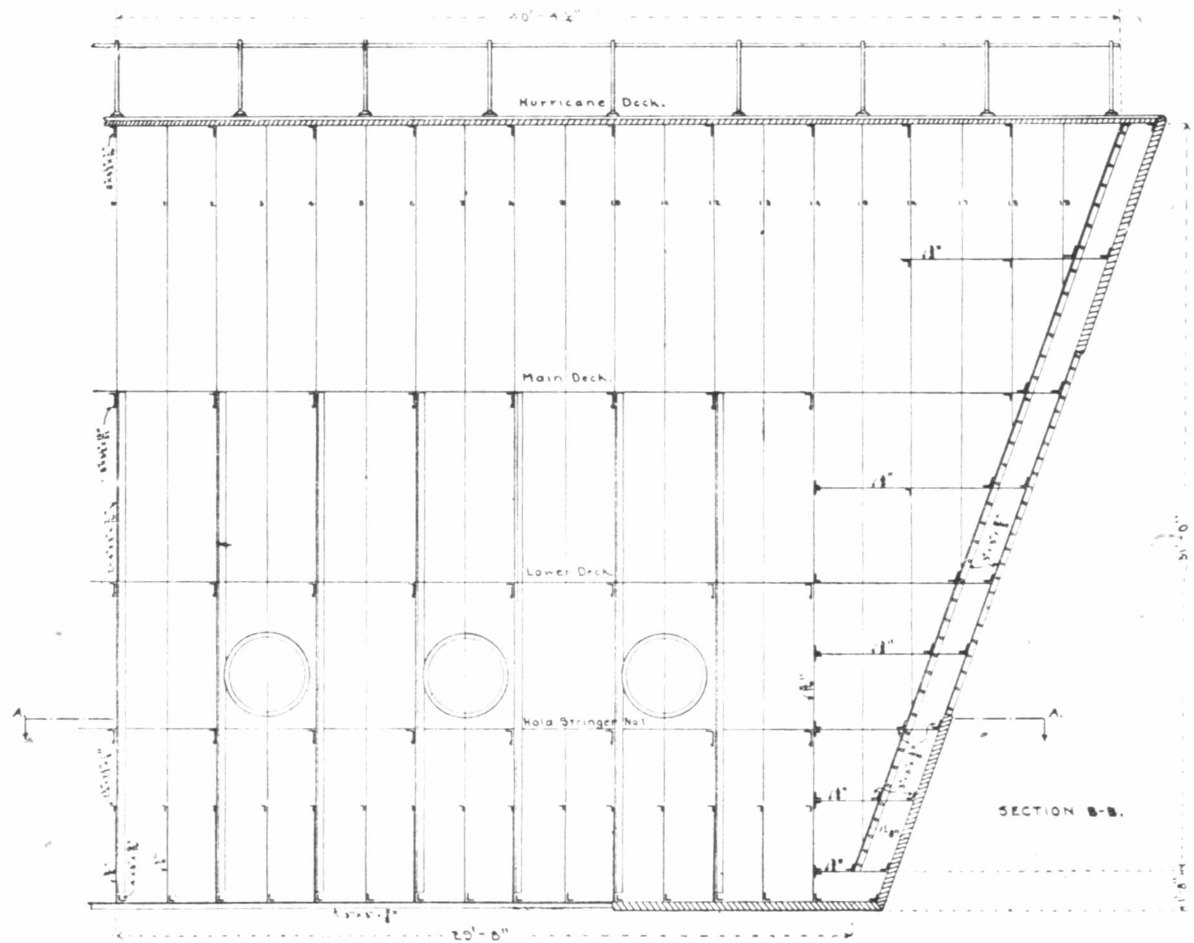
The writer concludes this paper with the words of the President of the Company, who in a recent letter to the author took occasion to say," In our three years operating the dock, we have made but one change, and that was to lengthen the smoke stack so as to cut out forced draft, otherwise if I had another dock to build, I would not make any change whatever."

