63D CONGRESS, 2d Session | HOUSE OF REPRESENTATIVES | DOCUMENT No. 480

FINAL REPORT ON REMOVING WRECK OF BATTLESHIP "MAINE" FROM HARBOR OF HABANA, CUBA

LETTER FROM THE SECRETARY OF WAR

TRANSMITTING

WITH A LETTER FROM THE CHIEF OF ENGINEERS FINAL REPORT OF A SPECIAL BOARD OF ENGINEER OFFICERS ON RAISING AND REMOVING THE WRECK OF THE U. S. BATTLESHIP "MAINE" FROM THE HARBOR OF HABANA, CUBA

DECEMBER 16, 1913.—Referred to the Committee on Rivers and Harbors and ordered to be printed, with illustrations

WASHINGTON
1914

LETTER OF TRANSMITTAL.

WAR DEPARTMENT,
Washington, December 13, 1913.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

SIR: I have the honor to transmit herewith a letter from the Acting Chief of Engineers, United States Army, dated 12th instant, together with final report dated April 17, 1913, with illustrations, upon the work of raising and removing the wreck of the U. S. S. *Maine* from the harbor of Habana, Cuba, authorized by an act of Congress approved May 9, 1910.

Very respectfully,

LINDLEY M. GARRISON,
Secretary of War.

LETTER OF SUBMITTAL.

War Department,
Office of the Chief of Engineers,
Washington, December 12, 1913.

From: The Chief of Engineers, United States Army.
To: The Secretary of War.
Subject: Wreck of the U. S. S. *Maine.*

1. There is submitted herewith, for transmission to Congress, the final report dated April 17, 1913, with illustrations, upon the work of raising and removing the wreck of the U. S. S. *Maine* from the harbor of Habana, Cuba.

2. This work was authorized by the following act of Congress approved May 9, 1910:

> *Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the Secretary of War and the Chief of Engineers are hereby authorized and directed to provide with all convenient speed for the raising or the removal of the wreck of the United States battleship *Maine* from the harbor of Habana, Cuba, and for the proper interment of the bodies therein in Arlington Cemetery; and the Secretary of War is authorized and directed to remove the mast of the wreck of said battleship *Maine* and place the same upon a proper foundation in Arlington National Cemetery at or near the spot where the bodies of those who died through such wreck are interred: *Provided, however,* That the consent in proper form of the Republic of Cuba shall be first obtained. The sum of one hundred thousand dollars is hereby appropriated out of any money in the Treasury not otherwise appropriated, on account of the work herein authorized.

3. After the enactment of the above-quoted provision of law, the Secretary of War transmitted to Congress on May 17, 1910, a letter from the Chief of Engineers relative to the raising of the wreck (see H. Doc. No. 119, 61st Cong., 2d sess.), in which the following statement was made:

> 1. * * * in the matter of the $100,000 appropriated for raising the battleship *Maine* from the harbor of Habana, I have the honor to report that the work contemplated can not be carried out for the sum appropriated by the act, and that that amount can not be economically and effectively expended in initial work.
>
> 2. It seems probable that the best plan for carrying out the provisions of the act will be to construct a cofferdam around the wreck and pump it out, thus permitting the removal of the human remains and a thorough examination of the hull. No estimate for such a structure has been made, but it is certain that it will cost considerably more than $100,000. Until the cofferdam is completed and the hull exposed to view, no estimate, even of the most approximate nature, can be formed of what it will cost to patch the hull of the wreck sufficiently to float it, or to remove the wreck piecemeal if it can not be floated.
>
> 3. In my opinion no work of construction should be undertaken unless it can be prosecuted continuously to a conclusion, and as it is impracticable to estimate in advance what it will cost to raise or remove the wreck, I recommend that legislation be enacted authorizing such expenditures as may be necessary, to be paid out of any money in the Treasury not otherwise appropriated. On account of rapid deterioration it would be highly inadvisable to start the work and then await further appropriations.
>
> 4. It is believed that the amount required for carrying out the provisions of the act will not be less than $500,000, and may be more. The only useful purpose that may be served by the appropriation of $100,000 carried by the act, unless further expenditures are authorized, is to utilize a part of it in making a detailed survey and examination of the site and the preparation of plans for the prosecution of the work.

4. Subsequent appropriations were made by Congress as follows: $200,000 in the deficiency act of June 25, 1910; $350,000 in the sundry civil act of March 4, 1911; and $250,000 in the urgent deficiency act of December 22, 1911; an aggregate of $900,000 for this work.

5. These appropriations were not based upon any estimate of final cost submitted or prepared by the Engineer Department, but were provided by Congress for the purpose of prosecuting continuously the work of removal in progress at the time each appropriation was made.

6. The duty of removing the wreck was assigned to a board of Engineer officers composed of Col. W. M. Black, Lieut. Col. M. M. Patrick, and Maj. Harley B. Ferguson, the plan of work to be subject to the approval of the Chief of Engineers and the Secretary of War.

7. Special reports explaining work already done and the reasons for need of further appropriations were submitted by the Chief of Engineers, Secretary of War, and the President during 1911 and 1912, and later published in House Report No. 754, Sixty-first Congress, second session; House Document No. 919, Sixty-first Congress, second session; Senate Document No. 765, Sixty-first Congress, third session; House Documents Nos. 60, 96, and 113, Sixty-second Congress, first session; and Senate Document No. 107, Sixty-second Congress, first session, and partial progress reports were also submitted in the regular annual reports of the Chief of Engineers and Secretary of War for 1911, pages 1119 and 3039; for 1912, pages 1344 and 3565; and for 1913, pages 1498 and 3277.

8. The work of the board was brought to a successful conclusion by the floating and sinking in deep water on March 16, 1912, of that portion of the wreck permitting of such treatment, the removal of a portion of the balance piecemeal, the sinking by means of dredging and the use of dynamite of such masses as were too heavy to be lifted, so as to clear the site of the wreck, and the removal of the cofferdam erected around it to a depth satisfactory to the Cuban Government, all as fully and technically described in the report of the board.

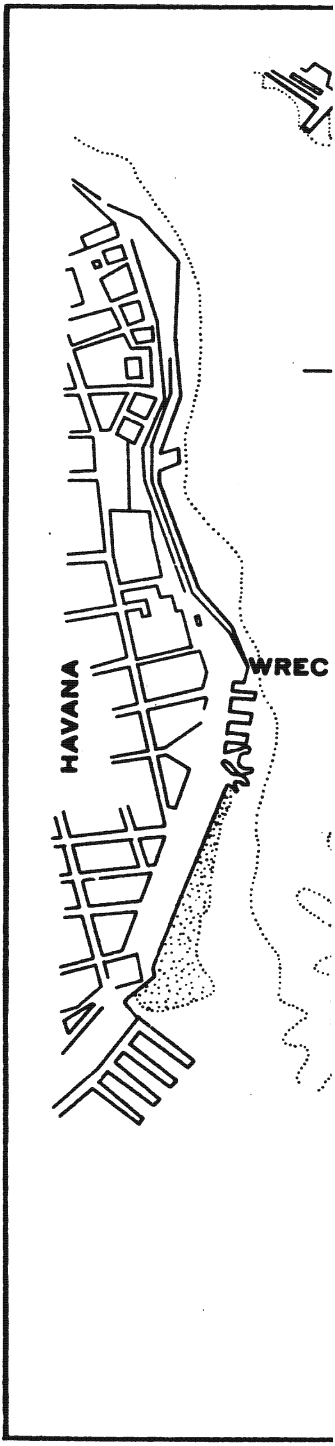
9. On December 3, 1912, the site was carefully swept to a depth of 37.5 feet in the presence of representatives of the Cuban Government and declared free of obstructions.

Financial statement.

Total amount of appropriations for this work, as before stated		$900,000.00
Net cost of removal of wreck	$785,774.83	
Removal of remains of bodies, etc., to Arlington	4,090.50	
Total expenditures and liabilities for work of actual removal of wreck		789,865.33
Returned to Treasury of the United States		4,290.97
Balance for constructing tablets, monument, or return to Treasury		[1] 105,843.70

EDW. BURR,
Colonel, Corps of Engineers,
Acting Chief of Engineers.

[1] This amount includes $5,000 allotted for the purpose of making tablets in conformity with the provisions of the urgent deficiency act of December 22, 1911, and $11,000 for commencement of the monument. The removal from Habana, Cuba, to Arlington, Va., of the remains of 67 members of the dead crew found during the above work was effected by the Quartermaster General, U. S. Army, using U. S. Navy vessels as transports. The distribution of relics and the erection of a memorial monument at Arlington is still in progress under joint direction of the Secretaries of War and Navy.



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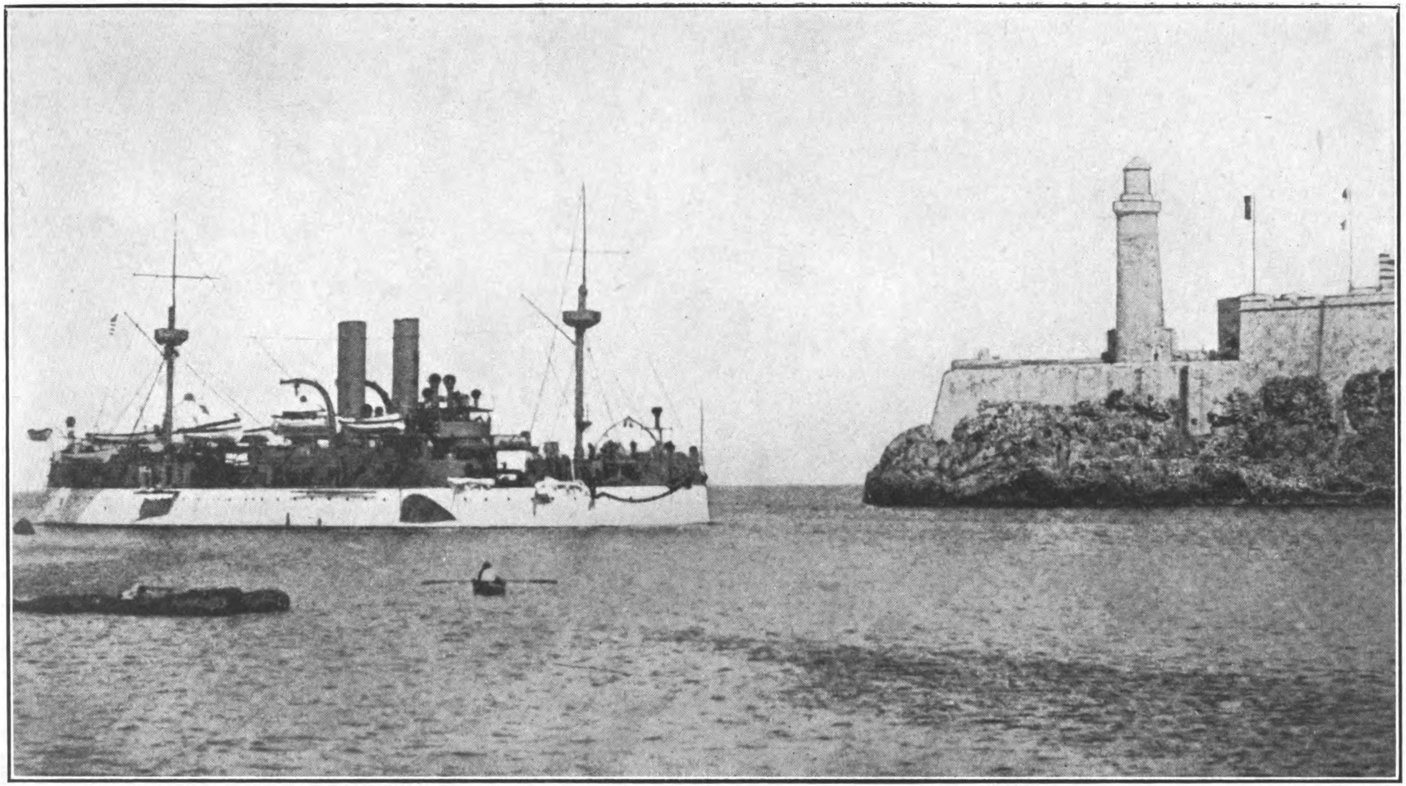

PLATE 2.—"MAINE" ENTERING HAVANA HARBOR JANUARY 25, 1898.

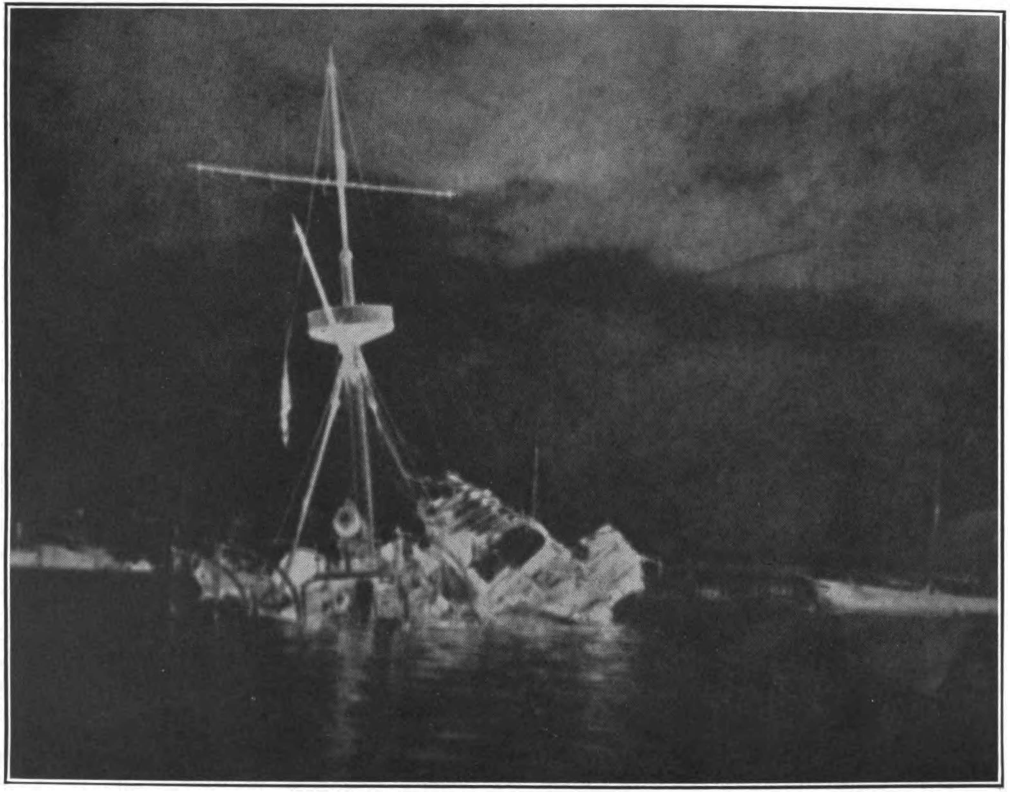

PLATE 4.—"MAINE" AT SUNRISE FEBRUARY 16, 1898.

REPORT OF SPECIAL BOARD OF ENGINEER OFFICERS ON RAISING THE U. S. S. "MAINE" FROM HARBOR OF HABANA, CUBA.

War Department,
United States Engineer Office,
New York City, April 17, 1913.

From: A special board of Engineer officers.
To: The Chief of Engineers, United States Army.
Subject: Final report "Raising U. S. S. *Maine* from harbor of Habana, Cuba."

1. The U. S. battleship *Maine* entered the harbor of Habana on January 25, 1898, and in accordance with the custom at that port was taken to one of the regular mooring buoys of the harbor and there made fast. The location of this mooring is shown on plate No. 1.

2. The *Maine* was 324 feet long, with a beam of 57 feet. Her draft, loaded, was 21½ feet and her displacement 6,650 tons. She had an armor belt 7 to 10 inches thick, a steel protective deck 2 inches thick, and two turrets of 8-inch armor. Her battery consisted of four 10-inch guns, mounted in pairs in the two turrets, six 6-inch guns, and a minor battery of 6-pounder rapid-fire guns. She was also provided with four torpedo tubes. The general appearance and arrangement of the ship are shown in plates Nos. 2 and 3.

3. About 9.40 p. m., February 15, 1898, the *Maine* sank at her moorings as a result of an explosion, which immediate investigation showed had destroyed a large portion of her hull from about amidships forward. Two officers and 258[1] enlisted men of the crew perished, including those who died of wounds shortly after the explosion. The bodies of 1 officer and of 74[1] of the men were supposed to have been entombed in the wreck. Plate No. 4 shows the appearance of the wreck on the morning of February 16.

4. The work of salving such of the guns and small movables as could be taken out by divers was carried on until interrupted by the outbreak of the War with Spain, after which the wreck was allowed to remain undisturbed for nearly 13 years, until the Congress of the United States in 1910 made an appropriation for its removal. This work was placed under the charge of the Secretary of War and the Chief of Engineers, United States Army. To conduct the necessary investigations, prepare the plans, and execute the work there was appointed a board of officers of the Corps of Engineers, consisting of Col. W. M. Black, Lieut. Col. Mason M. Patrick, and Maj. H. B. Ferguson.

5. The board held its first meeting in Washington on the 29th of August, 1910, and then decided that the only way to do the work in accordance with its understanding of the wishes of Congress was to

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[1] From Navy Department letter, August 4, 1913.

place a cofferdam around the wreck and unwater it so as to expose the wreck just as it lay on the bottom of the harbor. The reasons for this decision have been set forth at length in previous reports of the board. This decision received the approval of Brig. Gen. W. H. Bixby, Chief of Engineers, United States Army, the Hon. J. M. Dickinson, Secretary of War, and the Hon. W. H. Taft, President of the United Sates, and this method of work was thereafter steadily adhered to until everything had been exposed and the wreck successfully removed.

CONDITIONS AT THE SITE.

6. A careful examination and comparison of a harbor chart made prior to the sinking of the *Maine* with one made in 1907, nine years later, showed that but little change had taken place in the harbor bottom in the vicinity and that the average depth of the water around the wreck was about 35 feet. Soundings taken in 1910 verified the depths shown on these charts and indicated that the bottom was quite soft. Subsequent borings showed that the thickness of this layer of soft material was about 30 feet and that there was an underlying stratum of stiff clay at an average depth of about 60 feet. Rock was not struck until at depths of from about 98 to 118 feet. Some characteristic borings are shown on plate No. 5.

7. The datum for the above references, and for all which follow, is the plane of mean low water. In Habana Harbor there is but one appreciable tide each 24 hours, and the mean tidal rise and fall is about 18 inches.

THE PROBLEM.

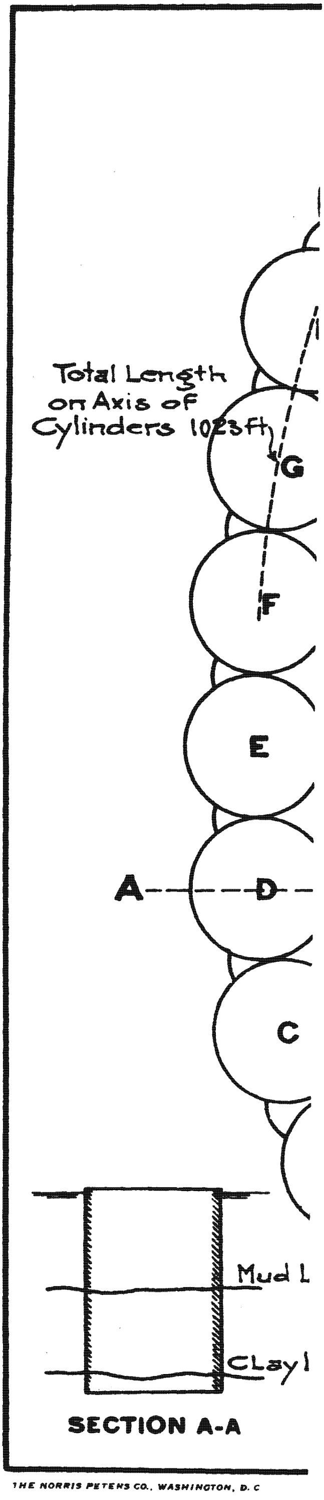
8. As stated earlier in this report, the *Maine* was originally 324 feet long and her maximum width was 57 feet. It was known that the forward part of the vessel had been badly shattered, that pieces of wreckage were scattered over a considerable area of the bottom for many feet on each side of the line of the keel, and that the wreck had settled in the soft mud until the keel, or at least its after half, was certainly not less than 42 feet below the water surface. Plate No. 6 shows the appearance of the wreck when the work of the board began.

9. The problem was to design a cofferdam with interior horizontal dimensions of about 350 by 170 feet, capable of resisting mud and water pressures developed when it should be unwatered to nearly 50 feet, this cofferdam to be erected in water 35 feet deep on a soft bottom in which hard clay is not found above an average depth of about 60 feet and rock above depths of about 100 feet and over. The dimensions of such a cofferdam were so great that interior bracing would be difficult and very costly; hence an effort was made to design a structure in which such bracing could be reduced to a minimum.

THE PLAN OF THE COFFERDAM.

10. After much consideration the board finally fixed upon the plan shown on plate No. 7. The 20 component cylinders of the dam were to be made of interlocking steel sheet piling and set nearly tangent to each other, the adjacent cylinders to be united by short arcs connected with the respective cylinders by a three-way pile in each. (See pl. No. 8.)

PLATE 6.—APPEARANCE OF WRECK SEPTEMBER, 1910.



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CALCULATIONS FOR STABILITY.

11. The plan was based upon calculations for stability which assumed that the individual cylinders would act as rigid columns, and it was hoped that they would approximate to this assumption—how far they failed to do so will appear later.

TYPE OF STEEL PILING.

12. The calculations for pressures showed that it was necessary to select a steel sheet pile which would be quite strong in the interlock. It was also desirable to use a pile which could be pulled easily when the time came to remove the dam. The type of piling made by the Lackawanna Steel Co. was chosen for this work. (For a cross section of this pile see pl. No. 8.) This piling was guaranteed to stand a strain of 9,700 pounds per linear inch in the interlock, and this was believed to be sufficient.

13. The individual piles in each cylinder were required to be about 75 feet long. As it was inconvenient to ship and to handle piles of such length, each pile was made in two pieces, half of the total number of piles being made up of 50-foot and 25-foot lengths and half of them of 40-foot and 35-foot lengths. The joint in each pile was made with two 7-inch 12¼-pound channel fishplates, with eight ⅞-inch bolts in each piece of pile. The adjacent piles in the cylinders broke joints and the joint was calculated to be as stiff as the remainder of the pile. (See pl. No. 8.)

14. Based upon the first reports of the borings, it was planned to have the piles penetrate about 10 feet in the hard clay stratum and extend about 5 feet above mean low water. Subsequently, as the clay layer was found in places to be more than 60 feet below the water surface, it was decided to drive all the piles so that their tops would be at elevation +2.5 feet, and around the outside half of the circumference of each cylinder to supplement the steel piles by short wooden sheet piles for the purpose of raising the filling to a height somewhat greater than would be possible with the steel piles alone when driven to the level above mentioned. As will appear later, it would have been better to have kept the tops of the steel piles at a somewhat higher elevation by using longer piling.

PLANT.

15. For a work of this magnitude it was necessary to assemble a considerable plant. The Cuban Government kindly offered the loan of such plant in charge of the department of public works as might be suitable for the purpose, and there were borrowed from this department the dredge *Sagua*, a 50-ton floating derrick (pl. 9), a pile driver and a number of barges. Two other barges were bought, and one was borrowed from the United States Navy. Most of the floating plant had to be overhauled, repaired, and remodeled to suit the requirements of this special work. The U. S. suction dredge *Barnard* was borrowed, and used as a quarter boat. This dredge did a little dredging for filling the cylinders, pumping material into a barge, from which it was later deposited in cylinder A. Her crew was employed in various capacities and rendered excellent service. A

list of the principal pieces of floating plant used at various times follows, together with photographs of some of the larger units:

Two tugs (hired).
Two launches (hired).
One 7-yard clamshell and dipper dredge, *Sagua* (lent by the Republic of Cuba).
One 36-inch hydraulic drag-suction dredge, *Barnard* (lent by the United States Engineer Department). See plate 19.
One 20-inch hydraulic cutter dredge, *Norman H. Davis* (hired). See plate 21.
Four combined pile drivers and derrick boats (3 adapted from plant loaned by the Republic of Cuba, and 1 from a derrick scow lent by the United States Navy Department) numbered *1*, *2*, *3*, and *4*. See plates 9, 10, 11, and 20.
Two 100-ton decked scows (bought).
One coal barge (lent by the United States Navy Department). See plate 17.
One steam lighter scow, *No. 5* (lent by the United States Engineer Department). See plate 18.
Three dump scows (lent by the Republic of Cuba).
One 50-ton decked scow, with 15 horsepower engine (hired).
One derrick boat (hired).