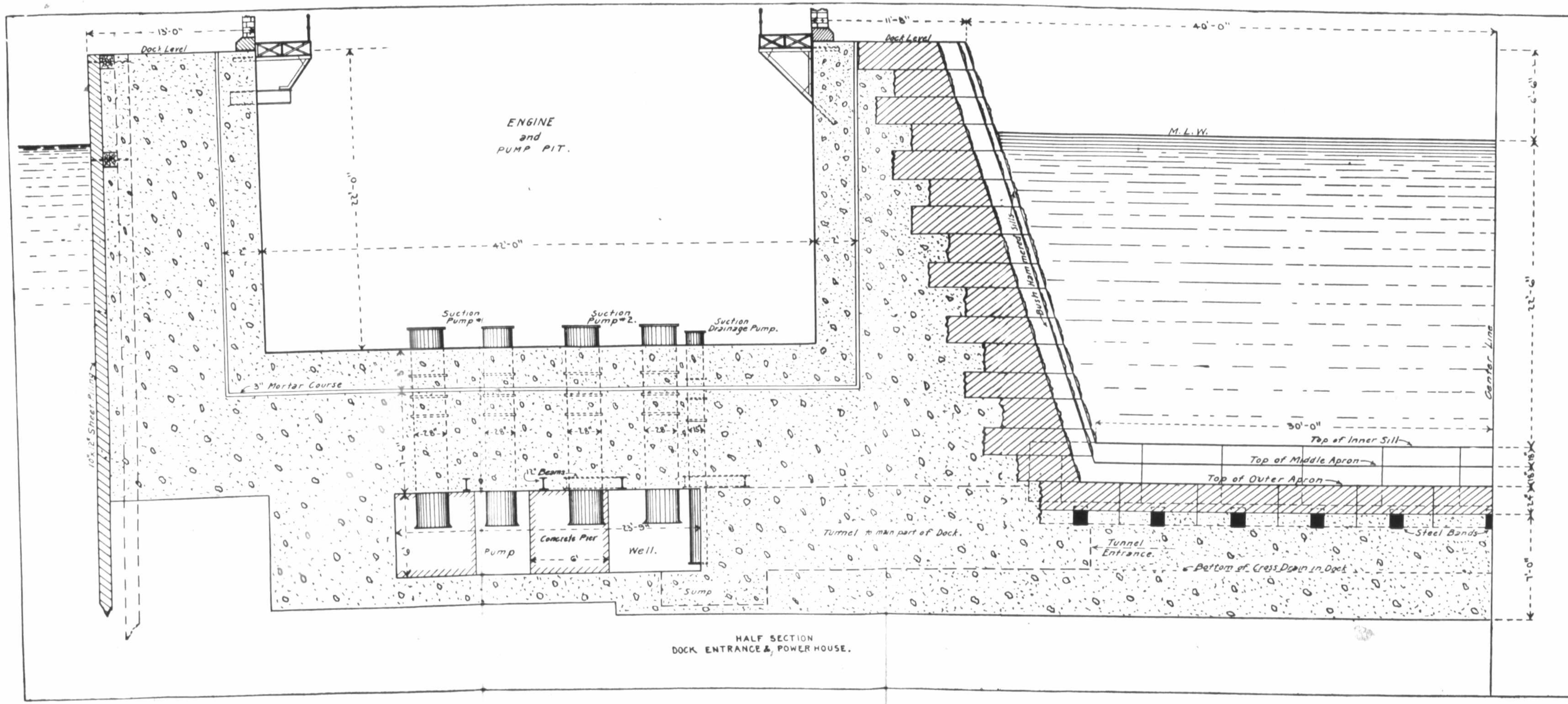


SECTION A-A.


HALF BODY PLAN.
HALF MIDSHIP SECTION.
6'-0"
Hurricane Deck.
Main Deck.
Lower Deck.
Hold Stringer No.1
Hold Stringer
Concrete No.2
A.
A.