Pile driver No. 1 (pl. 10) was equipped with a hoisting engine, and an A-frame boom long enough to handle piles of the full length of 75 feet. Few such whole piles were set in place, as they were difficult to handle and to swing into position without undue bending, especially when a strong wind was blowing.

FORMS FOR CYLINDERS.

16. It was planned to mark the center of each cylinder by a wooden pile, and with this pile to hold in place a floating circular form to guide in placing and driving the steel piles. These forms were to be full circles, made of fairly heavy material and faced with steel plates, so that they could be used over and over again. (See pl. 12.) Later it was found that half circles would answer. (See pls. 11, 14, 18, and 19.) After one or two cylinders had been completed and the forms removed, it was found that there was considerable motion of the piles, due to the waves from passing boats, etc., with a consequent deformation of the cylinders. Full circular forms, made of comparatively light material, had to be built and placed inside these finished cylinders. Similar forms were found to be satisfactory for use in building the remaining cylinders, and when each cylinder was completed its form was allowed to remain inside it until all of the cylinders were completed. Immediately before the fill was placed these forms were removed and the lumber of which they were built was used for other purposes. It will be observed that no forms were used below the water surface. Great care was exercised to drive the first pile in each cylinder as nearly vertical as possible, and thereafter it was found practicable, with careful handling, to place the remaining piles in their proper positions.

HANDLING PILES.

17. The steel piling was shipped by steamer from Philadelphia and landed on a wharf at Casa Blanca, belonging to the Cuban Government. The piling weighed about 40 pounds per linear foot, each 50-foot length weighing about 1 ton. Handling was difficult without considerable bending. It was found, however, that piling only slightly bent could be straightened without injury to the interlock.

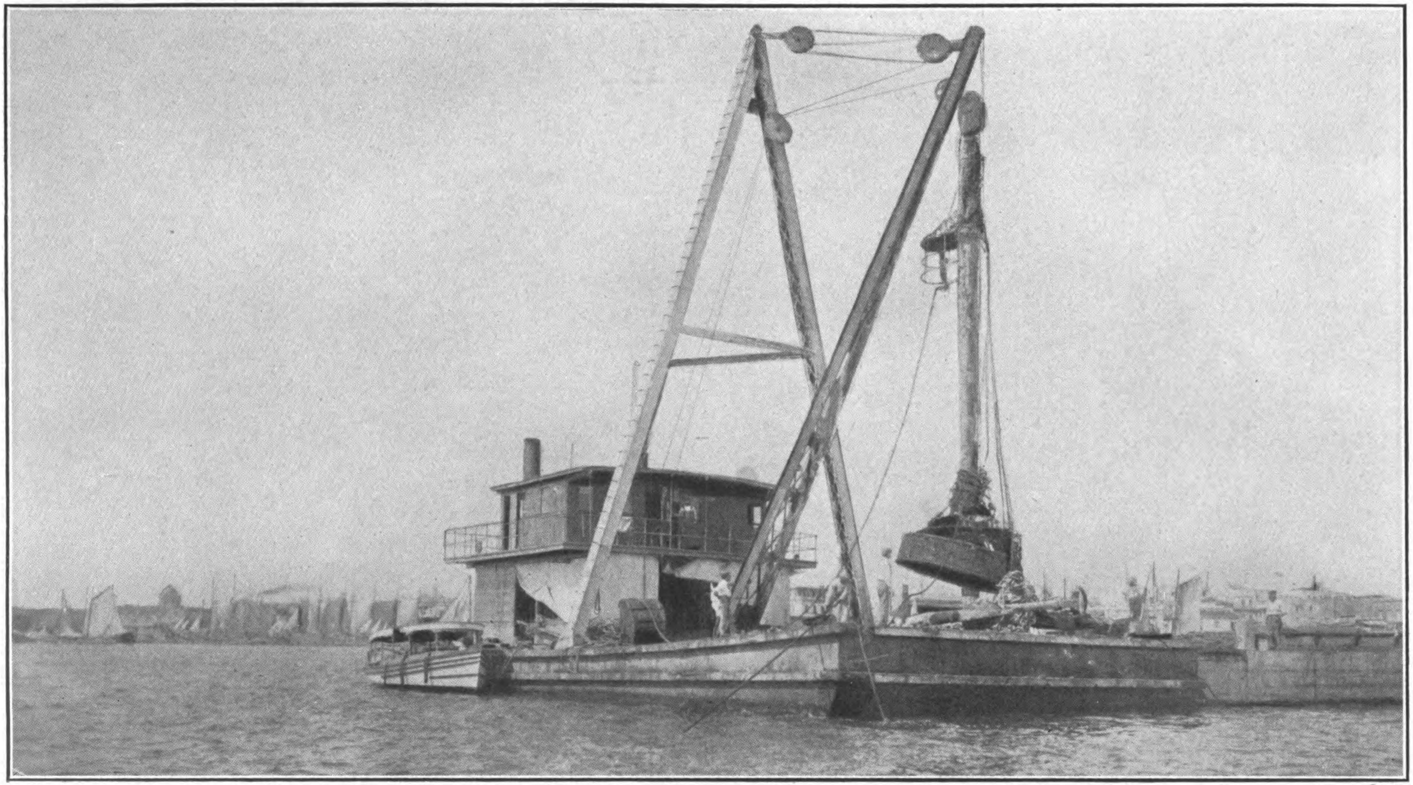


PLATE 9.—FLOATING 50-TON DERRICK RAISING FORE MAST OF "MAINE."

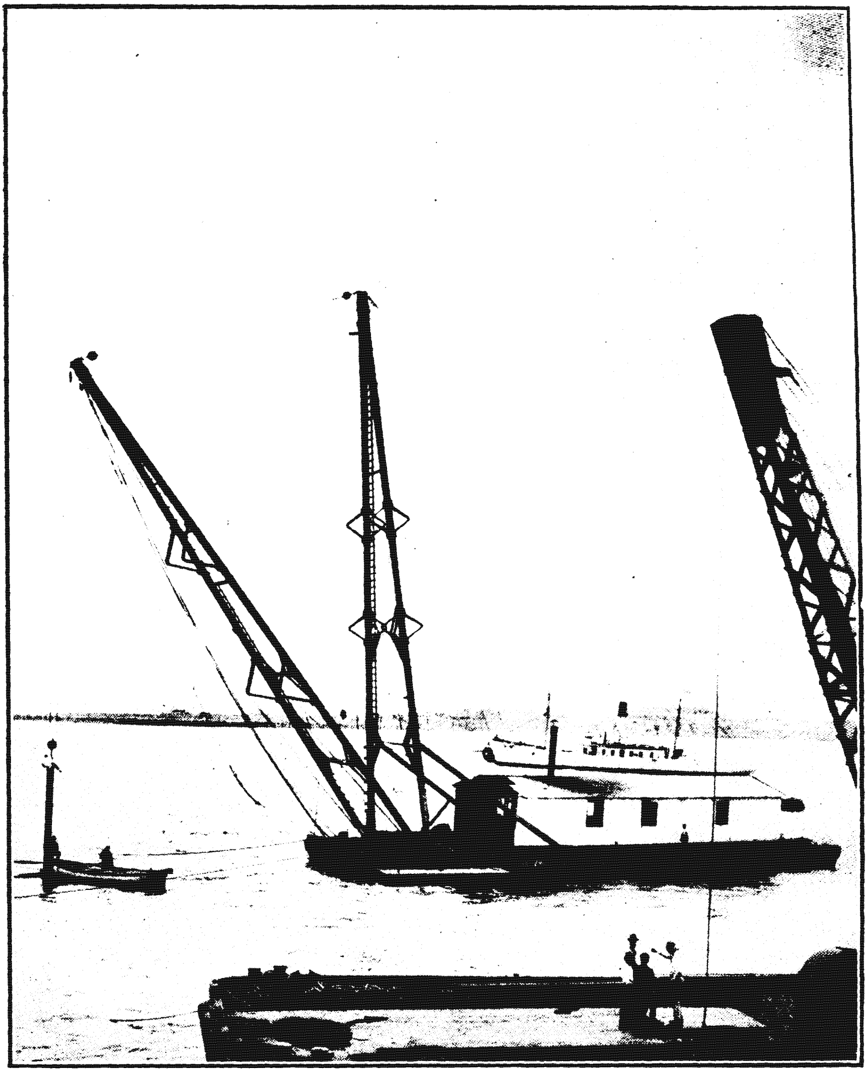


PLATE 10.—PILE DRIVER NO. 1.

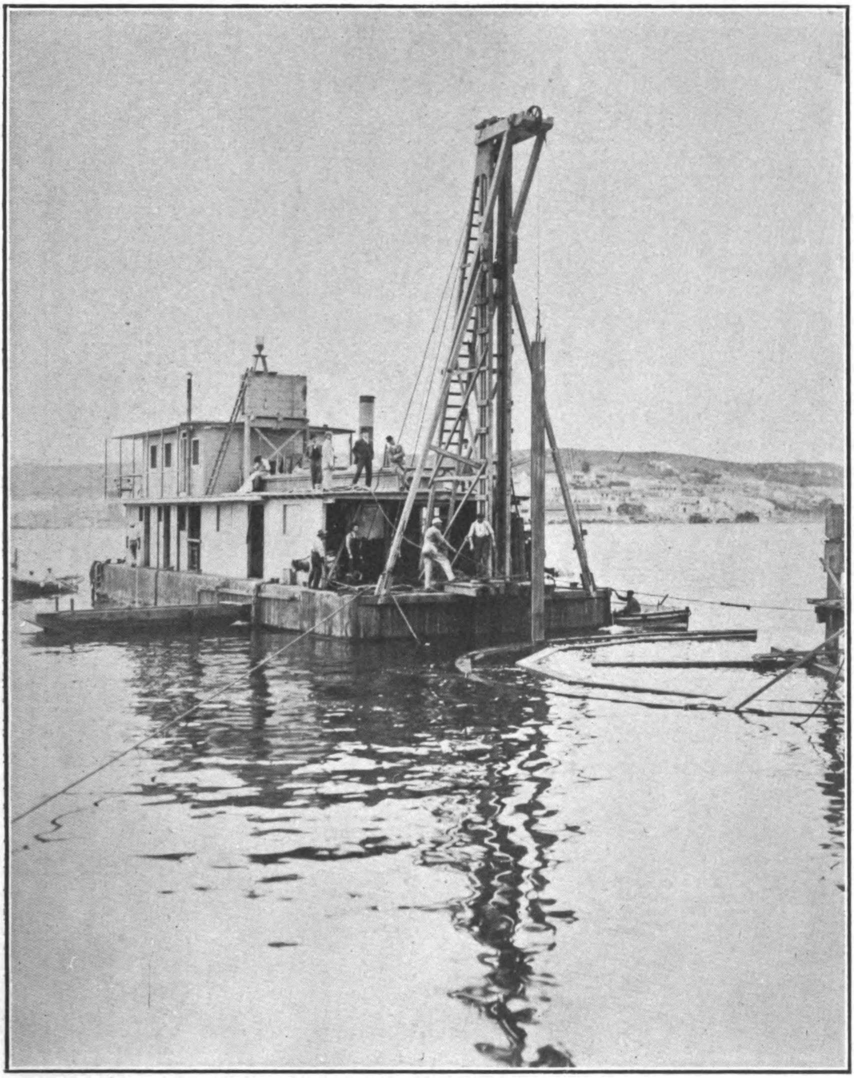


PLATE 11.—PILE DRIVER NO. 3, SETTING FIRST PILE IN PLACE DECEMBER 6, 1910.

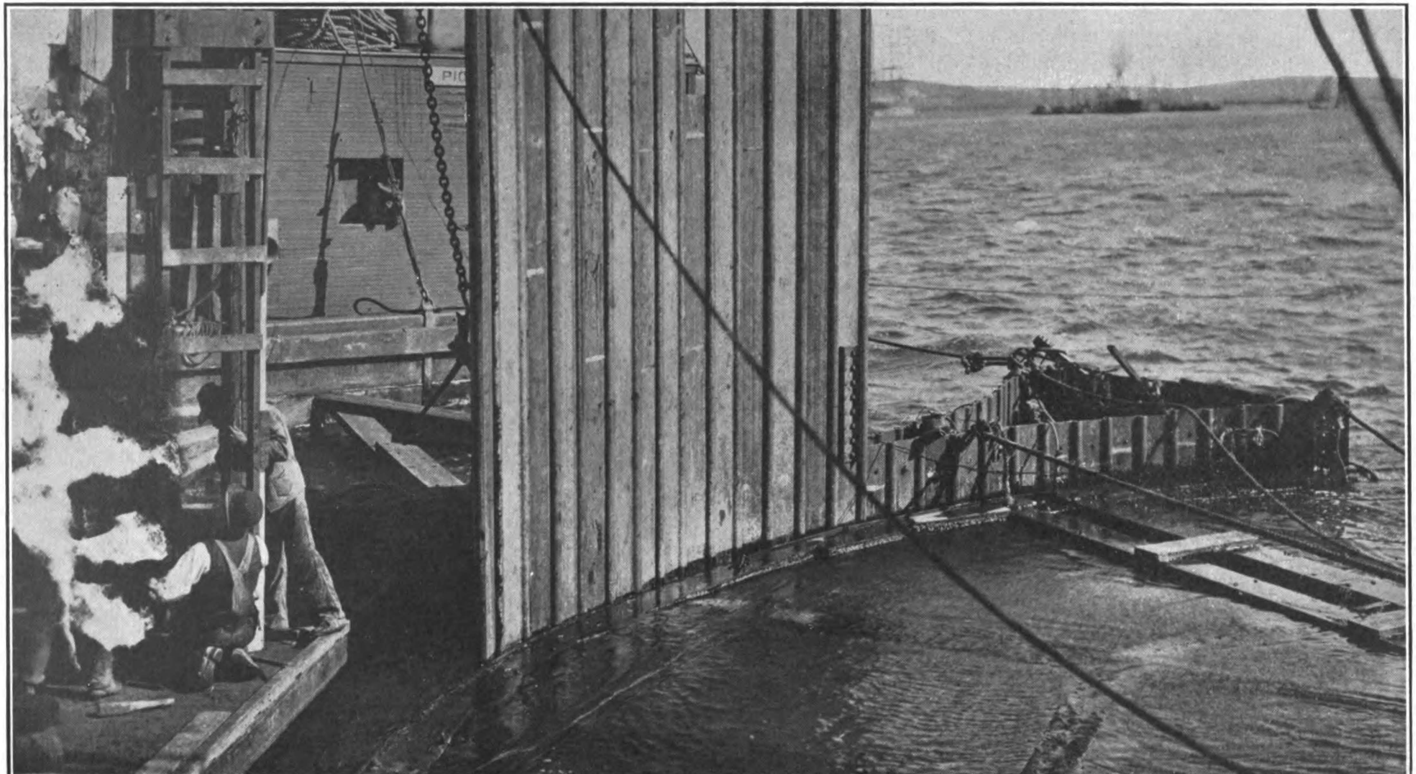


PLATE 12.—COMPLETED ARC AND PARTLY DRIVEN CYLINDER PILES SHOWING FALSE LEADS FOR STEAM HAMMER.

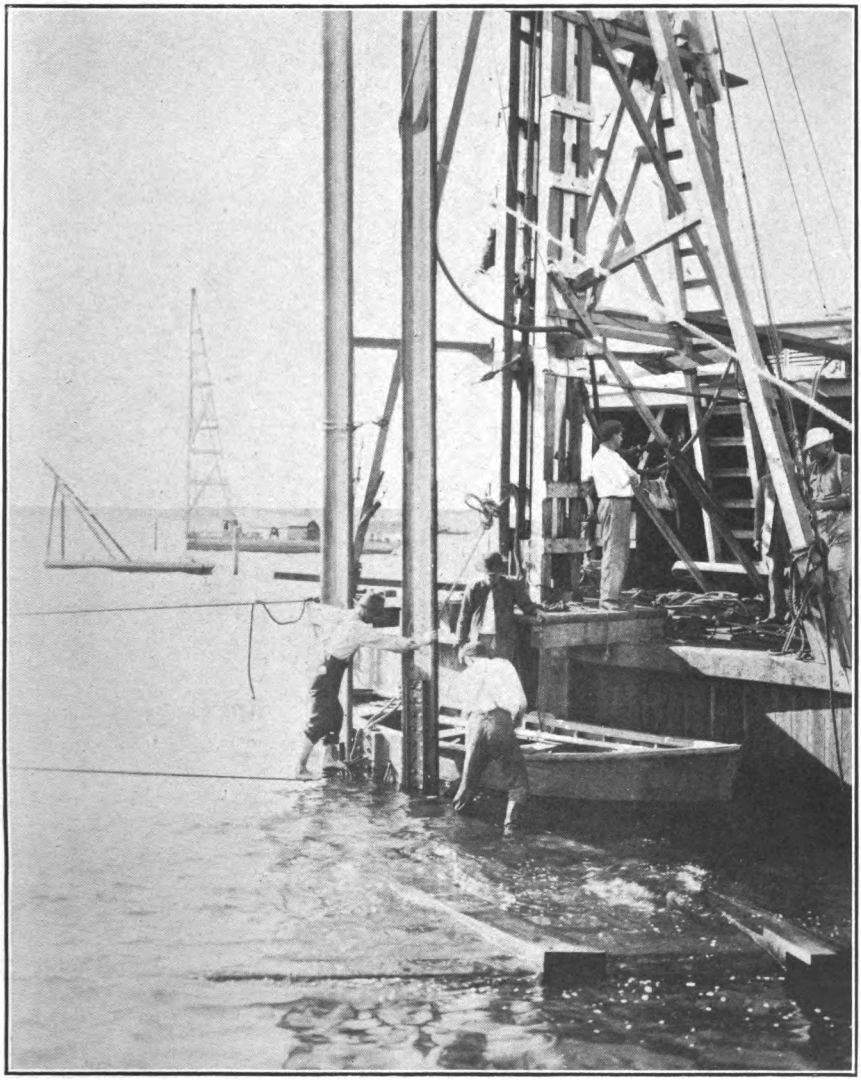


PLATE 13.—SETTING A PILE IN CYLINDER S

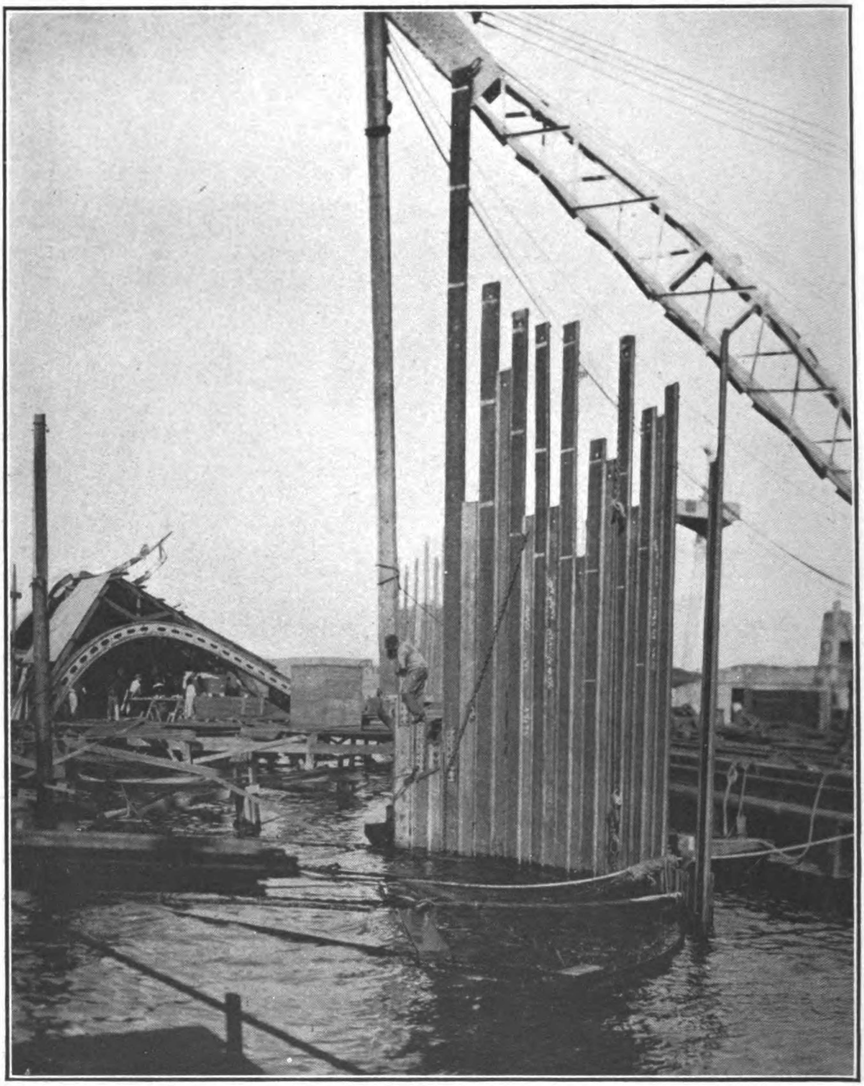


PLATE 14.—SETTING A TOP SECTION OF PILE.

Some of the piling was unloaded directly on barges and some was placed on the dock and rehandled to barges as required. The appliances for handling the piling were crude, the labor inefficient, and the yard space too small, so that the cost of handling, including sorting by lengths, was high, approximately $3.60 per ton of 2,000 pounds.

DRIVING PILES.

18. In order to facilitate making the closure of each cylinder and the interlocking of the closing pile with the pile on each side, it was planned at first to set around the forms the bottom sections of the piles, 50 feet and 40 feet long, and to drive none of them until the closure was made, adjusting them until it was possible to place the closing pile.

19. From the information derived from the earliest borings, it was thought that the bottom was firm enough to hold even the 40-foot sections of piling with their upper ends out of the water, but this proved not so, except in a few places where there seems to have been a peculiar hard crust overlying the softer mud. At the site of the cylinders around the stern of the ship where no outlying wreckage would be covered, clay dredged from a nearby shoal was dumped and, when enough of it was placed, this held up the bottom sections till the joint could be made. At some of the other cylinders wooden piles were driven to support the wooden driving forms, and the bottom lengths were held by temporary fastenings to these forms. (See pls. 12, 13, and 14.)

20. Later it was found practicable to drive the piles as they were placed, until there remained an interval to be filled by about 10 piles, the bottom sections of which were then set in place, and the closure made with about 5 undriven piles on each side of the closing pile. There was sufficient play in the interlocks of these 10 undriven piles to permit this method to be followed. In this latter method of driving the piles as placed, the undriven bottom was held to the last driven pile by a chain or wire until the joint could be made. (See pls. 15, 16, 17, and 18.)

21. There were many difficulties attending the placing and driving of the piling. At first, there were delays, due to the fact that the pieces of piling were not loaded on the barges properly, so that it was necessary, at times, to move many lengths in order to get at the one needed. The strong winds blowing most of the time were also a source of considerable inconvenience in handling and driving the piles. These winds were strong enough to bend the piling, if any considerable length of a partially driven pile was allowed to remain above water for more than a short time. In one case (cylinder S, one of the first cylinders built), the piles were only partially driven and were allowed to remain for a time with their tops about 25 feet above water. The wind, acting upon these exposed portions of the piles, forced over the cylinder until it was several feet out of plumb. It was found impracticable to straighten it up, and the driving had to be completed with the piles in this slanting position.

22. As previously stated, no forms were used below the water surface. Sometimes in driving it would be found that a pile had been twisted away from the form, and it was apparent that at the bottom it must have departed somewhat from the circle around

which it was intended to be driven. In such cases great care had to be exercised in placing the succeeding piles so that they would regain the circle gradually. The play in the interlock of each pile amounted to nearly one-half inch and permitted these necessary adjustments to be made. Some trouble was experienced due to wreckage where the piles were to be driven, although the cofferdam had been planned so that it was thought most of the wreckage would be avoided. At the site of cylinder K (see pls. 7 and 9) the foremast was found and was raised. At the site of cylinder N the top of the forward turret lay buried in the mud. This turret top was a disk of steel about 25 feet in diameter and about 2 inches thick. It had fallen on edge and had buried itself in the mud of the bottom with its lowest point nearly 60 feet below mean low-water level. At the same place were found the hood which belonged to this turret top and one of the *Maine's* large anchors. All had to be removed before cylinder N could be placed.

23. A careful record was kept of the time consumed in each of the operations connected with placing and driving the piles. Three thousand one hundred and ninety piles were driven in the completed cylinders and arcs, of which 204 were in the arcs. The first pile was driven on December 6, 1910, and the last on March 31, 1911. Subsequently, when the fill was placed, two of the cylinders were ruptured, as detailed later. The repairs to these cylinders were completed on June 5, and in their repairs 10 additional piles were required, making a total of 3,200 piles in the dam. The pile driver crews averaged only 13 complete piles placed and driven per crew in each eight-hour shift. The best record made by any pile-driver crew was 28 complete piles placed and driven in eight hours. The average number of piles driven by each eight-hour shift is low, partly on account of the many difficulties attending the handling of piles of such length and partly owing to the absolute lack of experience at first on the part of all of the workmen.

24. The actual placing in position of the bottom sections of piling, counting from the time when the pile was ready to be hoisted from the barge until it was finally placed, averaged 6 minutes. Placing the top sections in readiness for making the joint, counting from the same stage of the operation, took an average of 5 minutes. Making the joint took an average of about 10 minutes, as but two men could work at a time, and to secure the desired stiffness it was necessary to set up the nuts very tightly. It was found later that the driving loosened many of these nuts, no matter how tightly they were set up, and thereafter some additional time was consumed in upsetting the bolt threads to prevent the nuts being started by the driving. The actual driving of the piles, except the closure piles, took an average of four minutes each. For driving the piles there were used two No. 3 Arnott, one Vulcan, and one Monarch steam hammers, the first-named weighing 3,700 pounds and the Vulcan and Monarch hammers somewhat more. The tops of the piles when in position and ready to be driven were often as much as 40 feet above water, and it was difficult to set and hold the steam hammers on the piles at such a height. Several different kinds of false leads were improvised, as shown on the accompanying photographs, and they aided greatly in handling the hammers. These false leads are shown in plates 12, 15, 17, 18, 19, and 20.

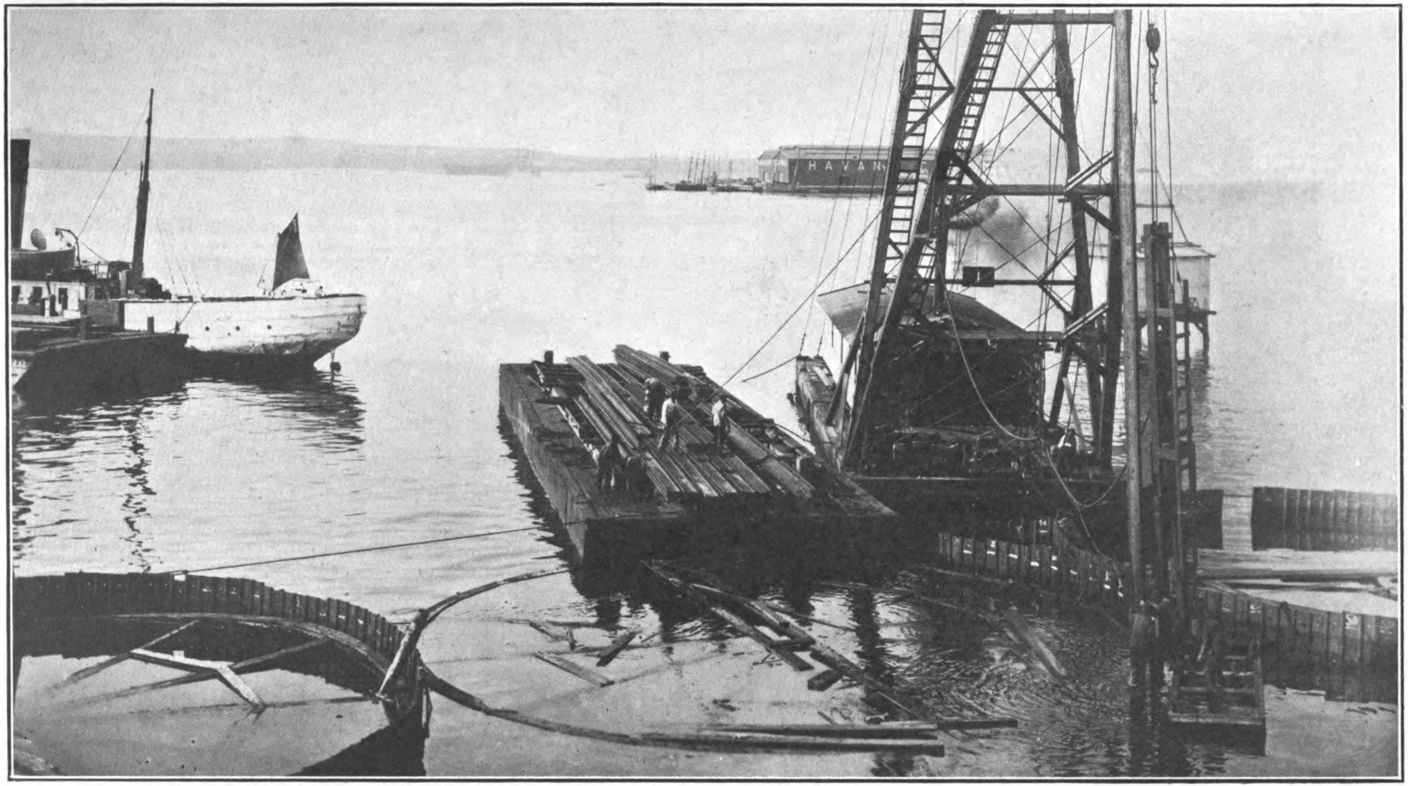


PLATE 15.—STARTING A CYLINDER.

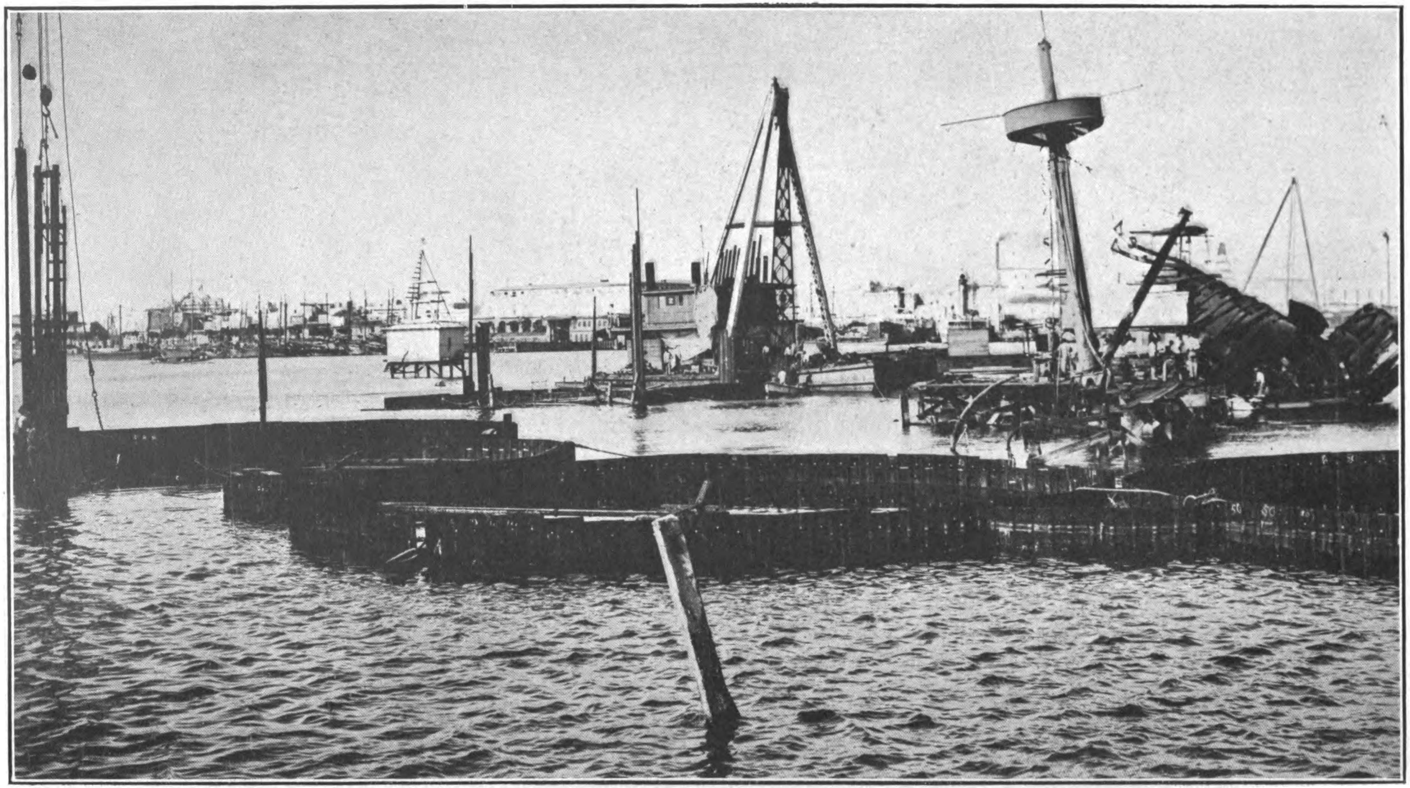


PLATE 16.—COMPLETING A CYLINDER.

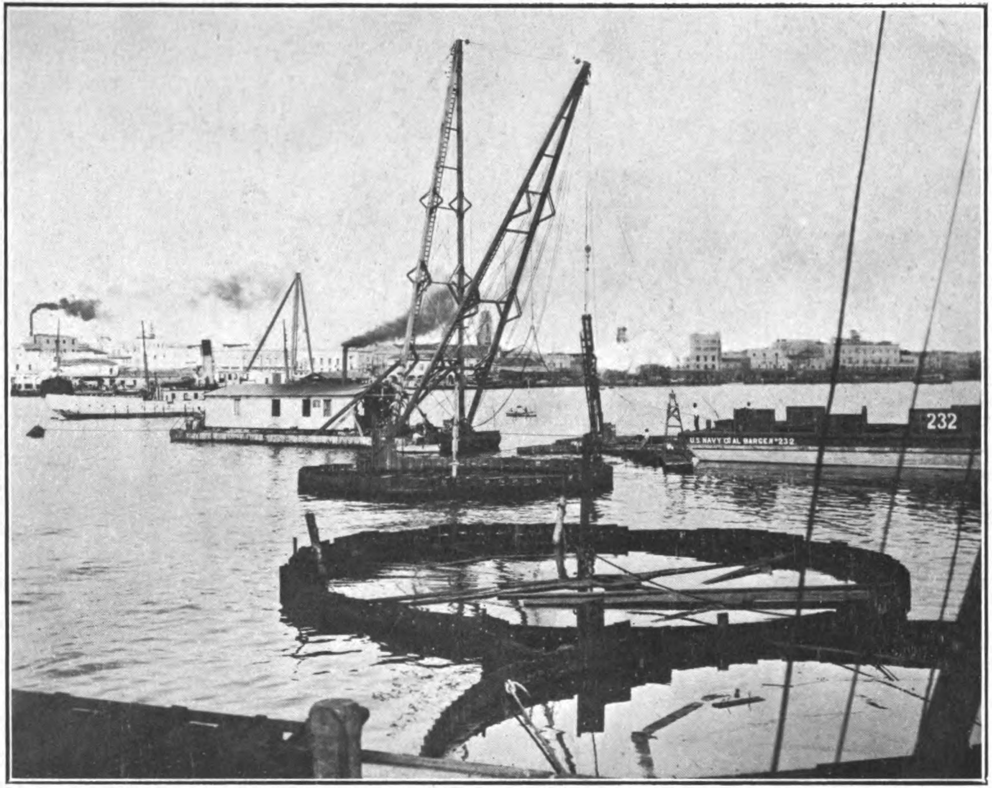


PLATE 17.—COMPLETED CYLINDERS, SHOWING PILE DRIVER NO. 1.

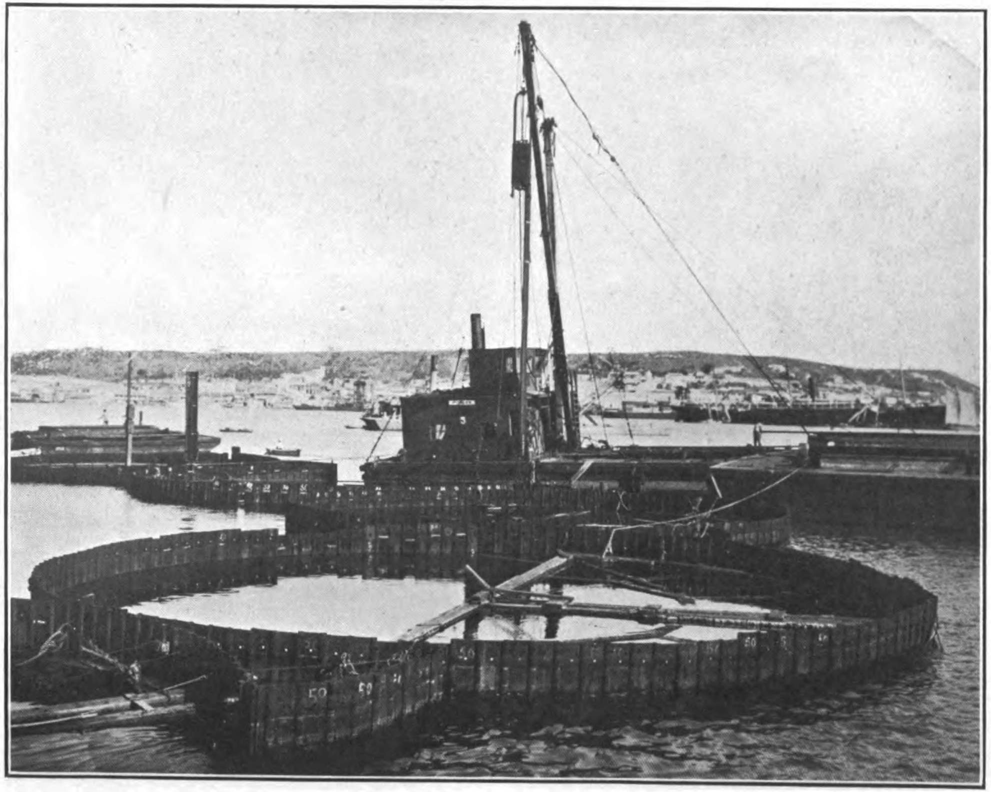


PLATE 18.—COMPLETED CYLINDERS, SHOWING PILE DRIVER NO. 5 AND FALSE LEADS.

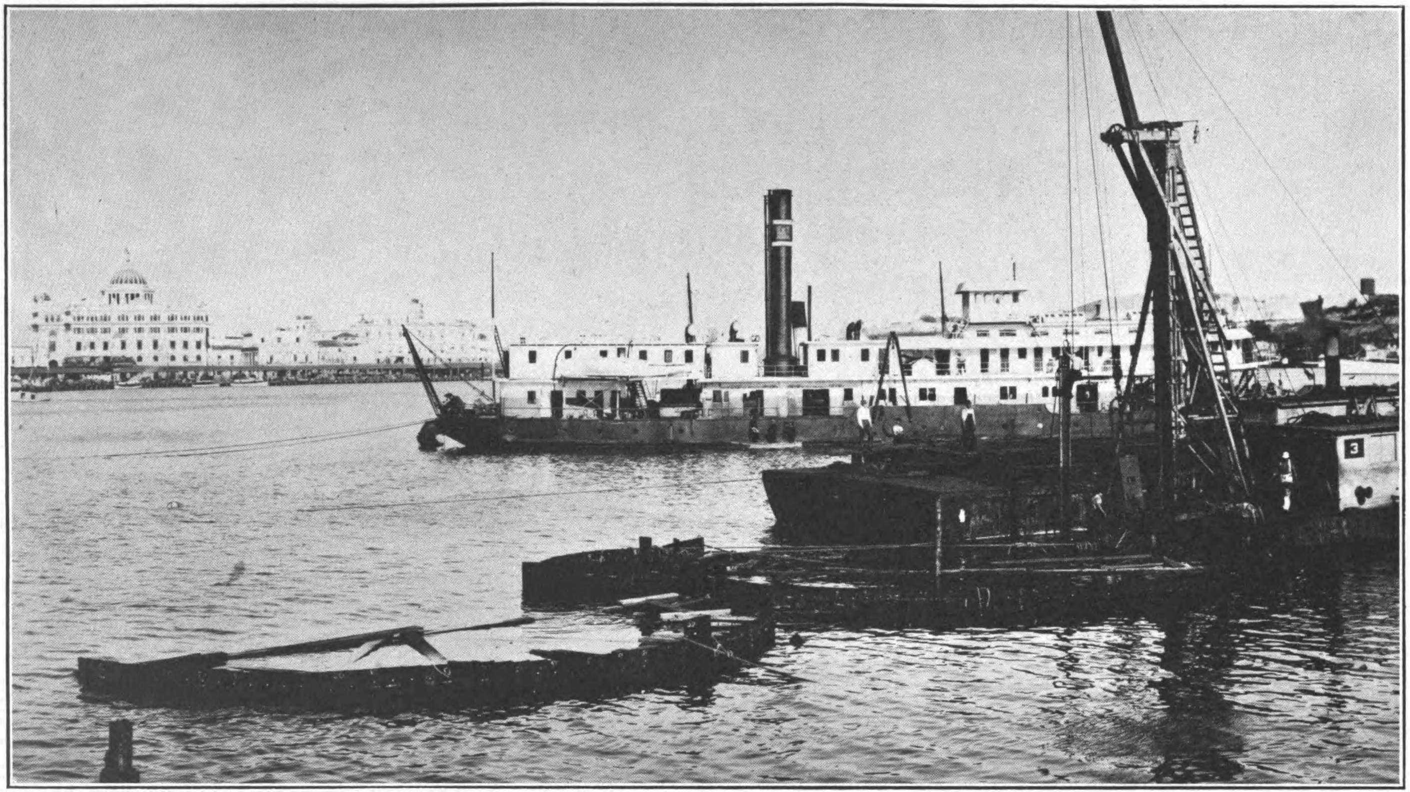


PLATE 19.—CYLINDERS UNDER CONSTRUCTION, DREDGE "BARNARD" IN BACKGROUND.

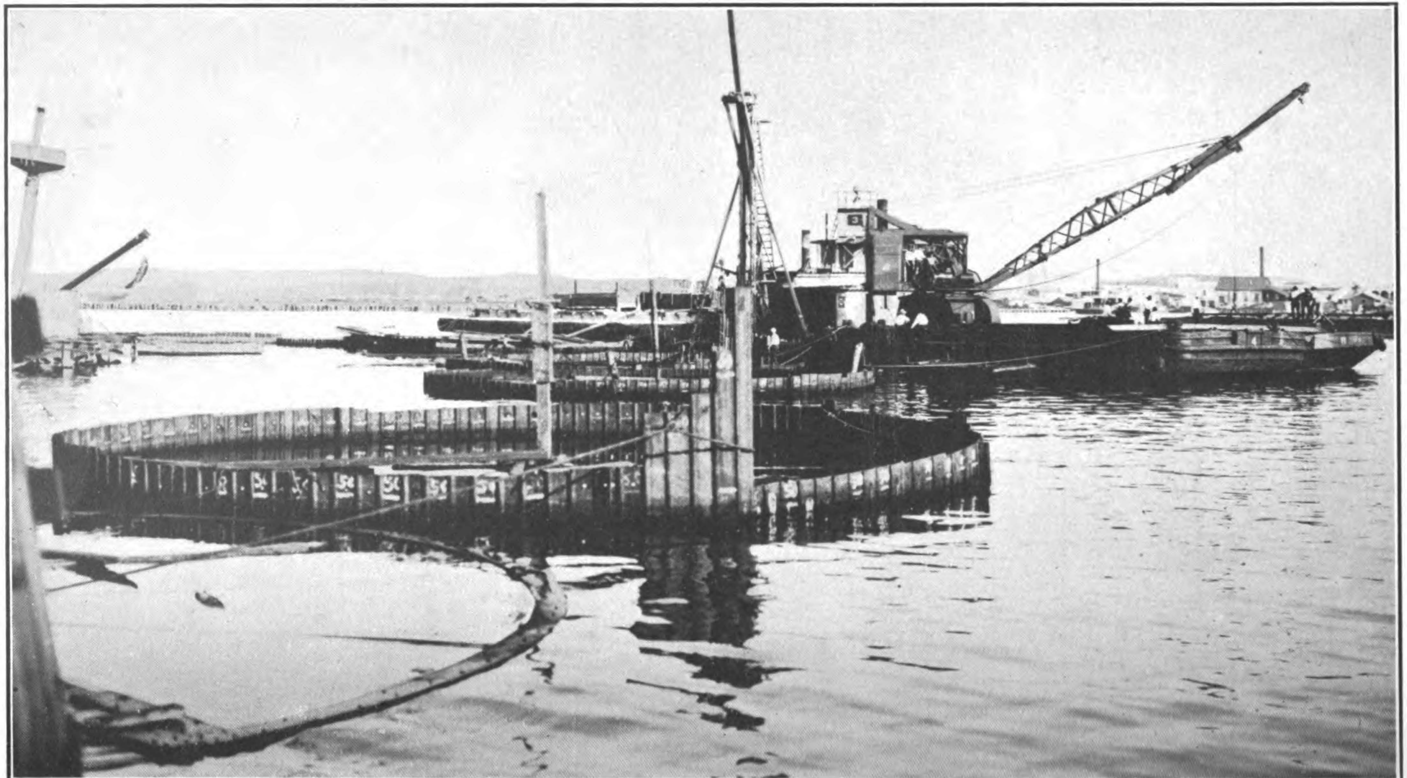


PLATE 20.—CYLINDERS UNDER CONSTRUCTION, NAVY DERRICK IN BACKGROUND.

25. The total cost of the construction of the shell of the cofferdam, excluding the cost of the steel piling, but including the cost of all other material, of all labor, subsistence, superintendence, and incidentals, amounted to about $41 per driven steel pile. The total cost of the completed cofferdam, including superintendence, incidentals, the cost of all labor, subsistence, of all materials, and of the filling and of the repairs to the two cylinders which burst (see pars. 32, 33), amounted to $330,500, or for the whole dam, 1,020 feet in length, measured along the oval drawn through the centers of the component cylinders, $324 per running foot, or about $6 per square foot of the area inclosed by the same oval.

FILLING THE CYLINDERS.

26. Within a few hundred feet of the site of the cofferdam there was a shoal which was found to be composed of a very tough, hard, heavy clay, and it was decided to use this material for filling the cylinders. The Cuban Government dredge *Sagua* was fitted for using a 7-yard clamshell or a 5-yard dipper. A trial showed that the clamshell could not dredge the hard clay. The dipper was tried and did but little better. This dredge was constantly breaking down and was found to be unable to finish the filling in any reasonable length of time. The interruptions due to breakdowns were many. The average output was scarcely more than 350 cubic yards per day of eight hours. At least 70,000 cubic yards were needed for the filling, and it was apparent that a more efficient dredge had to be secured. No suitable dipper or clamshell dredge could be hired in Cuba, nor was it possible to obtain one from the United States except at a price which was so excessive that it had to be rejected. A new 20-inch suction dredge, the *Norman H. Davis*, had just been delivered to its purchasers in Habana Harbor, and after a trial it was found that this dredge could excavate the stiff clay from the shoal above mentioned at a fair rate.

27. Under the circumstances, it was decided that the filling must be done by this hydraulic dredge. The dredge was hired and worked for a gross total of 45 days, between March 27 and May 11, 1911. It filled 19 of the 20 cylinders, putting in them about 57,000 cubic yards, and in addition it deposited around the outside of the dam about 24,000 cubic yards. This material was piled around the exterior of the cylinders to the level of about −25, with the design of lessening the tangential strain in the interlocks of the cylinder piles and of consolidating the soft harbor bottom immediately around the cofferdam—incidentally lessening possible leakage. This dredge was hired by the day and the work done by it cost $30,567. As the total amount of earth and banking which it put in place was about 81,000 cubic yards, the cost of dredging was about 40 cents per cubic yard. (Pl. 21.)

28. When forced to its decision to employ the hydraulic method of filling cylinders, the board was aware that the fill thus made would contain much water and that it would take much time to consolidate. The clay was so stiff and heavy it was hoped that it would be delivered by the pump in lumps of quite good size, that these would sink quickly, and that the finer material would spill outside the cylinders. This hope was realized only partially. As the cylinders deformed

somewhat while being filled, it was found necessary to carry the filling up as nearly simultaneously as possible, hence the discharge pipe was shifted from one to another and they were really filled in layers. Some of the finer material of course settled between the layers, and the resulting fill was not homogeneous. The output of the pump was not as lumpy nor did it settle as quickly as had been expected. Nevertheless, a very short time after the filling of any cylinder was completed a man could walk on the surface of the fill without difficulty, and this fill did gradually settle and compact to a considerable degree.

29. Within a week or two after the filling was finished, where a 2-inch pipe was forced down 40 feet through the fill and then withdrawn, although the holes thus made filled up with water, they retained their shape and size, showing that the fill did not flow readily. It was in a somewhat plastic condition, but it was reasonably certain that it was not acting as a liquid.