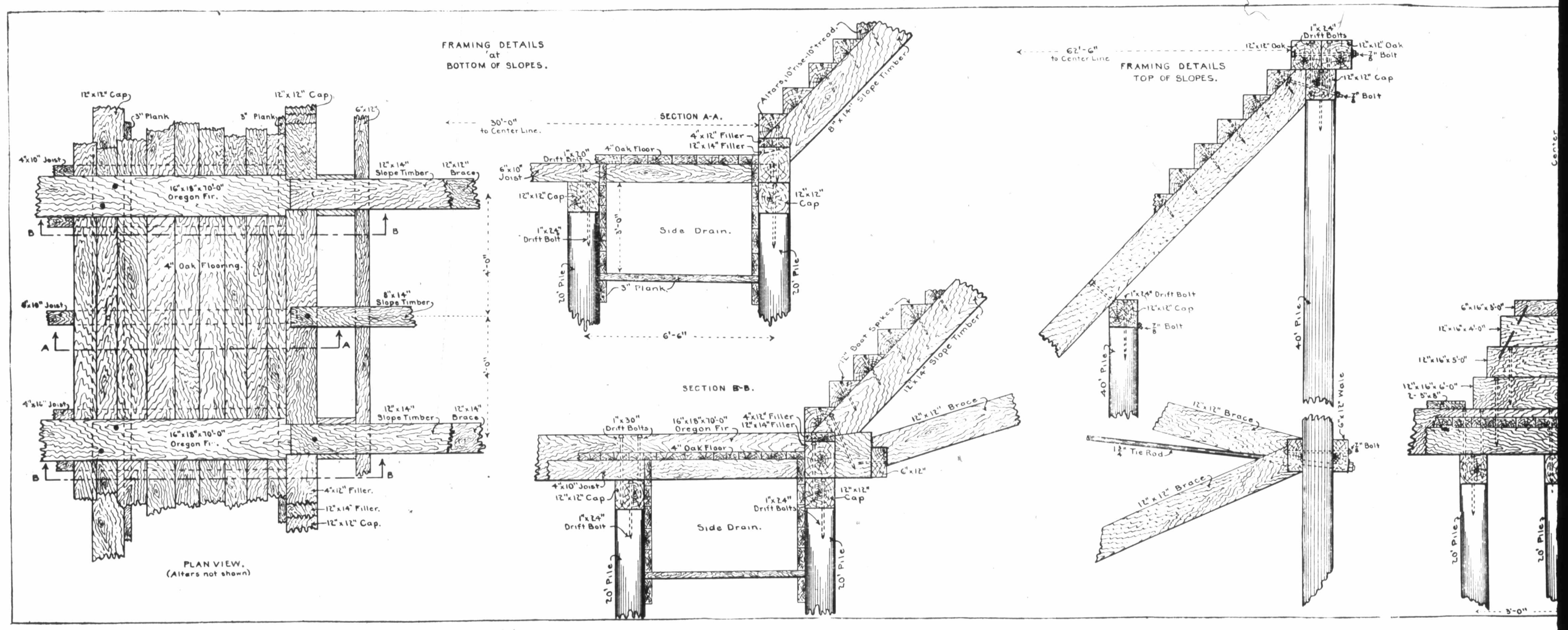

Hurricane Deck.


40'-4½"
Hurricane Deck.
Main Deck.
Lower Deck.
Hold Stringer No. 1
A.
A.
29'-8"
SECTION B-B.