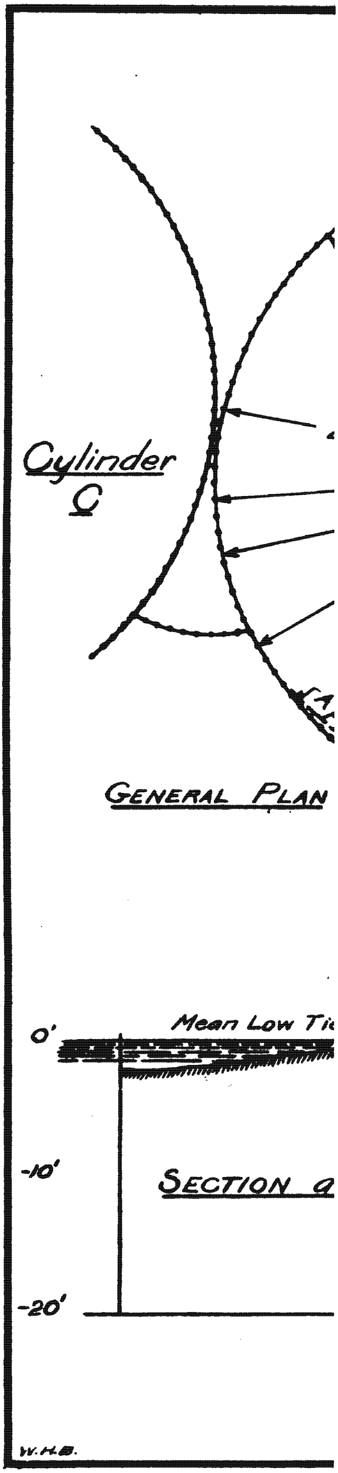
30. It was quite evident that this fill could be dried and made to harden only by draining and that it could be drained only as the water level within the cofferdam was lowered. It was necessary that the drying and hardening should take place, so that there should not be too much deformation of the cylinders under the arching action which must take place when the dam was unwatered. As will be shown later, it was planned to lower the water level within the cofferdam by stages, holding it at each stage until the fill in the cylinders was compacted sufficiently.

31. Much of the subsequent trouble with the cofferdam is attributed to the character of the fill in the cylinders, and to the fact that much of it remained saturated with water and very plastic. This matter will be discussed later.

ACCIDENTS.

32. On March 25, 1911, just after its filling had been completed, cylinder B (see pls. Nos. 7 and 22) burst and a portion of the filling ran out. Investigation showed that the opening out of this cylinder was due to the fact that the interlock on one side of the closing pile had been pulled out in driving. It was known that this pile had been hard to drive and it became apparent that although it fitted the interval between the two adjoining piles at the top, these two piles were not quite parallel to each other and that the play was not sufficient to enable the closing pile to be driven without pulling out its interlock. When this cylinder burst and part of the filling spilled out at the break, a number of the piles on each side of the break were bent and the opening itself became V shaped. It was necessary to pull three piles on one side and eight piles on the other side of the break, and then to complete the cylinder again and fill it. Thirteen piles were used to close the break, one of them being a wedge-shaped special pile, built up on the work. This failure gave a chance to examine the hydraulic fill and it was found that, while a portion had escaped through the opening in the cylinder, that which remained had assumed a slope of about 1 on 1, giving rise to the hope that this fill was really more compact and more solid than might have been expected. (See pl. No. 22.)

PLATE 21.—FILLING CYLINDERS, HYDRAULIC DREDGE "NORMAN H. DAVIS" AND DIPPER DREDGE "SAGUA."



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33. On May 8, 1911, cylinder N likewise burst, just as its filling was being completed (see pls. Nos. 7 and 23), but this failure was from an entirely different cause. A short distance to one side of the closing pile was a pile made of a 40-foot and 35-foot section, the longer of the two on top. This 40-foot section was found to have split through the middle of the web for its entire length. As the thickness of the metal was three-eighths of an inch the tensile strength per linear inch should have been about twice the strength of the interlock per inch, and the failure of the web rather than the interlock plainly indicates that the pile was defective. Subsequent tests showed this to be the case. Plate No. 24 shows a portion of this pile and the location of the split. It was also found that the adjoining pile had failed to enter the interlock of the lower 35-foot section of the pile in which the split occurred, the two sections of this latter pile having apparently twisted enough to make the next pile miss the interlock in its lower section. Cylinder N opened out in the same V shape as had cylinder B, and a portion of the filling escaped through this opening, but, as in cylinder B, the filling that remained within assumed quite a steep slope under water. (See pl. No. 23.) Of course, some piles on each side of the opening were badly bent, and it was necessary to pull 13 on one side and 22 on the other side before starting to rebuild the cylinder. To close the gap, 43 piles were driven. This cylinder was finally again completed on June 5, 1911, and its filling finished immediately thereafter.

34. The normal interval between adjacent cylinders was about 8 inches. A short distance inside of the point where the cylinders were most nearly tangent, a palm pile was driven between each pair. This was fastened at the top to a steel pile on each side. These palm piles were soft and crushed as the cylinders were forced closely together as the dam was unwatered, compressing the filling between them. Piles of harder timber, which would not compress with the filling, would have brought a great strain on the interlocks of the steel piles in immediate contact with them, and the rupture of the interlocks might have followed. The space bounded by the adjacent cylinders, the palm pile, and the connecting arc was filled in part with stone and clay rammed in place, the remainder of the filling being clay similar to that used in filling the cylinders themselves. The efficacy of the method of filling this space between the cylinders will be discussed under the head of "Leakage."

PRESSURE GAUGES.

35. In order to obtain a record of the pressure exerted by the fill in the cylinders at various depths, pressure gauges (see pl. No. 25) were attached to certain piles in cylinders F, G, and M at depths as follows: In cylinder F, 2 on a wooden pile near pile No. 53, at elevations −30 and −40 feet, 2 on a wooden pile near piles Nos. 133 and 134, at elevations of −30 and −40 feet, and 1 on a wooden pile outside the cylinder near pile No. 133, at elevation −40 feet. In cylinder G, 2 on the drain box at elevations −20 and −40 feet. In cylinder M, 4 on pile No. 113, at elevations −20, −30, −40, and −50 feet. All but two of these gauges were torn loose from the piles, presumably when the piles were drawn, and lost, the means of attaching them to the piles being too weak. In those recovered it was found that

electrolytic action had taken place between the steel of the punch and the recording cylinder, a deposit from the metal of the punch having been made on the disk. Assuming that the record had been made before the punch had been injured, the pressures required to duplicate the holes were measured. The gauges recovered were two of those in cylinder M. Pile 113 in this cylinder was one of the outer cylinder elements. To duplicate the holes in the recording disks, pressures of 3,500 pounds and 7,250 pounds were required. The cylinder piston heads had an area of one-half square foot, and an initial pressure of 730 pounds and 410 pounds, respectively, had to be applied to overcome the friction of the piston on the cylinders. The pressures apparently recorded were then $(3,500+730)\times2=8,460$ pounds and $(7,250+410)\times2=15,320$ pounds per square foot, respectively, for the depths of 20 and 30 feet. These pressures are so great that it must be concluded either that the record is wrong or that the pressures confirm the statement made by Mr. E. P. Goodrich in his paper on Lateral Earth Pressures (Trans. Am. Soc., C. E., Vol. VIII, p. 303): "In moist earths the first large application of pressure is likely to produce a permanent set which exerts excessive lateral thrusts at low repetitions of pressure." Such low repetitions could have been made by the movements made in the fill of cylinder M, as elsewhere mentioned, and by the load of stones, wreckage, etc., later placed in the cylinder.

UNWATERING.

36. With the completion of filling of cylinder N on June 5, 1911, after its rebuilding as above, the cofferdam was considered finished and ready for beginning the unwatering. For pumping out the water there had been purchased two electrically driven centrifugal pumps, one 8 and one 12 inch. These were installed on floats within the dam and were to discharge across it, the discharge pipes being so arranged that they would permit the pumps to descend on their floats as they lowered the water level. The capacity of these pumps was 1,800 gallons and 4,200 gallons per minute, respectively, when running at 1,200 revolutions per minute against a 65-foot head.

37. The first pumping was done on June 2, 1911, for the purpose of testing the pump, before the rebuilding of cylinder N had been quite completed, the water within the dam being lowered about 1 foot. Regular pumping began on June 5, using only the 8-inch pump. (See pl. 26.) The water level was lowered from −0.75 to −2.45 in 7 hours, and the leakage was sufficient at that time to raise this water level about 0.03 foot per hour when the pump was stopped. The level was further reduced to −5 feet on June 6 in 12½ hours, net time. (See pl. 27.) It was planned to lower the level inside of the dam in successive stages of about 5 feet, holding it at each level until the fill in the cylinders could be drained and dried out. It was also decided to remove the filling from the inner half of each cylinder and pile this material on top of that in the outer half. This was done for two reasons. It was expected that the fill would settle somewhat as it drained and dried, and the additional material piled on the outer half would compensate somewhat for the shrinkage, and its removal from the inner half would have the effect of lessening

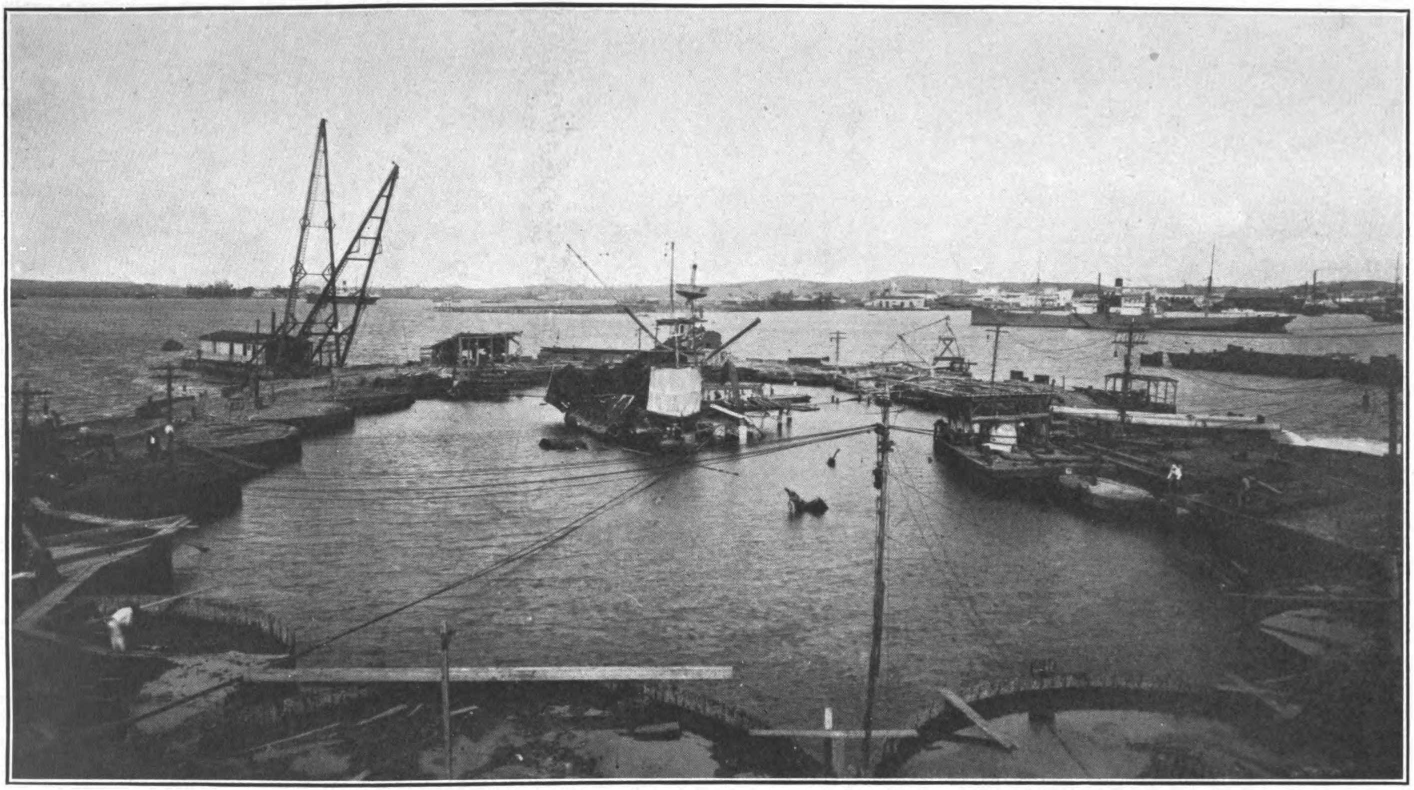


PLATE 26.—GENERAL VIEW OF COMPLETED COFFER DAM, PUMPING JUST STARTED.

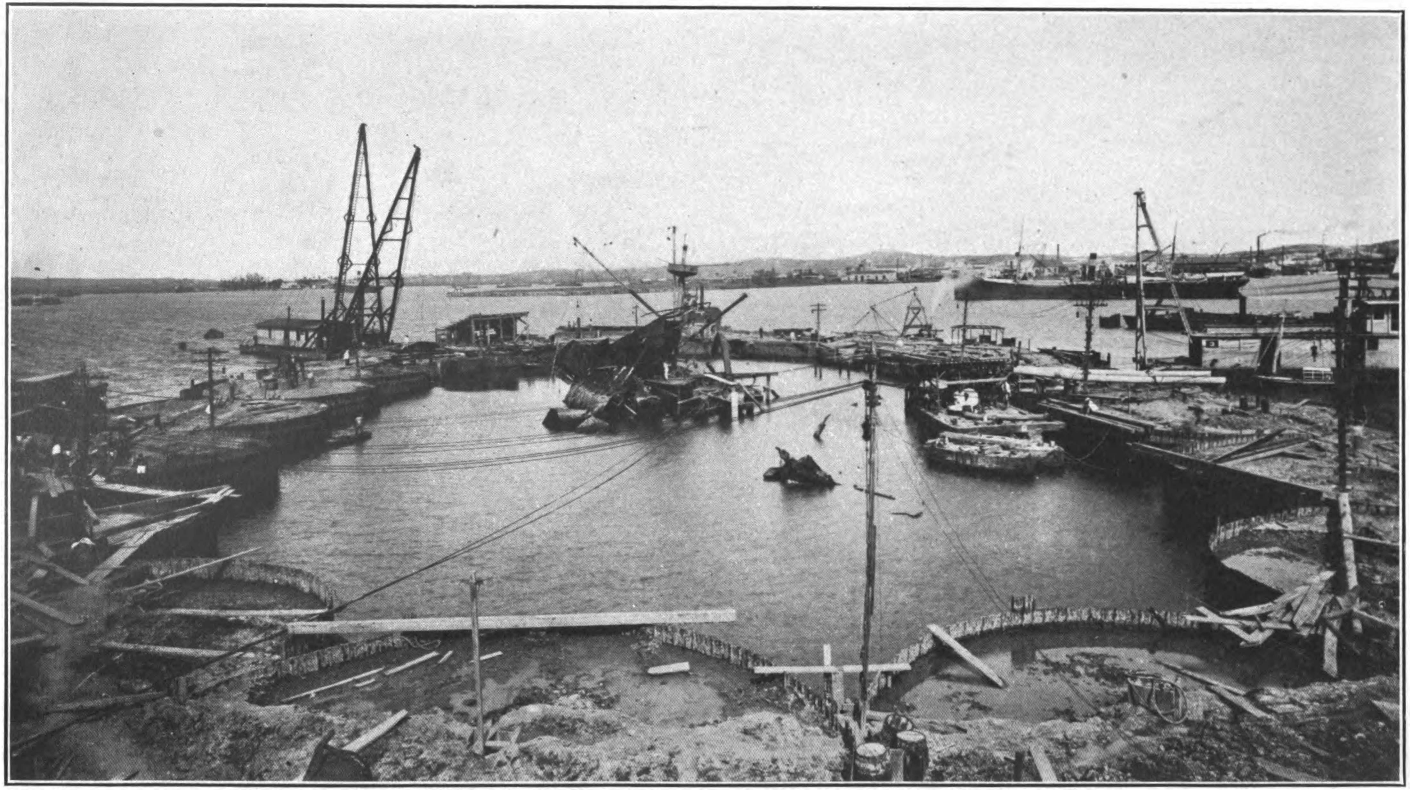
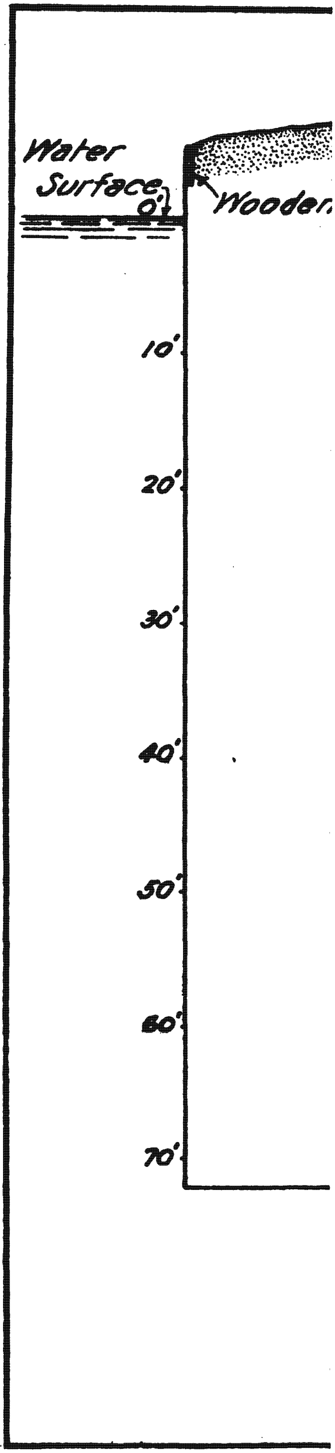


PLATE 27.—GENERAL VIEW. WATER LEVEL IN DAM —5 FEET.



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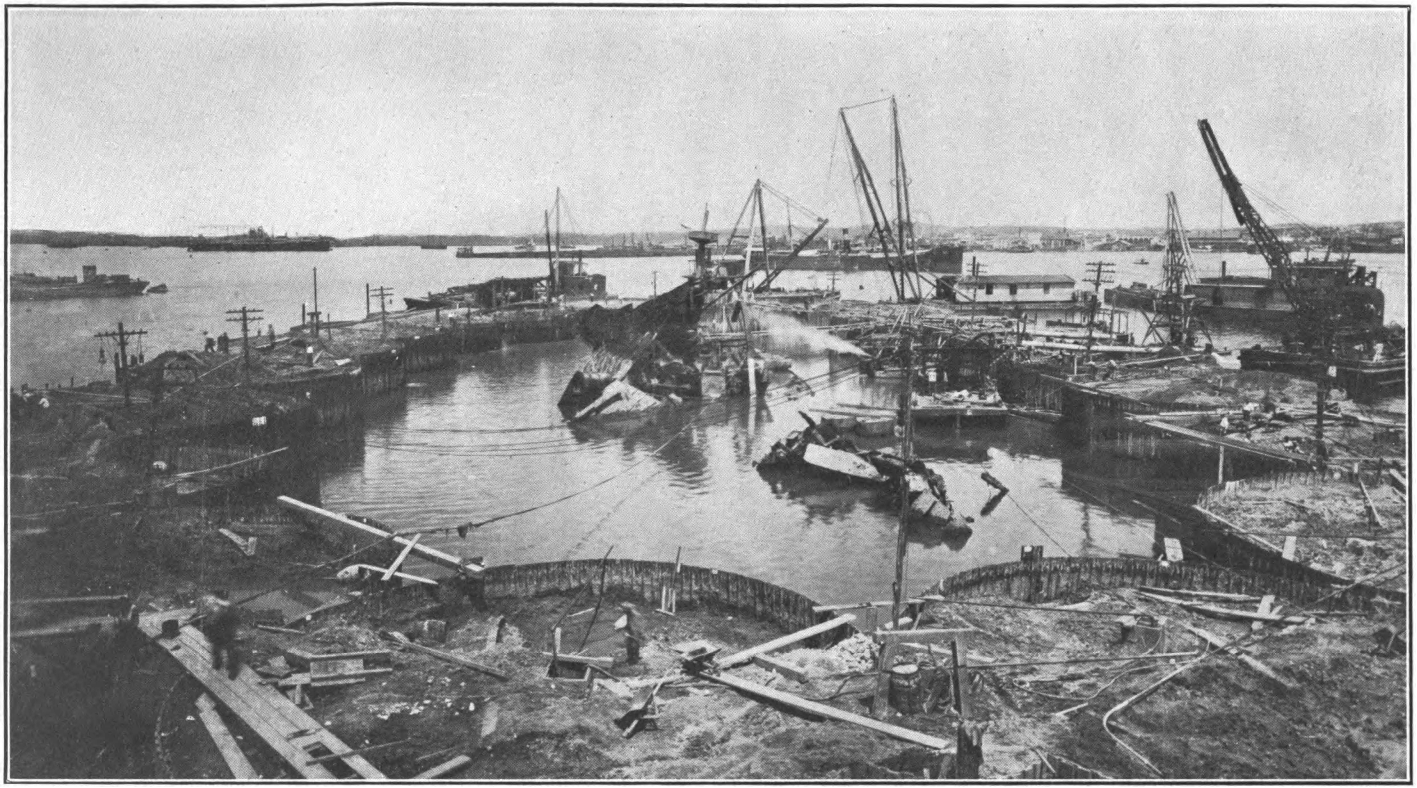


PLATE 29.—GENERAL VIEW JUNE 16, 1911. WATER LEVEL, −10 FEET.

PLATE 30.—BOW WRECKAGE JUNE 16, 1911. WATER LEVEL —10 FEET.

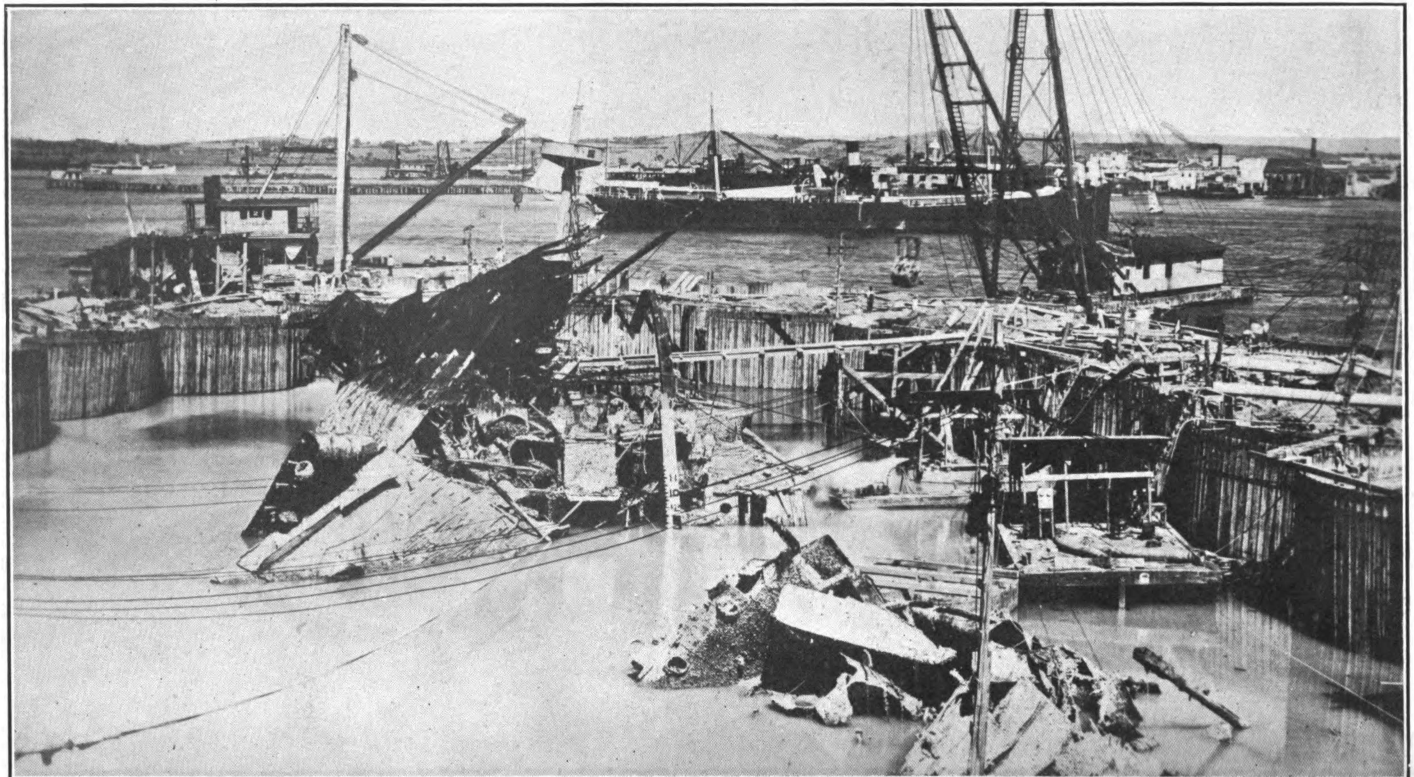


PLATE 31.—GENERAL VIEW JUNE 21, 1911. WATER LEVEL —15 FEET.

the bursting pressure on the inner parts of the cylinders from which the opposing water pressure would be removed as the dam was unwatered. Plate No. 28 shows the extent to which this filling was shifted. The expected settlement of the fill took place. No movement of the cylinders and no deformation was noted with the water inside of the dam at about −5 feet, where it was held for 9 days, or until June 15. By the next day it had been lowered to −10 feet, and it was again further lowered to −15 feet on June 20. (See pls. 29, 30, and 31.)