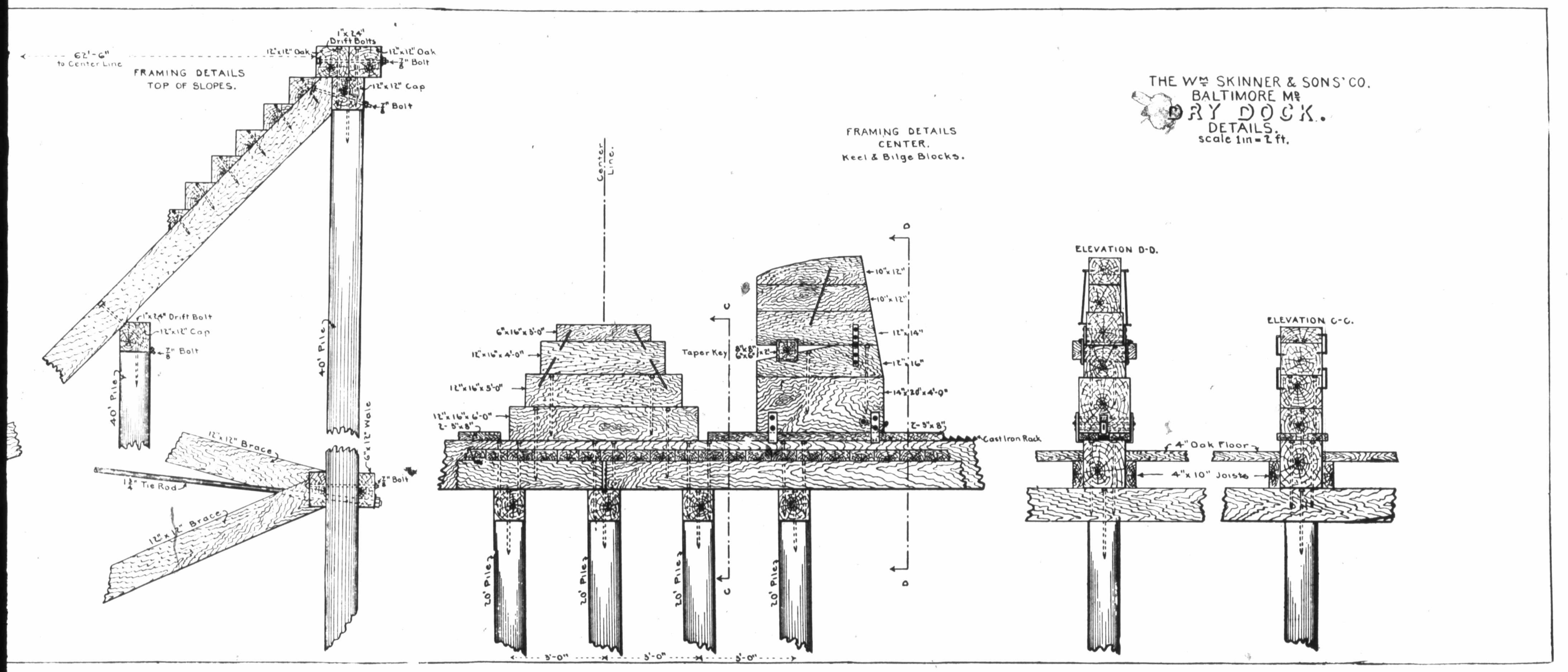


HALF SECTION
DOCK ENTRANCE & POWER HOUSE.

THE WM SKINNER & SONS CO.
BALTIMORE MD
DRY DOCK.
SECTION
scale 1in.=5.ft.



FRAMING DETAILS at BOTTOM OF SLOPES.
SECTION A-A.
SECTION B-B.
Side Drain.
4" Oak Flooring.
PLAN VIEW. (Altars not shown)
FRAMING DETAILS TOP OF SLOPES.



FRAMING DETAILS TOP OF SLOPES.
THE Wm. SKINNER & SONS' CO.
BALTIMORE Md.
DRY DOCK.
DETAILS.
scale 1in = 1 ft.
FRAMING DETAILS CENTER. Keel & Bilge Blocks.
ELEVATION D-D.
ELEVATION C-C.

THE W^M SKINNER & SONS' CO.
BALTIMORE M^D
DRY DOCK.
GENERAL PLAN.
scale 1in = 20ft.
WATER
Covered Sluice Way for Pump Discharge
Concrete
Pump Pit
Boiler House
(Concrete)
Earthfilling
(Sheet Piling)
Port Warden Line
Coffer Dam
Granite Abutment
Granite Aprons
Cross Drain
Altars
Chute
Covered drain
OPEN WATER
LAND
(Masonry Retaining Wall)
76.58
80.17
368.0
104.0
24.17
125.0
60.0
16.0

Top Permanent Bulkhead
Low Water Line
Temporary Coffer Dam
Bottom of Basin
Concrete
Steel Band
Sheet Pile 10x12"
CHUTE
Angle
2 Oak Caps 12"x 12"
4" Filler
4" Oak Flooring
4"x 10" Floor Joists
12"x 12" Yellow Pine Caps
Oregon Fir
20' Piles
4' C to C
Side Drain
S Plank
12"x 12" Oak
do. Yellow Pine
Elev 106.5
HALF MIDSHIP SECTION.
76'5
44'0
80'17
368'0
368'0
30'0
32'5
104'0
30'42