MOVEMENT OF CYLINDERS.

38. Careful measurements had been made across the tops of all cylinders along two diameters at right angles to each other. Beginning on June 17, measurements were also taken between the cylinders on opposite sides of the dam. It then became apparent that there was a gradual inward movement of the tops of all the cylinders. This movement was not uniform, no two cylinders showing the same amount of movement, while, as was to be expected, the cylinders on the sides of the dam moved considerably more than those at the ends. The water level was maintained at the elevation of −15 feet for about 2 days with the hope that this movement would cease, and the cylinders all come to rest, but at the end of this period the movement was still continuing, and the maximum movement from June 17, when the first measurement had been taken, was found to be that between cylinder F and its opposite cylinder P, the two tops having come in a combined total of 32 inches.

39. It was then decided that the stability of the dam must be increased, and that this could be done by putting considerable quantities of stone along the inner circumferences of the cylinders; that is, a stone toe inside the dam. The water level inside the dam was allowed to come up by June 22 to between −10 and −12 feet, and was held at about that elevation while the stone was being put in place. After about 4,200 cubic yards of stone had been dumped inside of the dam it was further unwatered to about −16 feet on July 8.

40. In order to determine the amount of the inward movement of the tops of the cylinders for each cylinder, a wire was attached to a convenient place on the wreck and run over a pulley attached to a post bolted to one of the steel piles along the inner circumference of the cylinder. A weight was fastened to the end of the wire, and at a suitable height the wire carried a pointer which moved along the surface of a planed board as the cylinder top moved in or out. The movement, as shown by the pointer, was recorded in a notebook and plotted on cross-section paper. These telltales furnished a valuable record, and made it possible to determine which of the cylinders was moving at the most rapid rate, and to regulate the placing of the stone toe accordingly. This work was continued steadily, the greatest amounts of stone being placed along the north and south sides, and the least at the east end. At the west end there was placed a large amount of stone and clay obtained from a contractor who was dredging a near-by shoal to improve Habana Harbor. In addition to the stone placed inside the dam, as much stone as possible was piled up on the fill in the outer half of each cylinder for the pur-

pose of further compacting this fill and of adding to the stability by the greater weight of stone. The total amount of stone placed in the toe and on the cylinders was 14,900 cubic yards. As a check upon the telltales the cross measurements with steel tape between opposite cylinders were continued. Plate No. 32 shows the results of these measurements for certain typical cylinders.

41. This plate shows distinctly the prompt increase in the rate of movement of the tops of the cylinders when the water level was lowered from about −16 feet on the 17th of July to about −20 feet, and then to about −22 feet by July 28. (Ordinary high tides increased the difference between the level of the water inside and outside the dam by about 1.5 feet.) This plate also shows that after a short time the rate of movement decreased appreciably, and then continued to be quite uniform. Further discussion of this movement is made later in this report. By August 5 the maximum movement inward since July 5 had been that of cylinder E, amounting to 49¾ inches. It was then decided that this movement could not be allowed to continue longer unchecked, and that some means must be employed to bring the cylinders to rest. While deciding what should be done, the level of the water inside the dam was allowed to rise gradually to about −15 feet, and the effect is shown plainly on the plate. Plate No. 33 shows the appearance of the wreckage with the water at −22.

BRACING.

42. The possible necessity for using some form of bracing in the interior of the cofferdam had been recognized by the board from the beginning. The inward movement of the cylinder tops showed that the flexibility of the cofferdam walls was greater than had been anticipated. There was no evidence of overturning, and no certainty that a limit of flexibility would not be attained and the inward movement of the tops then cease. On the other hand, no risks could be run. It was therefore decided to put in place braces which would stop the inward movement of the cylinders and permit unwatering and excavation to the necessary depth. Plates 33 and 34 show the location of the wreckage as exposed to view or found by borings in the mud. It was essential that the system of bracing adopted should be one which would offer a minimum of impediment to the removal of this wreckage. Around the after, intact portion of the ship such bracing presented no great difficulties. Bracing across the forward, destroyed portion of the wreck was not such an easy matter. Cylinders G and O, opposite each other, seemed to be the most critical ones. Their movement had been no greater than some of the others, but its character and their positions in the dam indicated that it was imperative to place a strong brace between them. The distance to be spanned by such a brace was approximately 143 feet. Fortunately soundings disclosed two places about on the line of this brace and about 50 feet apart where there was no wreckage and where piles could be driven down to clay.

43. The general plan of the bracing actually put in place is shown on plate No. 35, and on plate No. 36 is shown the O–G brace in plan and elevation. No bracing was provided for the cylinders at the bow end; their stability had been reenforced by the large quantity of earth and stone dumped against them on the inside of the dam. In order

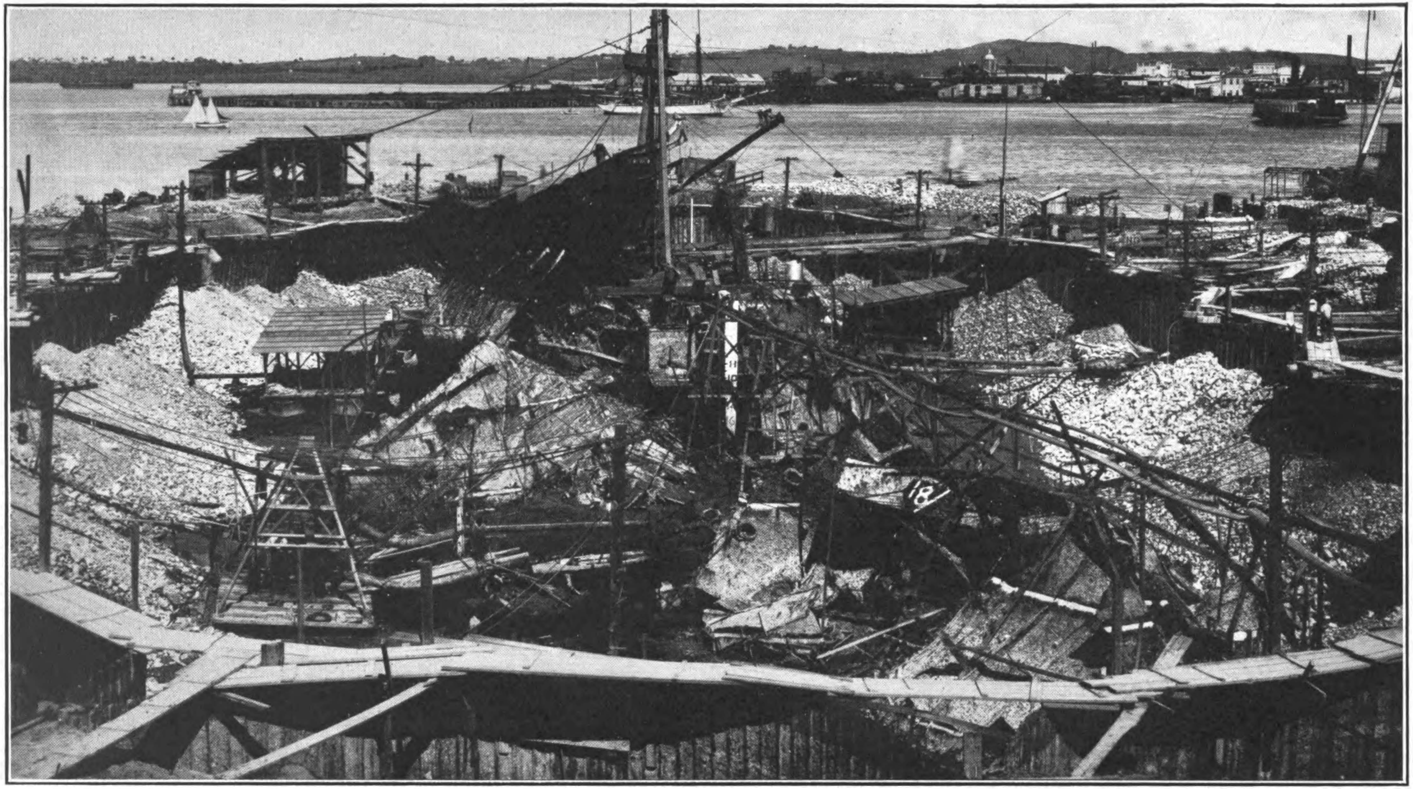


PLATE 33.—GENERAL VIEW OF WORK AUGUST 2, 1911. WATER LEVEL —22 FEET.

to avoid the concentration of the pressure on a few piles in each cylinder, a mass of concrete, a 1–3–6 mixture, was placed in front of each, as shown on plate 36. In front of O and of G there were placed about 60 cubic yards, and a less amount (10 yards being the least) in front of the other cylinders. Holes were left in this concrete so that it might be broken up by explosives later when it was desired to remove it. These masses of concrete had a bearing varying from about 100 to about 200 square feet against each cylinder, and the lengths along the vertical edges of each mass next the cylinder were from 5 to 9 feet, depending on the load to be carried. The minimum bearing area was based on a limiting pressure of about 3,000 pounds per square foot to be transmitted through the piles to the somewhat soft filling in the cylinders. It was expected that there might be some deformation of the cylinders along the edges of the concrete, and careful observations were made to detect such as did occur. None were noted until November 10, when the piles close to the concrete on the bow side of cylinder S were found to have moved outward slightly. Soon after a similar slight movement was noted in all the cylinders supported by struts, and later in those at the bow end of the dam where the support was merely earth and stone. None of these deformations were serious; few of them could be detected without measuring; they did not increase, and subsequently caused no anxiety.

44. The bracing between cylinders G and O and between F and P was to be placed with its center line at about El. −15.5, but it was found necessary between F and P to slope the timbers upward so that the ends at the wreck would pass over the armor belt. The upward thrust resulting therefrom was cared for by vertical tie-rods secured to the ship. In proportioning the sizes for the G to O bracing, which was to carry the heaviest strains, allowance was made for removing the mud to El. −40, and for the pressure from all tide effect from El. 0.0 to El. +1.5, since observations when the cylinders were carrying a head of 20 feet had showed that little or no inward movement took place until the tide had risen above zero. Computations on this basis showed a probable total pressure of 620,000 pounds per cylinder, and to carry this a cross section of ten 12 by 12 inch timbers was required, giving a strain per square inch of about 420 pounds and a factor of safety of 8 to 10. This moderate value was taken so as to provide against the uncertainties of movements and of pressures. However, as 12 by 12 inch timbers of suitable length could not be obtained in Habana, different sizes had to be used as indicated on plate 36. Views of the G–O brace at different stages of the work are given in plates 38, 39, 40, 41, and 42.

45. Between cylinders F and P it was assumed that most of the mud would be left in place, and accordingly timbers were provided to support about one-half of the load provided for between G and O. Much of this mud, however, ultimately had to be removed, and the strain carried by the pieces became in consequence very heavy, especially as there developed a slight movement sideways in cylinder F, and later a forward movement of the wreck. The timber from F on the side next the stern bowed upward 5 inches and compressed the head sill from a thickness of 8 inches to a thickness of 4 inches, and after a service of about three months the combined movements of the mud, the ship, and the cylinders had warped the timbers of this brace until they were of no more use.

46. With the remaining cylinders, where bracing was used, a pressure of 300,000 pounds per cylinder was assumed, as had been done with F and P, since the mud in front of them would not be removed. To carry this, five 12 by 12 inch timbers, or an equivalent section, were provided at each point, and the pieces were butted against the side of the ship, on the port side at the level of the main deck and on the starboard side at the level of the next deck below. As it was impracticable to cut the ends to an exact fit, neat cement was used to fill up any voids, and was found to act satisfactorily in transmitting the heavy pressures.

47. In order to measure the actual pressure upon the G–O brace, four 150-ton hydraulic jacks were put in place, as shown by the plan. To each jack there was attached a pressure gauge, and readings were taken daily of the pressures recorded by the gauges. (See Pl. 39.) The results are shown in plate 43, the maximum recorded being 676,000 pounds, part of which appeared to be due to the movement of the adjoining cylinder N.

48. A 50-ton hydraulic jack and gauge were placed in the bracing of cylinder D and the readings of the gauge recorded. The maximum reading of this gauge was 12 tons, and as there were six struts in this brace, assuming that each strut carried the same load, the total maximum pressure on this brace was 72 tons. Judging by the compression in the headstick, however, this brace for some reason carried a much less strain than did those of the adjoining cylinders, and therefore the recorded pressure probably does not fairly represent the general conditions. The first brace completed was that for cylinder S on September 21, and the last ones were those between F and P and between G and O, completed on October 24 and 27, respectively. (See pls. 44, 45, and 46.) After the braces were in position the level of the water and mud inside was lowered as rapidly as possible and the entire bottom and sides of the destroyed portion of the wreck were eventually laid bare. (See pls. 38, 44, 46, 47, 48, 49, 50, 51, 52, and 53.)

49. Where the ratio of width of side to total length of brace did not exceed 1 to 25, there was found to be no objectionable tendency to bending or sagging. Thus 12 by 12 inch timbers 25 feet long remained practically straight under all the pressures carried. As the removal of the mud and wreckage progressed, and began to affect some of the supports of the timbers, it was found necessary to put in wedging, tie rods, side struts, etc., at occasional points to care for the secondary stresses developed. Those used for the G–O brace are indicated on the plan and shown on plates 38, 40, 41, and 42.

50. The concrete abutments at G and O also settled vertically in spite of their pile supports, and it became necessary on two occasions to release the jacks and level up the timbers. This could be done safely, as the cylinders moved very slowly. On the first occasion the pressure was released entirely for two days and partially for three days more, and the inward movements of the cylinder tops during that time were only 1⅝ inches for G and 3¼ inches for O. Toward the end of the work, however, when it became necessary to remove the bracing, the cylinders appeared to have lost some of their rigidity. Thus, when the brace from Q to the wreck was

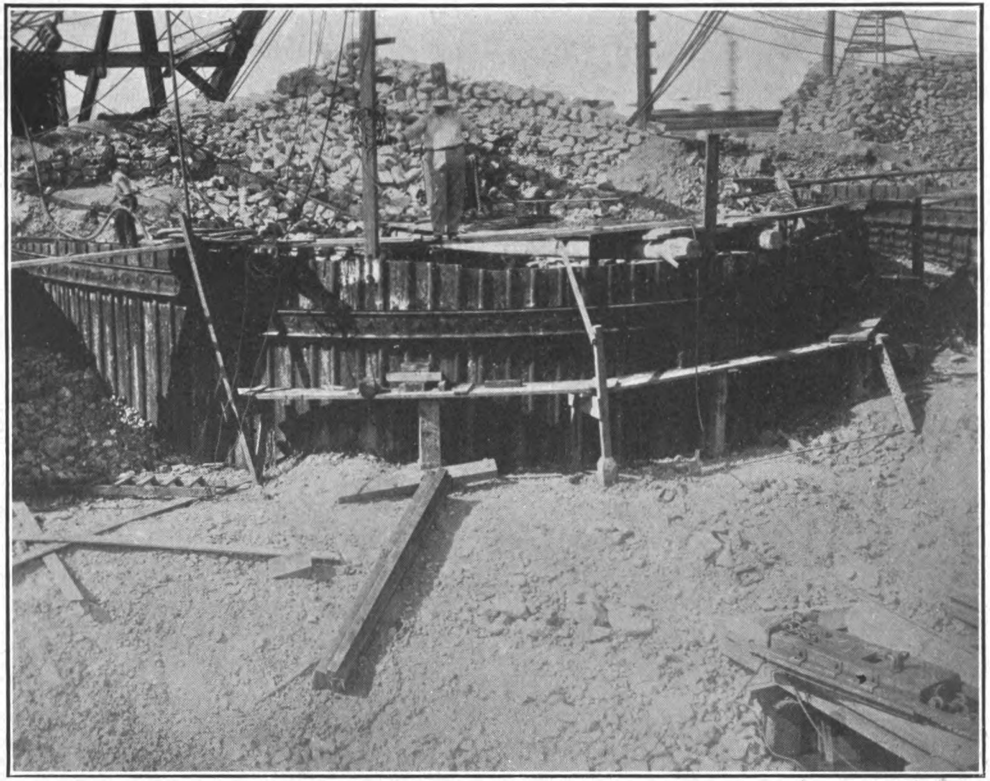


PLATE 37.—CYLINDER G, SHOWING BAND ON TOP AND FIRST PILE SUPPORT FOR BRACE G-O, SEPTEMBER 6, 1911.

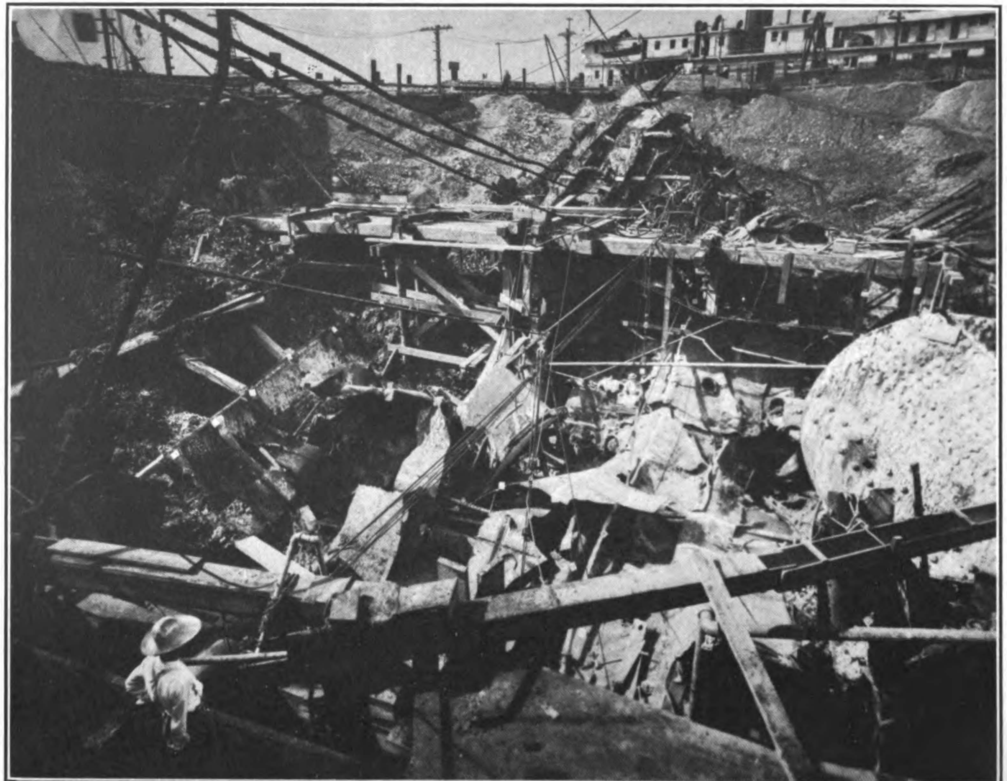


PLATE 38.—GENERAL VIEW OF WRECKAGE FORWARD OF FRAME 41 NOVEMBER 5, 1911. LINE OF KEEL MARKED IN WHITE.

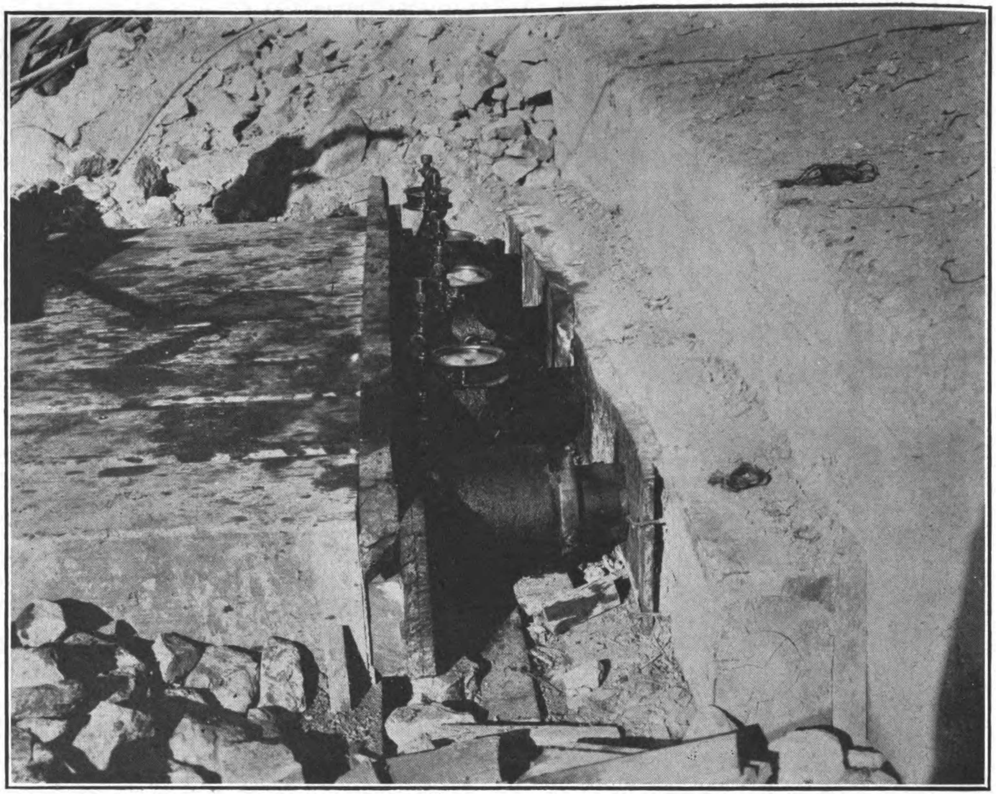


PLATE 39.—HYDRAULIC JACKS FOR RECORDING PRESSURE ON G-O BRACE.

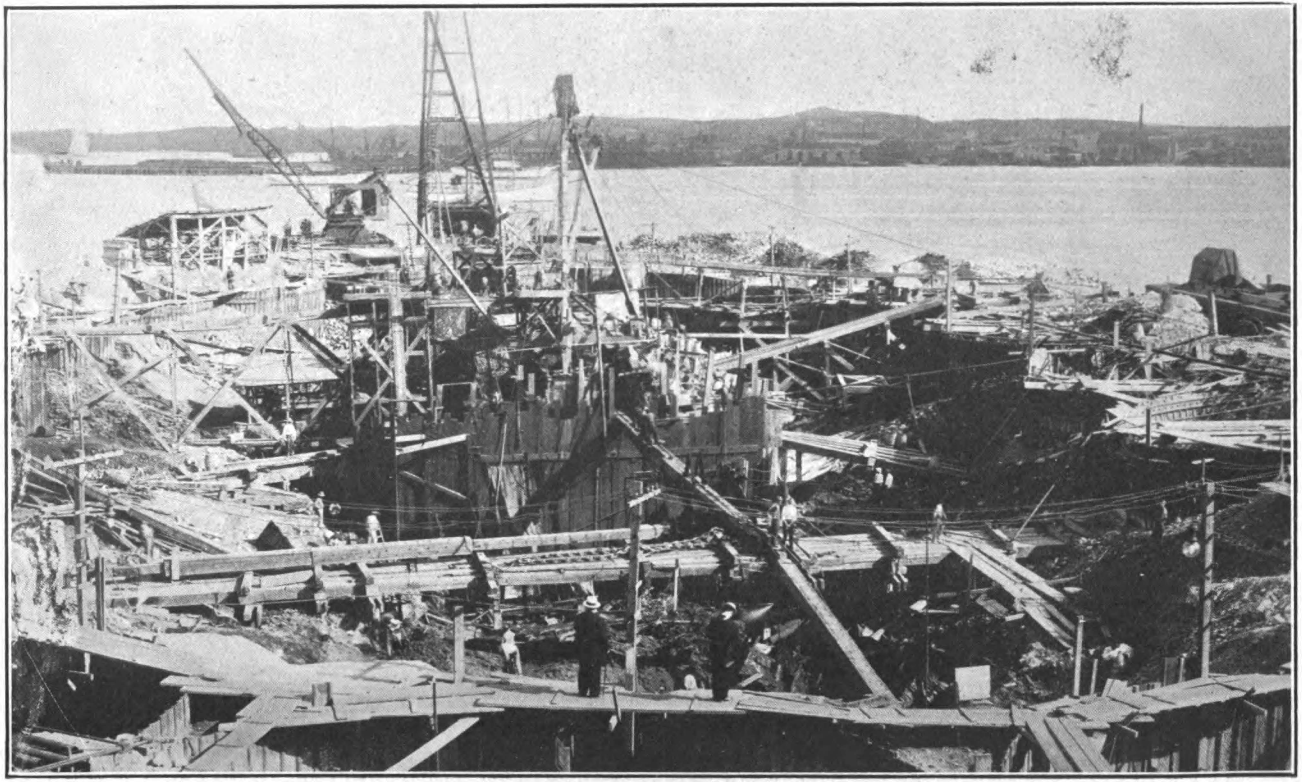


PLATE 40.—GENERAL VIEW OF WORK JANUARY 12, 1912.

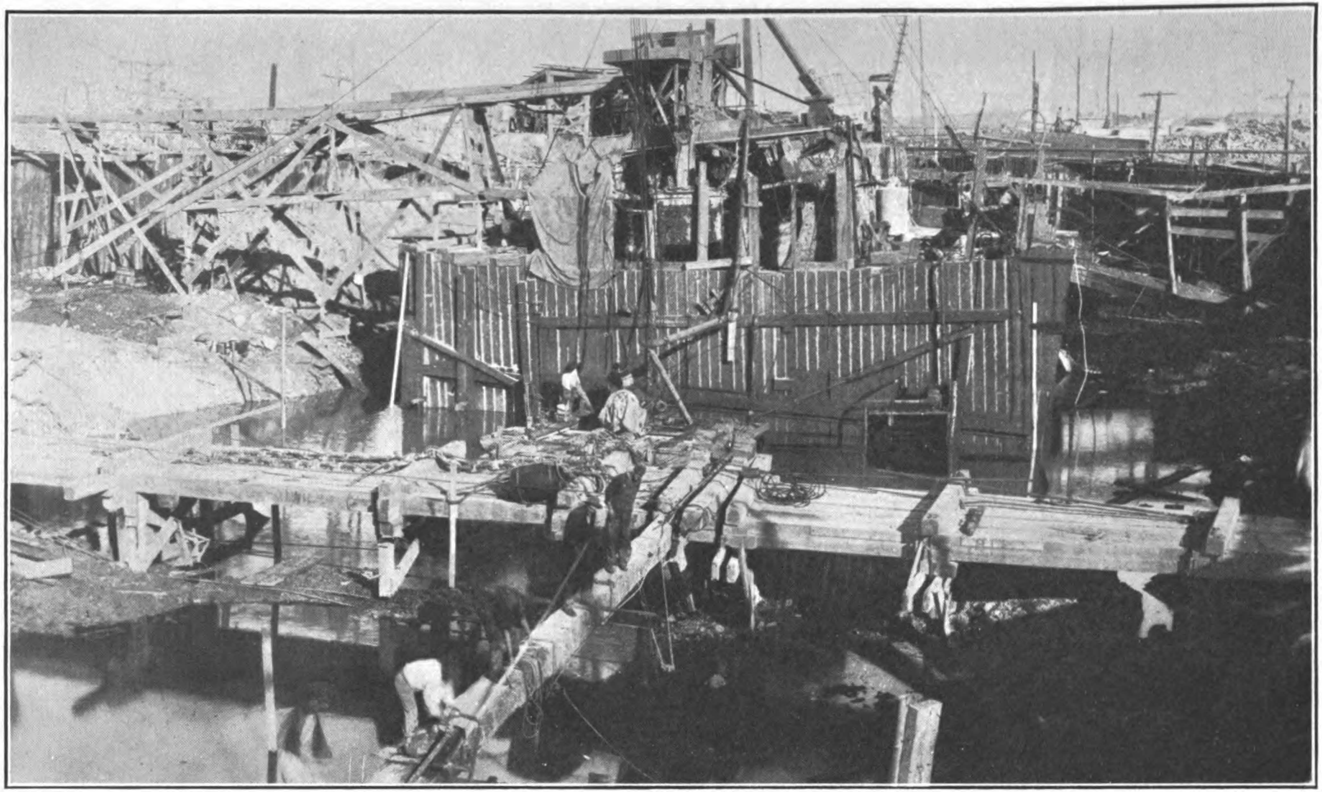


PLATE 41.—BRACE G-O AND BULKHEAD AT FRAME 41 FEBRUARY 11, 1912.

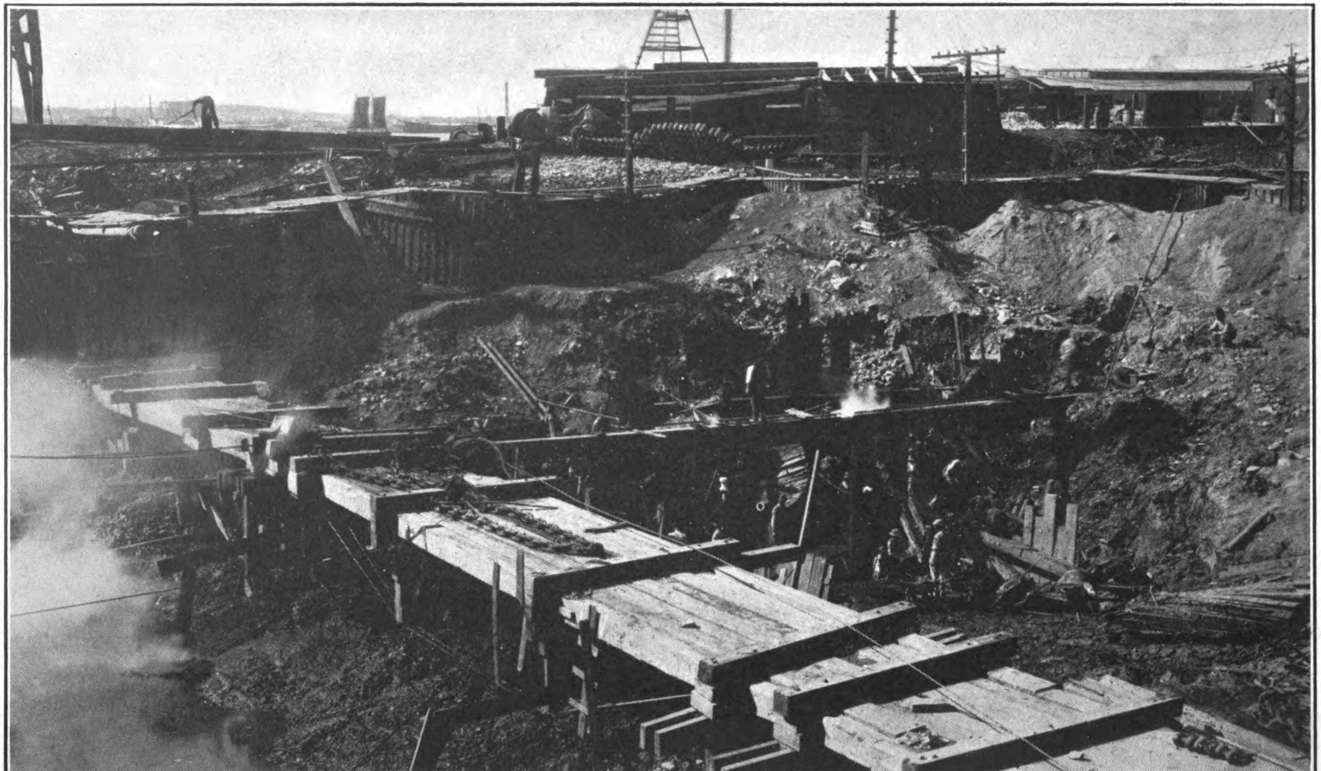


PLATE 42.—G-O BRACE AND FORWARD WRECKAGE FEBRUARY 10, 1912.

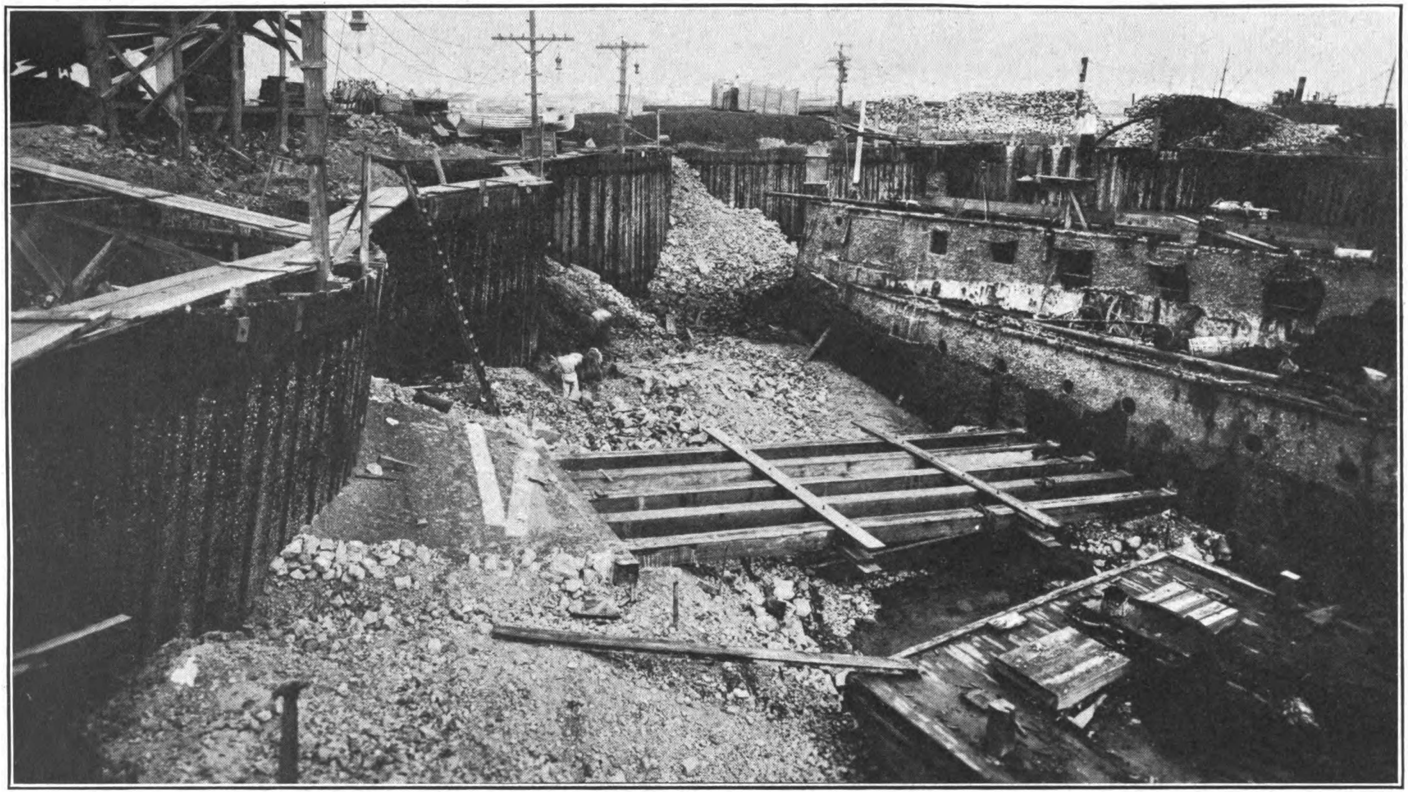


PLATE 44.—BRACE FROM CYLINDER Q TO WRECK SEPTEMBER 23, 1911.

PLATE 45.—BRACE END AT CYLINDER Q, DECEMBER 20, 1911.

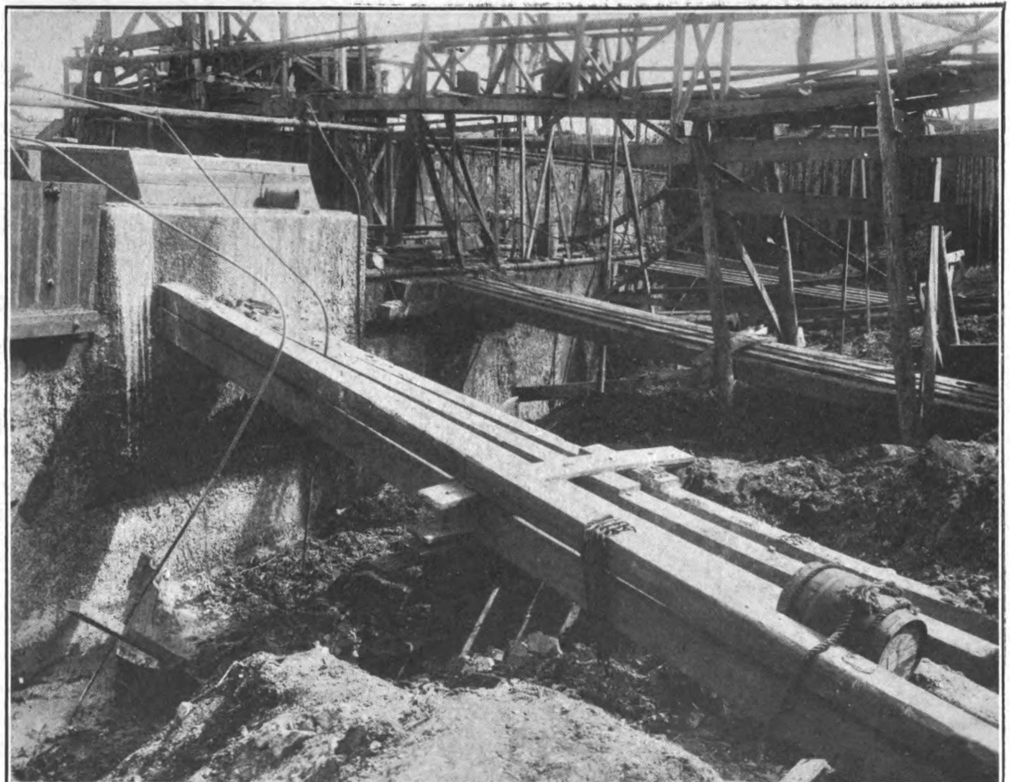


PLATE 46.—BRACES ALONG AFTER PORT SIDE OF "MAINE" FEBRUARY 10, 1912.

PLATE 47.—STARBOARD SIDE OF WRECK AFT OF FRAME 41, AS FIRST EXPOSED, JUNE 16, 1911. WATER LEVEL –10 FEET.

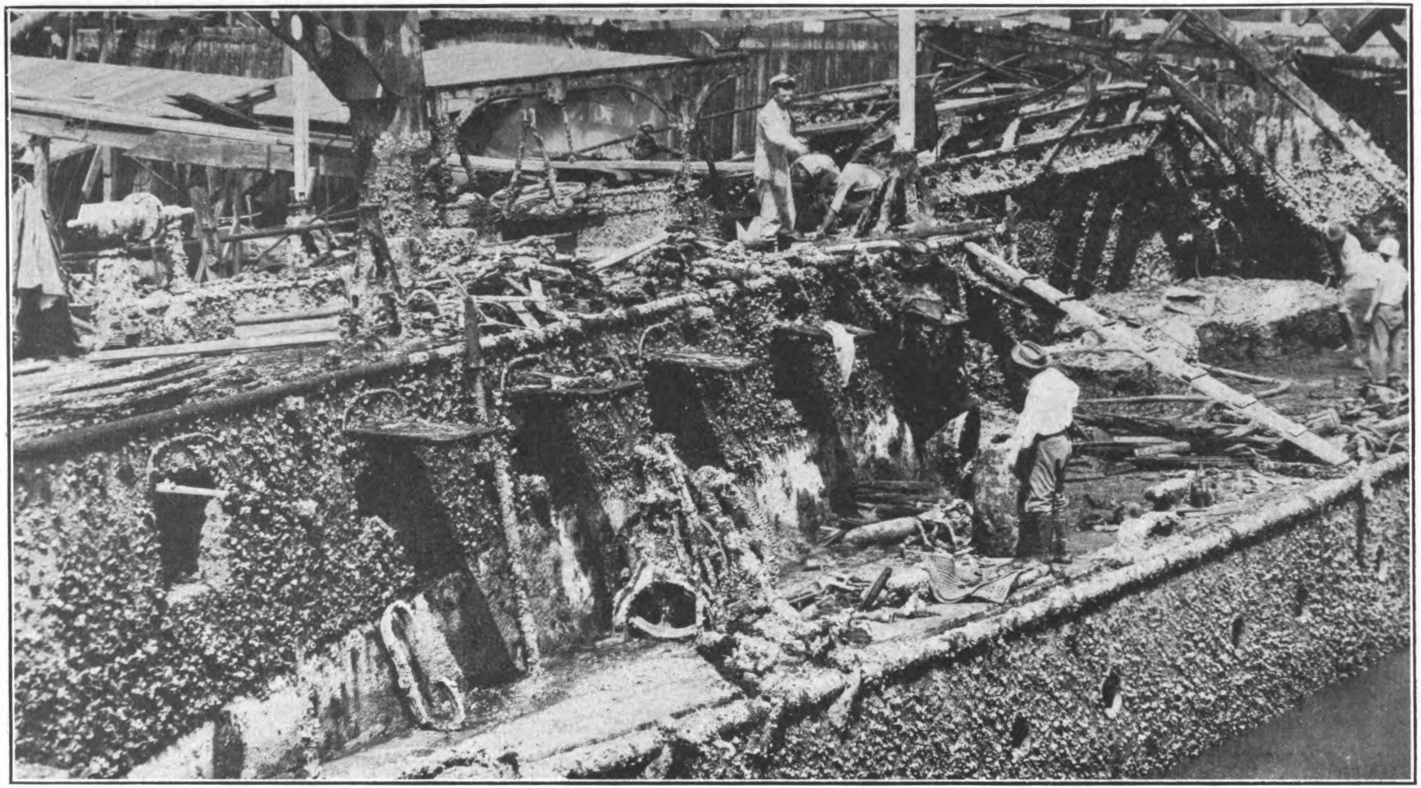


PLATE 48.—STARBOARD SIDE OF WRECK AFT OF FRAME 41 JUNE 21, 1911

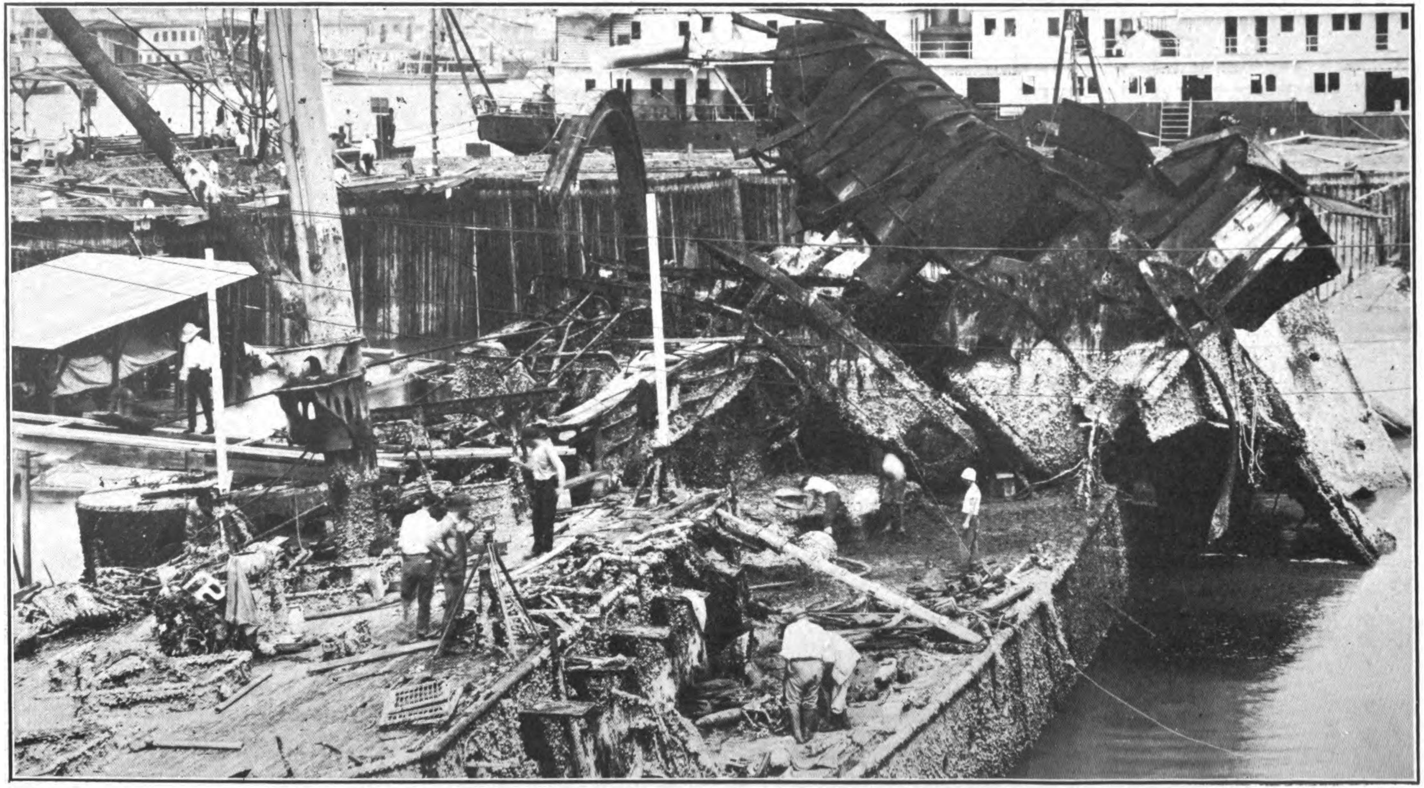


PLATE 49.—STARBOARD SIDE OF WRECK AFT OF FRAME 41 JUNE 21, 1911.

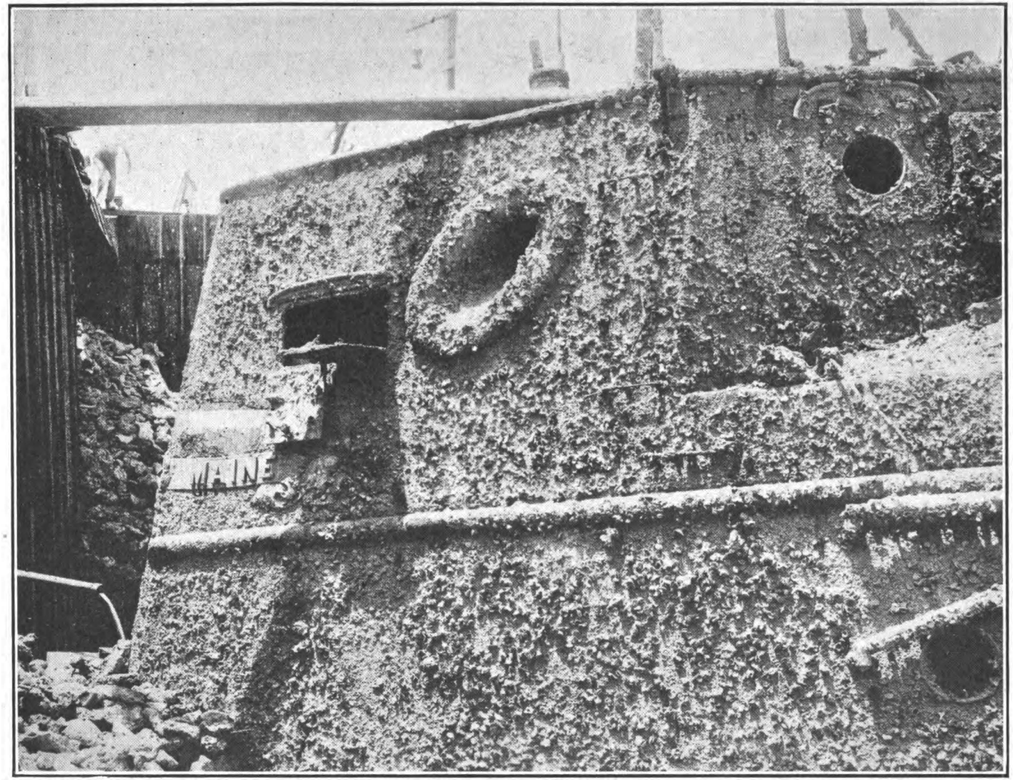


PLATE 50.—STERN OF "MAINE" JULY 23, 1911.

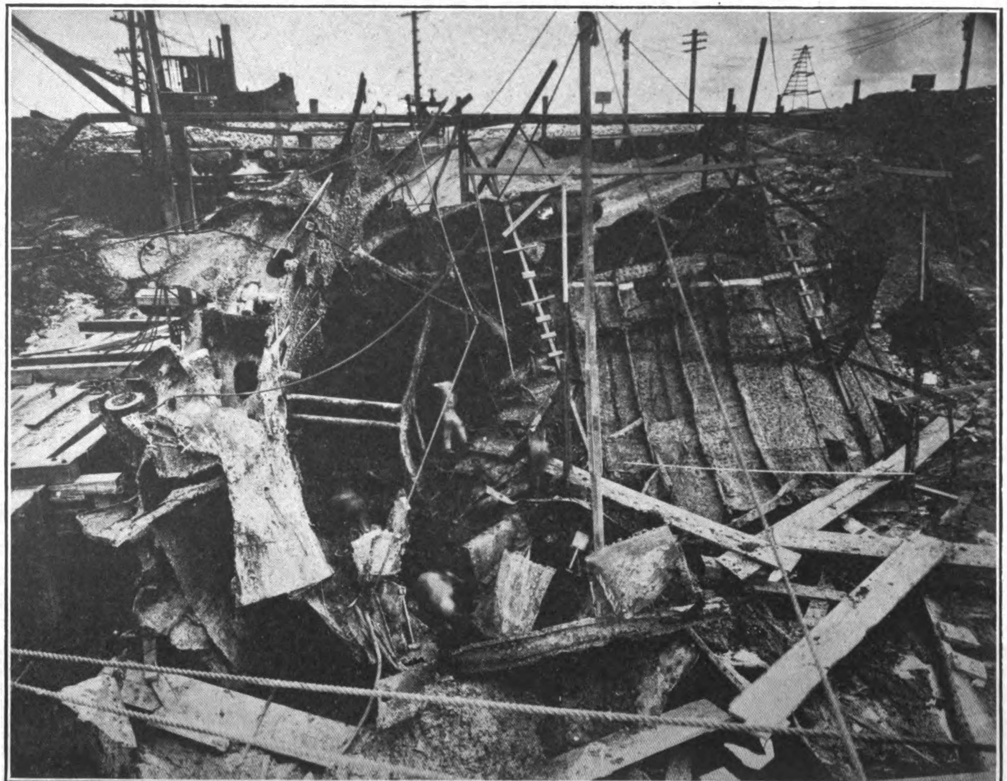


PLATE 51.—WRECKAGE FROM FRAME 18 FORWARD OCTOBER 16, 1911.

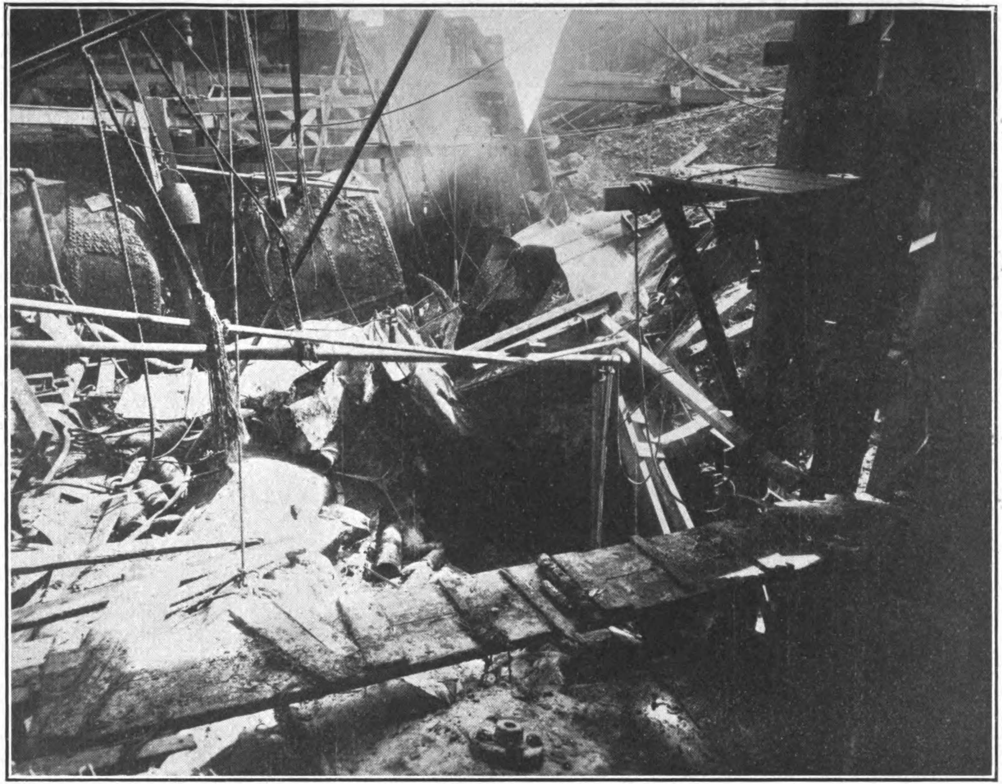


PLATE 52.—WRECKAGE LOOKING AFT FROM FRAME 18 NOVEMBER 3, 1911.

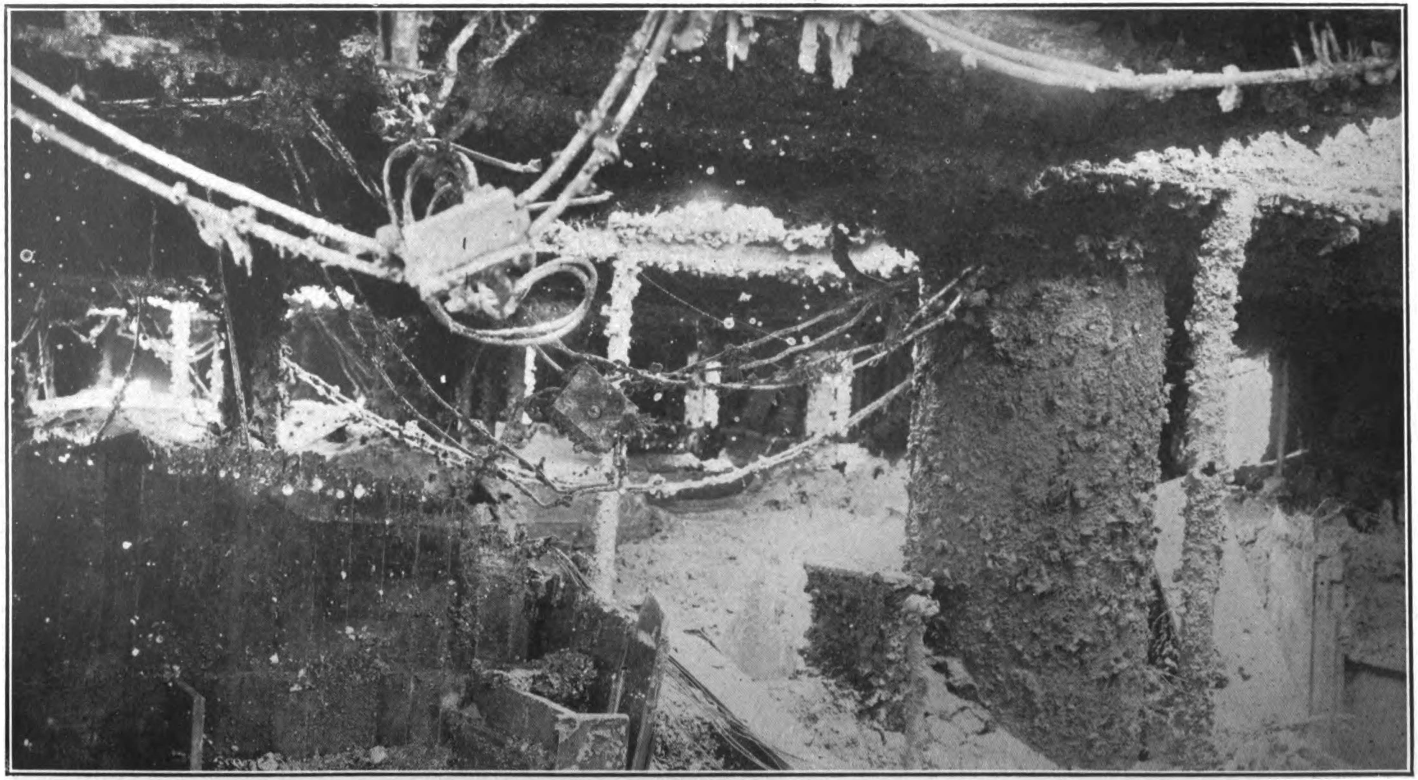


PLATE 53.—INTERIOR OF CAPTAIN'S CABIN JUNE 21, 1911.

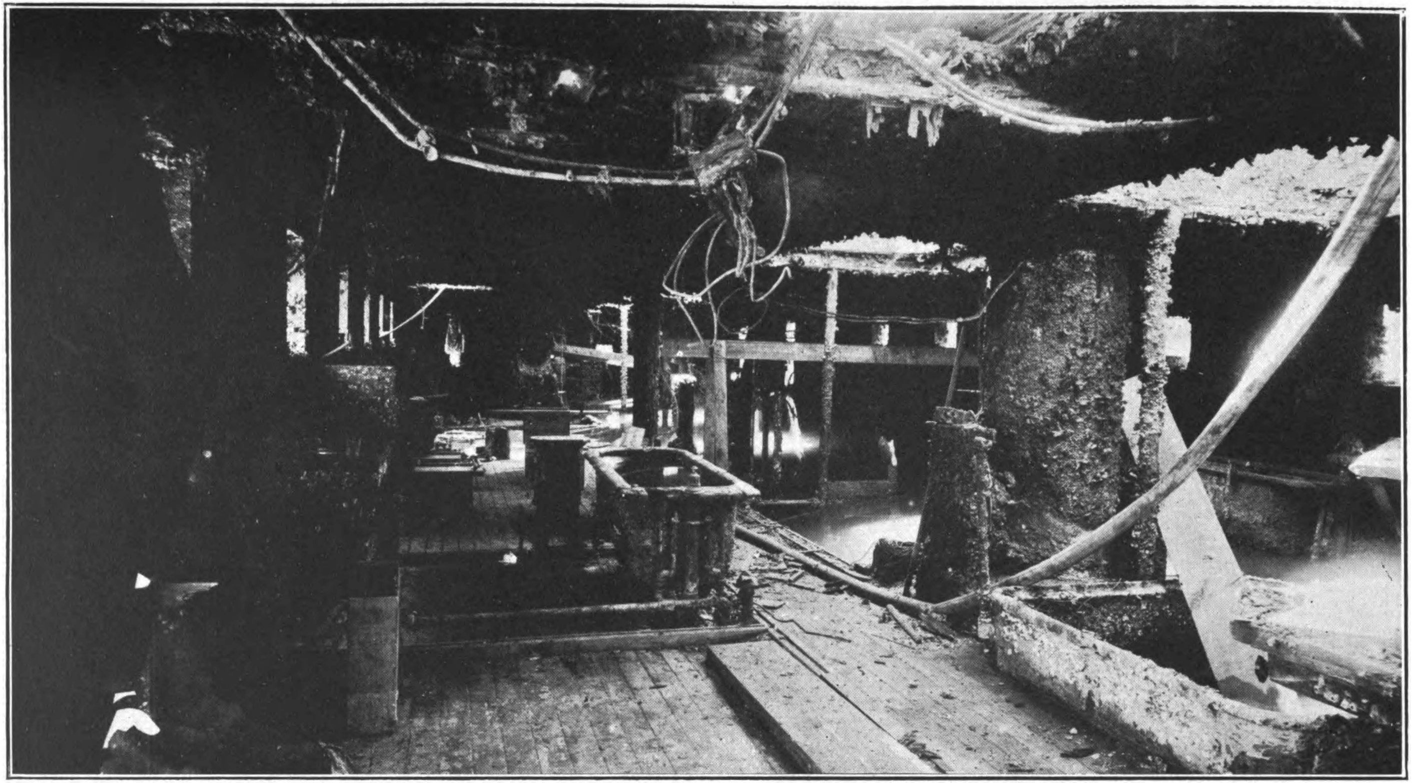


PLATE 54.—INTERIOR OF CAPTAIN'S CABIN, AFTER CLEARING, JUNE 25, 1911

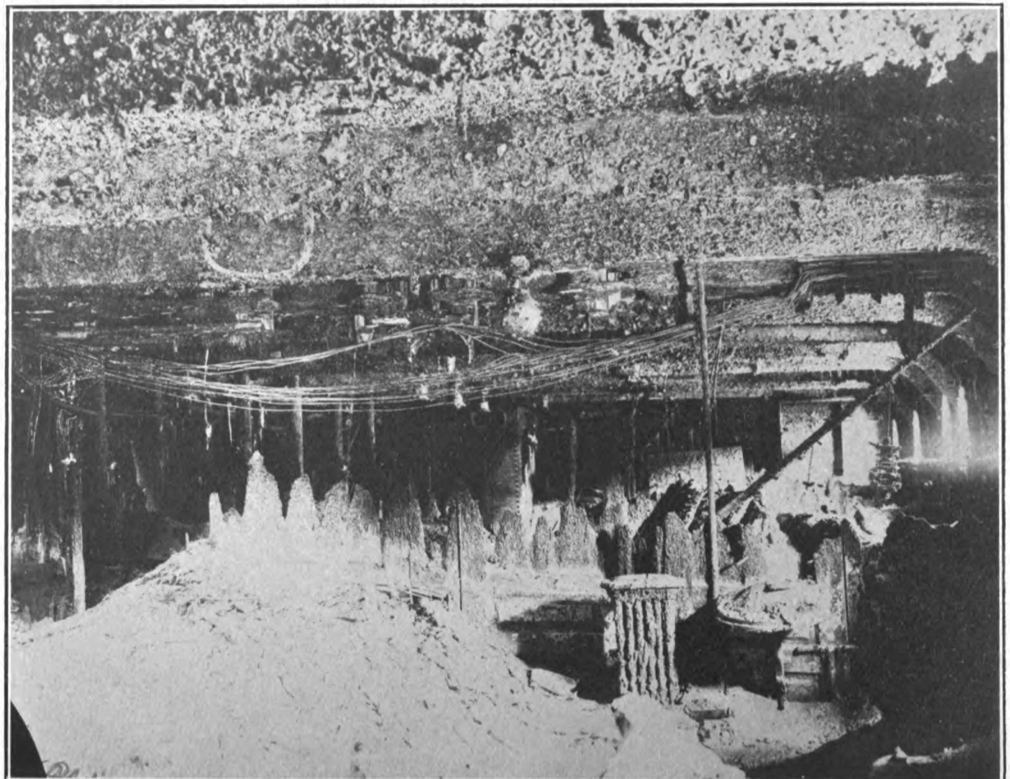


PLATE 55.—INTERIOR OF BERTH DECK, STARBOARD SIDE, LOOKING FORWARD, SHOWING OFFICERS' STATEROOMS AS FIRST EXPOSED.

PLATE 56.—VIEW IN OFFICERS' QUARTERS, BERTH DECK, JULY 23, 1911.

removed, about 12 inches were cut off each timber in order to free it. The removal of this brace was completed, with the exception of one piece which had been thus shortened and which was left in position overnight. By the next morning the cylinder had moved inward sufficiently to bind the ends of this piece, and it had to be shortened again before it could be removed.

REMOVAL OF MUD.

51. At the first unwatering, the mud inside the cofferdam inclosure was found to be practically liquid, and a rod could be pushed into it at any point 8 or 10 feet with little effort. Its general surface at that time averaged about elevation −23, as a large amount of fine material had run into the inclosure during the hydraulic filling of the cylinders, and as its surface had also been forced up by the riprap deposited against the latter inside the dam.

52. Continued pumping lowered the mud level several feet, as this material flowed easily toward the pump, but its surface hardened very slowly in spite of the hot sun and the wind. Later the included water and the leakage which came into the dam found several subsurface channels into the buried wreckage. Additional pumps were installed for its removal from sumps, and in a few weeks the surface mud became hard enough to walk upon. During the subsequent removal of certain portions of the wreckage, about two months after beginning the final unwatering, excavations made in this mud stood with vertical faces several feet in height. This hardening of the mud, while it aided some of the later work, prevented the removal of the mud itself by pumping, as had been intended, and necessitated the employment of other methods. The mud in the intact portion of the ship, all of which was black harbor silt, was found in deposits from 1 to 4 feet in depth over all the decks. (See pls. 47, 53, 55, and 56.) This was removed from the upper decks by shoveling and sluicing into the space between the ship and the cylinders. From the lower decks it was hoisted in buckets and dumped or sluiced outside the cofferdam. Its removal was necessarily slow and costly, partly because of the confined spaces and partly because it was necessary to examine carefully all the material removed, so as to recover the human remains, personal belongings, etc. This examination was made by washing the material through wire screens.

53. The mud above and around the destroyed forward part of the wreck was removed partly by derrick boat and dump boxes, and partly by buckets running on a small improvised cableway. All of it was dumped just outside the cofferdam. Toward the close of the work, when space became available, the mud removed in excavating one portion of the wreckage was disposed of in places where the removal of other wreckage had been finished. It is estimated that the total amount of mud moved inside the cofferdam during the work was about 5,300 cubic yards, including the yardage which had to be rehandled, and the lowest point reached during the excavation was in a trench across the ship under frame 41, the bottom of which was about elevation −50.0. The adjoining excavation sloped upward toward the bow, commencing at about elevation −45.0.

LEAKAGE.

54. Knowing there would be considerable included water in the clay filling of the cylinders, especially after it was decided to place this filling by the hydraulic process, open wells about 3 feet square with wooden sides were placed near the centers of the cylinders, and these are shown on the photographs of the cylinders after filling. (See pls. 21 and 29.) These wells were about 50 feet in depth and holes were bored through their sides. It was hoped that the included water could be drained into these wells and pumped out, thus assisting in draining and drying the filling. Although the water from these wells was pumped out at frequent intervals during the early part of the work, the leakage into the cylinders was so great that it was impracticable to dry out the filling in this manner to any appreciable extent. After being pumped out, the wells invariably filled up slowly, the maximum rise of the water in any well being about 4 feet per hour (in cylinder F) and the minimum about 1 foot per hour (in cylinder J.)

55. In addition to these wells built in the cylinders, 2½-inch pipes with well points, and also some perforated 6-inch pipes were driven into the filling of certain cylinders, about 3 feet from the harbor side, hoping to control the leakage in this manner and thus aid in drying the filling. These pipes likewise did but little good and further attempts to drain and dry the filling in this manner were abandoned.

56. It had been expected that the internal pressure, due to the filling of the cylinders, would tighten the piling in the interlocks and practically close all these joints so that the leakage through them would be very small. This expectation was practically realized. In a short time a dense marine growth covered all the outer surfaces of the piling and the leakage through the interlocks was practically negligible.

57. The leakage which entered the cylinders and prevented the draining of the filling is largely accounted for by the fact that the piling was driven so that the tops were only about 1.5 feet above the ordinary high water. It was impossible to make a tight joint between this piling and the wooden fence placed around the outer circumference of each cylinder as hereinbefore described. The hole made in each steel pile for pulling it was some distance below its top. Abnormal tides and waves caused by the wind and passing boats enabled considerable water to enter the cylinders. In addition, it was found that the driving had displaced a number of the nuts on the joint bolts and that much water probably entered through the bolt holes. Across several of the cylinders there had been placed wooden flumes whose bottoms were about 3 feet below mean low tide. These flumes were intended to permit the filling of the cofferdam in case of emergency and they were supplied with gates at their outer ends. Of course, the steel piling at the flume ends had to be driven down below the water level and to the level of the flume bottom. It was found impracticable to make tight the joints between the flumes and this submerged piling, and considerable leakage found its way into these cylinders underneath and along the flumes.

58. Except in a very few places where some mechanical injury of the interlock had taken place, there was no apparent leakage whatever into the dam through the interlock of the piling along the outer

circumferences of the cylinders. To assist in draining the cylinders, and to concentrate all the leakage into channels across or through the filling, holes were drilled through the piling of the inner surface of the cylinders, through which all leakage water was brought into the dam. It was then drained, piped, or troughed to the sumps, whence it could be pumped out of the dam. Although the leakage into the cylinders was sufficient to keep the filling wet, that which found its way into the dam was remarkably small in quantity. On June 10, 1911, with a 5-foot head outside the dam, when the pump was stopped, the water within the dam rose at a rate of two one-hundredths of a foot per hour, equivalent to a leakage of about three-tenths of a cubic foot per second for the entire dam. On June 16, with a 10-foot head, this rise was only one-tenth of a foot per hour, and as the water level within the dam was taken to lower levels, the leakage remained substantially constant and gave but little trouble. At the worst, all of the leakage into the dam was easily controlled by a 5-inch pump, working intermittently. On January 26, 1912, in the deepest part of the excavation within the dam, the water had been allowed to rise to elevation −37.5 feet. At this time the leakage was measured and was found to be only five-tenths of a cubic foot per second for the entire dam, and of this amount by far the larger portion came from cylinder C, across which one of the emergency flumes had been placed, and through the joints between this flume and the piles. There was practically no leakage whatever between adjacent cylinders. The filling in the arcs and the filling packed between the cylinders acted well and prevented any such leakage.

GENERAL REMARKS.

59. When the dam was first designed, it was expected that there would be some yielding of the component cylinders, but it was hoped that the filling would be stiff enough to make them sufficiently stable and that they would soon reach a condition of equilibrium. That this hope was not more nearly realized, and that the cylinders displayed a great deal more flexibility than had been expected, is attributed to the plasticity of the filling more than to any other one thing, and this condition of the filling material was due, largely, to the necessity for employing the hydraulic process to fill the cylinders.

60. As described earlier in this report, the first indication of this flexibility of the cylinders was a general inward movement of the tops of the cylinders; the next was the slow change from the circular form shown by the X Y measurements (pl. No. 57), due to side pressures from the adjacent cylinders. Later the bracing which held some portions of the several cylinders practically rigid while the other parts of the cylinders were capable of movement, contributed to their still further deformation. In all of the cylinders as they leaned inward, there was observed a slipping or sliding of some of the piles in those portions of the cylinders near the points of tangency where this leaning caused a tendency in the piles to bend edgewise. The amount of this sliding seemed to be about proportional to the amount of such leaning and edgewise bending.

61. It was exceedingly difficult to determine just how this movement of the cylinders was taking place. Soundings were made with a heavy drill rod, provided with a horizontal projecting tooth, to

determine the inclination of the outside piling in those cylinders where the leaning was most pronounced. The maximum depth which could be reached by this sounding rod was about 40 feet and, when plotted, these soundings showed that the slope of this outside piling was practically uniform, while the piling on the inside faces of some of these very cylinders remained nearly vertical as far down as it was exposed to view. (See pls. 40, 44, and 49.) Changes in the form of the cylinders due to side pressures and arching action were anticipated. The actual changes at the tops of the cylinders, as shown by diametric measurements, are given on plate 57. They were fairly uniform, quite gradual, produced no particularly undesirable effects, and but little attention was paid to them beyond keeping a careful record of their amounts. A further distortion or deformation of the tops, after the bracing came into play, was naturally expected, and when this became too pronounced in any cylinder, rods 1 inch to 1½ inches in diameter were placed so as to tie the bulging piles to those on the opposite side where a good support was given by the filling. In cylinders G and O, where the greatest strain was expected, a sloping and semicircular mass of concrete about 3 feet in thickness was placed inside each cylinder, the lower edge being on a level with the strut abutment, the upper edge ending half way across the cylinder, where it abutted against dry filling. In addition to this, pieces of bent steel piling had been placed horizontally around the inner portions of the circumferences, and bolted to each pile with 2-inch bolts. These measures prevented any considerable additional deformation of the tops of these two cylinders. The maximum inward movements of the cylinders occurred along the sides of the dam and were greatest on the south side, where the bottom had been found to be noticeably soft and where the average depth of the soft clay stratum was the greatest. The least inward movement occurred at the ends of the dam, where the arching action was, of course, the greatest. (See pl. No. 58.)

62. Between July 8 and August 30, 1911, the top of cylinder O had moved inward 3 feet 4½ inches. On the latter date both the inner and outer faces appeared to be almost plumb, and the soundings showed that there was a leaning of the outer piling of only 4 inches in 30 feet. Cylinders D and R showed almost identical measurements, their inward movements between the same dates being 4 feet 4 inches at the top while the leaning of their outer piles was 3 feet 10½ inches in 40 feet, and with cylinder T the inward movement of the top had been 2 feet 11½ inches, the lean of the outer piling being 2 feet 8 inches in the same distance of 40 feet. A portion of this apparent inward movement is of course attributable to the elongation of the Y diameters of the cylinders in the distortion of these latter under pressure. (See pl. 58.) When the cofferdam was finally flooded the tops of the inside piles of cylinder G were about 3 feet lower than those of the outer piles, or about 4 feet below their original level. A portion of this difference of top elevation is attributable to the bending of the piling, but to shorten a 75-foot pile 4 feet would require a maximum departure from a straight line of about 10 feet, measured normal to the original pile length. The piles near the points of tangency, however, by their constant sliding on each other and the unbroken line (or plane) of their tops, appeared to indicate a uniform downward and inward movement. In some cylinders the

slant of the outer and inner faces differed. This may have been due to the side pressures from the adjoining cylinders. Where most pronounced it is possible that the interlock of the piles may have yielded in whole or in part (several cases were later found of piles not interlocked), thus allowing a difference of movement. The tops of one or two of the cylinders moved in bodily several feet, while their piling, when it could be observed, remained nearly vertical. This seems to indicate a bending of the entire cylinder so that each of its elements had in it a reverse curve, with the top and bottom vertical, since there is no evidence that the base, held firmly in the stiff clay, had been displaced.

63. A type of settlement appears to have been as shown above for G—a forward movement, and a downward movement increasing uniformly from outside to inside. The following may have happened: The weight of the fill tended to compress the soft mud on which it rested. This compression would increase as the dam was unwatered, and the outside water pressure would add a tilting effect. The adhesion of the filling and of the outside mud to the piles was very great, and appeared to be the chief resistance to be overcome when pulling the piles. If this adhesion existed during the settlement, it must have tended to bring a heavy load on each pile, which the thin bases were not fitted to support, and the piles would thus tend to settle slowly into the clay. Examinations at various times showed that the filling and the piles were settling together.

64. This leaning and gradual inward movement of the tops of the cylinders continued until after a few months the rise of tide to 1.5 feet above zero brought the water several inches above the tops of the outer piles, which had been originally about 2.5 feet above zero. The maximum inward movement between any two opposite cylinders from June 17, 1911, to February 11, 1912, as shown by the tape measurements, occurred between cylinders P and F and amounted to 21 feet 5½ inches. The maximum inward movement of any one cylinder between July 8, 1911, and February 11, 1912, as recorded by the "telltales," was 9 feet 6¼ inches on cylinder S, and the minimum so recorded between the same dates, 3 feet 3¼ inches in cylinder A.

65. It is difficult to make a satisfactory analysis of the causes of the cylinder movements since the conditions varied for each cylinder. For example, the harbor bottom was noticeably soft at cylinders F and G, and the site of cylinder N had been dredged in part to a depth of 50 feet in the removal of wreckage as previously described. The ends of the cofferdam were built on a radius sufficiently small to permit the development of an arch action under the exterior pressure when the dam was unwatered. This action is shown in the form of deformation of the cylinders J, K, L, M, and B, A, U, and T, and in the limited movement of their tops as compared with those of the side cylinders. (See pl. 58.)

66. Plate 32 shows the curves of inward movement of the tops of six typical cylinders, the rates of movement being indicated by the slope of the curves. These cylinders as they stood in pairs opposite each other were G and O, F and P, and D and R. G and O were ultimately steadied by a brace across the dam between them. F, P, and D were braced against the after part of the wreck. R had no brace other than the mud and stone fill in the cofferdam up to eleva-

tion −21.5 between it and a sunken barge and between this barge and the wreck. The plate also has a curve showing the greatest and least daily head between the water surface outside and inside the dam, as well as a tidal curve. The records of movement are for 10-day periods—after September 20, 1911—so that only a rate of increase during such a period can be noted. Taking first cylinders G and O, the curves show the movement to have been fairly uniform from July 8 to 20. From the 20th to the 30th an increase of the rate of movement took place due to the increased pressure head, the rate of movement becoming more constant when the head remained unchanged and dropping as the head was lowered. Between September 18 and 25 the head was again increased and the rate of movement became greater. It remained practically constant until the period October 20 to October 31, when the brace finished on October 27 began to show its effects. Thereafter changes of rate of movement corresponded to the various dates of resetting the brace, as previously described. Between November 17 and December 6 the pressure head was markedly increased by excavation within the cofferdam, and the braces required several resettings. During the period following November 17, much heavy wreckage was removed from the bottom of the excavation, and though the pressure head was not increased the resistance was decreased with increases of tendency to movement. Before the G–O brace was removed an earth dam had been built across the cofferdam between these cylinders, so that there was no movement until the pressure was relieved by flooding the cofferdam. For cylinders F and P the analysis of the curve gives practically the same results. On December 8 the ship's bottom was cut off at frame 41, and a mud wave began to form forward of frame 41, with a slight rise of the wreck aft of frame 41. This was reflected by the break in the curve of movement of cylinder P for this period. About January 24 the braces were removed from these and the adjacent cylinders, with an increase of the rate of movement. The curves for cylinders D and R show about the same results. For these cylinders the opening of a trench in the mud along the sides of the wreck was reflected in the change of rate for the January 1 to 20 period. The subsequent increases of rate can be accounted for by the general removal of the braces of the cylinders along the after part of the wreck.

CONDITION OF THE WRECK.

67. As the unwatering and excavation progressed the condition of the wreck could be determined. An examination of plate 3 will show the location of the transverse frames or floor plates between the inner and outer bottoms. Frame No. 41 was nearly amidships, beneath the bulkhead between the forward and after boiler rooms. Frame No. 30 was under the bulkhead separating the forward boiler room from the forward magazines, 44 feet forward from frame 41. Frame No. 18 was beneath the forward bulkhead of the forward 6-inch magazine, 48 feet forward from frame 30. The foremast rested on the protective deck immediately aft of this bulkhead.

68. Aft of frame 52 the hull was found intact with a list to port of about $6\frac{1}{2}°$ and slightly down by the stern. Between frames Nos. 52 and 41 the hull was intact below the top of the armor belt. The four after boilers were in place and undisturbed. In this section, on

the starboard side, one of the armor plates had been slightly displaced, and the after part of the amidships superstructure and the main deck beneath it had been crushed in somewhat by the weight of the wreckage comprising a portion of the main deck forward of frame 41 and the conning tower which had been thrown back on it. (See pls. Nos. 49 and 59.) On the port side, the four outer strakes of the protective deck for a length of 36 feet were split loose and rolled up, back, and out to port, under the main deck. This movement of the protective deck lifted the main deck above it, shearing off one of the deck beams. The latter deck then settled back to about 2 feet above its normal position. The plating of the ship's side between the main and protective decks was blown out to about frame No. 52.

69. Forward of frame No. 41, the ship was destroyed. From frame No. 41 to frame No. 30, a length of 44 feet, all of the upper portion of the ship had been blown away, the decks above the protective deck having been thrown up aft and to starboard, revolving about an axis, approximately above frame No. 41. The protective deck had been thrown out to starboard. The sides were thrown out. The ship's bottom was nearly intact to the bilge on either side and lay nearly horizontal. Forward of frame No. 32, the ship's bottom on the port side was broken and displaced.

70. Between frames 30 and 18, a length of about 48 feet, the destruction was much the same. (See pl. No. 38.) The forward turret was found nearly under its position in the ship. Its barbette fell separately upside down and aft of the turret, having been found near frame 41. Its top with the hood was found at the site of cylinder N, all as shown on plate 34. The athwartship armor plating nearly above frame No. 24 had been displaced aft, and was found on end with about one-third of its total length of 45 feet buried in the mud of the original bottom.

71. Only about half of the ship's bottom was in place, mainly on the starboard side. The keel was inclined up at an angle of about 15° from about frame No. 35 to frame No. 22. From frame No. 22 to frame No. 18 it was vertical, the flat outer keel there being attached to the remains of the bow section. The vertical keel and flat keelson were broken at frames Nos. 30, 21½, and 18, and the flat keelson also at frame No. 27. The upper decks of this portion were displaced both forward and aft.

72. The bow of the ship from frame No. 18 forward, a length of about 60 feet, had been destroyed above the level of the protective deck. The portion below the protective deck was found pointed nose down in the mud at an angle of 35° with the horizontal, to port, and lying on its starboard side. (See pl. No. 51.) The bow had traveled to port through an angle of about 113°. At frame No. 18, the keel line was 31 feet higher than the prolongation of the keel of the after intact portion. Along the port side, the protective deck had been blown out. The interior transverse bulkheads had been blown forward.

73. Inside the intact portion of the ship all the decks were covered with a deposit of black harbor silt which had penetrated everywhere. Its thickness varied from a few inches at a distance from any opening to from 4 to 5 feet under the hatchways. All metal parts not covered with mud were incrusted with shells and similar marine

growth. The framing and plating of the ship in general, except all of that which had remained above water, were in excellent condition. All woodwork, such as cabin partitions, etc., not covered with the mud, was nearly entirely eaten away by marine insects. Rubber packing and rubber valves, etc., were found to be in as good condition as when they had been submerged and several steam pumps, removed from the engine room, were cleaned, put to work, and found to have been unharmed by their long immersion.

74. About one-half of the bunkers were found to be almost full of coal, which was in excellent condition. Much of it was removed and burned under the boilers of the plant engaged on the work, and it seemed to have lost little of its heating value. A portion of this coal was sent to the United States for test by the Navy Department.

REMOVAL OF WRECKAGE.

75. The work of removing the wreck divided itself naturally into the bulkheading and floating of the after, intact portion of the ship, and the cutting up and removal of the remaining wreckage. For cutting up this wreckage the oxy-acetylene process was employed, two torches being used most of the time, although as many as six such torches were in use occasionally. This method proved most efficient, as many cuts had to be made in and under tangled masses of wreckage where drilling or chipping would have been difficult, if not impossible.

76. A number of the cuts were made with a head of several feet of water on the opposite side of the piece being cut, and the flame had sufficient force to keep the point of application clear. For instance, no difficulty was experienced in cutting holes through the bottom of the ship (as will be described later), even though in several cases there was a head of water of from 2 to 5 feet against the outside, and the flow of water through the opening made by the torch followed immediately behind the flame.

77. Successful cutting with this process depends very much upon the skill of the operator. Experience showed a difference of as much as 50 per cent in the amount of work done by different men. The cutting should always be begun at the lowest point and the molten metal should not be permitted to lodge in the cut, but should be blown clear of it all the time. In burning holes through horizontal plates, where the molten metal has no chance to run off, the top diameter of the burned hole must be not less than twice the thickness of the plate. After a hole is cut through such a plate, the ordinary width of cut of from one-eighth to one-fourth of an inch, depending upon the plate's thickness, can be maintained.

78. While cutting the turret armor (Harveyized, 8 inches thick), it was found necessary to keep the cut open at the outside, or starting places until the distance across the opening was about one-half the depth of the cut. An attempt to force the cutting to the point where the angle of clearance was less than about 22° caused a clogging of the cut which could not be removed with the flame and which it became necessary to chisel out. When the cut was finished in the case of this armor, the amount of metal actually removed represented a wedge 4 inches at the base and one-fourth inch at the point. The steel tube of the conning tower (about 33 inches in

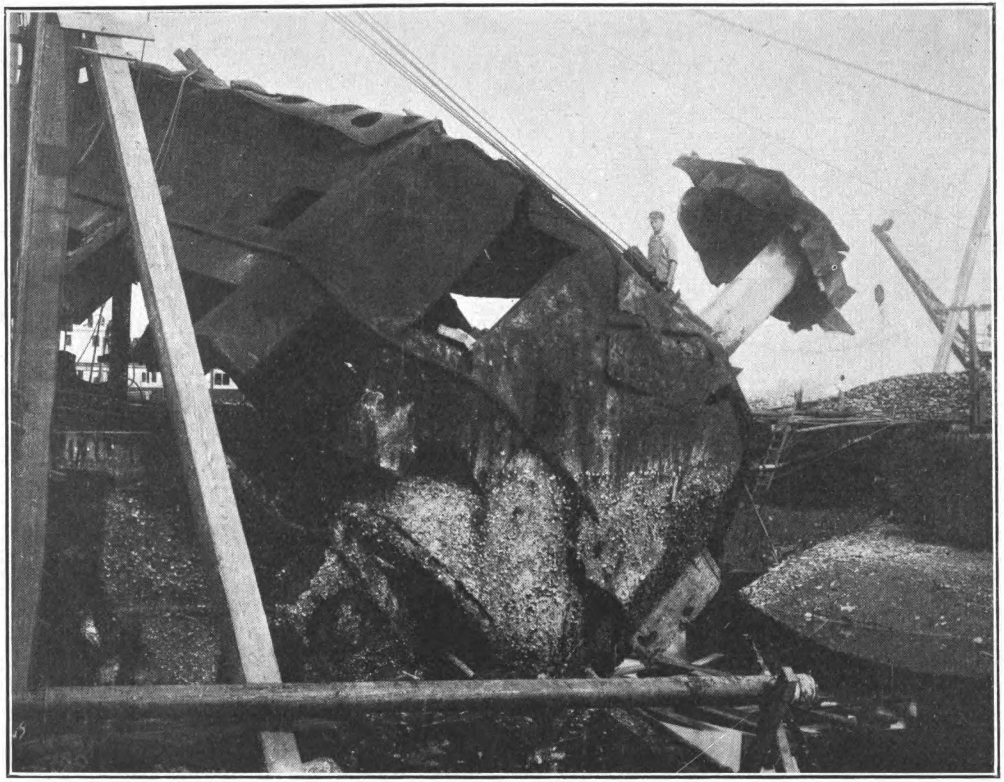


PLATE 59.—CONNING TOWER FROM AFT, SHOWING PORTION OF BASE CUT AWAY, AUGUST 15, 1911

exterior diameter), with walls 5 inches thick (see pl. No. 59), was cut by an expert operator in 58 minutes, and the wedge-shaped slot varied from about $2\frac{1}{2}$ inches to $2\frac{1}{4}$ inches at the head and was never more than one-eighth inch at the point. For all cutting by this process, the metal *must* be clear of rust on the starting face, and if possible, on both faces. When two thicknesses of plate were bolted or riveted together, and rust had accumulated between them, the cost of cutting was increased by about 50 per cent. The flame from the torches has no effect upon rust and little effect upon timber.

79. Most of the oxygen used in this cutting was shipped from New York to Habana in metal cylinders, each holding 100 cubic feet. The acetylene was generated in a generator, set up on the wreck, and carried in $\frac{1}{2}$-inch pipes for any distance to the place where used. The oxygen cylinders were easily carried from place to place, and the wire-covered tube carrying the oxygen supply was limited to 10 feet in length, in order that the operator might keep close watch upon the gauges attached to the cylinders and regulate them with ease. Wrenches other than those furnished by the makers should not be used in the adjustment of the torch springs or on the nozzles and points, as these parts are delicately made and easily broken by using large or ill-fitting wrenches. With careful handling, a point will last for a number of days, but a careless operator will destroy these points in a very short space of time; in fact, a novice will use from two to five times as many points as an experienced man, by failing to keep openings clear of molten metal and by allowing the point to come too close to his work and become overheated.

80. A great deal depends upon the judgment of the man using the torch, and it is poor economy to employ other than the most capable men for this work. The angle at which the flame strikes the cut will make a difference of 50 per cent in the amount of work done. The place for beginning a cut is of importance, as indicated above, and recutting should be avoided as far as possible, This means that the operator must know before beginning the width of cut necessary to cut through the metal without clogging. Perfect combustion seems to be impossible after the end of the nozzle has been burned off one-fourth inch, and except in case of emergency a new nozzle should be put on when it has been shortened by one-eighth of an inch.

81. This oxy-acetylene process was found most useful on other work than that of cutting, and one torch was kept busy nearly all the time by the mechanics repairing machinery and tools, such as pumps, engine beds, piston rods, etc. In one particular case a broken pump frame was welded at a cost of about \$5, while to have had a new one cast, with the resulting loss of time, would probably have cost at least \$100. The welding of cast or wrought iron or of steel is a simple process, and copper or brass can be brazed if the work is done with care. Steel can also be welded to either cast or wrought iron, but the use of a flux is necessary to weld cast iron alone or to weld steel to either cast or wrought iron. In welding, a V-shaped joint must be made between the two parts, care must be taken to keep the bottom of this V very hot, and no attempt should be made to carry one side up ahead of the other. Such a weld should never be cooled with water or with oil. Lugs and collars can easily be built up, shaped

fairly well with the torch, and afterwards dressed to their proper size.

82. The amount of cutting which could be done on such a work as the removal of the *Maine* varied greatly with the varying conditions. On the superstructure above the mud line in ordinary plating not exceeding one-half inch in thickness, as much as 300 linear feet of cutting was done per torch in eight hours, but where it was difficult to get at the plating, 30 to 40 feet per torch in the same length of time was considered a good average. In cutting the 2-inch plating of the protective deck, one torch made a record of 80 linear feet in eight hours, but the average for cutting this plating was not more than about 40 feet per day of the same number of hours. The cost of cutting the superstructure and of all wreckage above the mud line averaged about $10 per ton, the pieces ranging from 1 to 5 tons in weight. In fact, this sum of $10 per ton is a fair estimate of the cost of cutting and removing all of the wreckage except those portions near the explosion center and the bow section, which were more difficult to reach. The removal of some of this latter wreckage cost as much as $20 per ton. A fair division of this average cost of $10 per ton for the removal of most of the wreckage is as follows: Cleaning, cutting, and supervision, one-third; oxygen and acetylene, one-third; disposal, one-sixth; overhead charges, repairs to tools, etc., one-sixth.

83. After the wreckage had been cut in pieces of suitable size it was pulled out by derrick boats and placed on their decks or temporarily upon the cofferdam and later loaded on barges, towed to sea, and thrown overboard. The maximum weight of any single piece thus handled was about 10 tons and the average weight of all these pieces of wreckage was about 2 tons. The armor belt of the after-turret was disconnected by removing the bolts and splice plates, and the sections, which weighed about 17 tons each, were lifted to a cradle by a 12 by 12 inch gin pole, then drawn up greased inclined ways to the top of cylinder E. The two 10-inch guns, weighing about 29 tons each, were lifted and disposed of in a similar manner. These guns and parts of the turret were later placed ashore and given to the Cuban Government, to be incorporated in a *Maine* memorial in Habana.

BULKHEADING THE SHIP.

84. As soon as the wreckage and mud were sufficiently removed, the construction of a wooden athwartship bulkhead was begun at frame 41. (See Pls. Nos. 41 and 60.) It was composed of a single thickness of 3-inch plank, placed vertically and supported against 10 by 10 inch horizontal timbers (spaced to suit the water pressures), which were in turn backed by 10 by 10 inch verticals, spaced from 3 to 5 feet centers and braced to the framing of the ship, to the adjacent boilers, and to such other points as would afford good support. The tops of the planks were made about flush with the main deck, and the bulkheading was carried around the sides above the armor belt as far as the plating had been blown out. The bottoms of the planks were spiked to a sill bolted to the bottom plating and backed with concrete, and the horizontal timbers supporting the plank were X-braced, as were also some of the short back struts. Where necessary, weak points were supported by concrete or cement mortar, and especial care was taken to make water-tight all joints between the

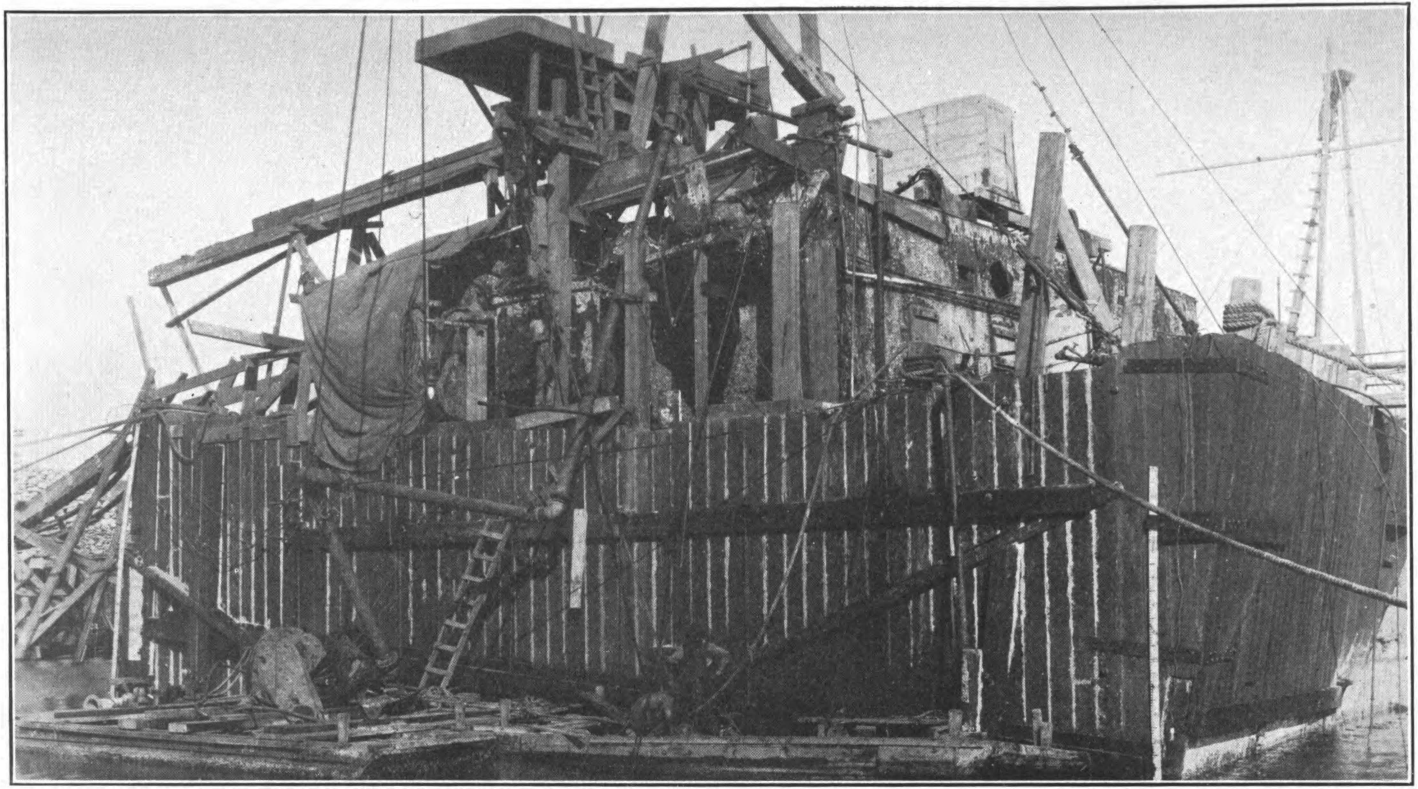


PLATE 60.—BULKHEAD AT FRAME 41 AND ALONG PORT SIDE FEBRUARY 12, 1912.

planking and the ship. The joints between the planks themselves were calked with oakum. In addition to the struts, 2-inch tie-rods and other fastenings were run across the ship a little below the main deck and additional vertical and horizontal tie-rods 1¼ inches in diameter were used to hold the bulkhead framing to the ship. An X brace of 2-inch tie-rods was placed on the outside of the bulkhead, running about from the bilge keels to the main deck. The bulkhead was designed to support a head of 30 feet, so that, had it been necessary, the cofferdam could have been flooded to the level of the main deck. The maximum head actually supported, however, did not exceed about 22 feet. Owing to the care taken in its construction, the bulkhead was practically water-tight.

FLOATING THE WRECK.

85. On January 26, 1912, when the bulkhead was nearly completed, the water in the cofferdam was allowed to rise a few feet. A tendency of the mud to rise in the open space in front of frame 41 had been noticed soon after the removal of the wreckage had been begun, and when the keel was cut the movement became marked. The mud banked against the cylinders slowly settled and a mud wave commenced to rise in the space which had been freed of wreckage. At the time when the water was allowed to cover it finally, the maximum upward movement of this mud, which occurred where the excavation was deepest, just forward of the bulkhead, had amounted to about 3 feet. A similar but lesser movement had taken place under the ship, the port side at frame 41 having risen 0.55 foot and the starboard side 0.16 foot by January 26. The stern at the same time had risen 0.41 foot.

86. While the wreckage was being removed, twenty-nine 6-inch holes were cut with the oxy-acetylene flame, through the bottom, between the bilge keels, and between frames 41 and 55, extending from the wooden bulkhead to the bulkhead dividing the engine room from the after part of the ship. Six-inch flanges were bolted over these holes and each made fast by six ¾-inch bolts. A reducer to 2 inches was screwed into each. The holes were connected by a system of 2-inch piping into three groups; one group of 14 in the boiler room, one of 8 in the magazine, and one of 7 in the engine room. The three groups were united into a single 6-inch line on the main deck where two separate sources of water supply were provided, one from a large force pump on deck and one from the *Barnard*. A system of 1-inch jets at 10-foot intervals extended from frame 45 to the stern along both sides of the wreck, connected to the pumping system on the main deck. The pump capacity was sufficient to supply water for the entire system at once, and the arrangement of valves was such as to allow the opening or closing of any one of the bottom holes or jets without affecting the others. The clay was jetted from under each of the 29 bottom holes until a cavity about 2 feet square, (8 cubic feet) was made, which naturally filled with water. The 2-inch connections to the pump line were then completed. The side jets were bent, so as to follow closely against the ship's sides, and when brought into play were forced down until the bilge keels were reached. When they reached that depth they were allowed to "run" for about 15 minutes and then stopped.

87. Both pumps were started, and a pressure of 60 pounds on the pipe line was maintained for 40 hours. At times the pressure rose to 80 pounds for a few minutes. At the end of 40 hours, three streams of water, one under each bilge keel and one under the flat keel, broke through at frame 41 and the pressure in the pipe line immediately fell to 10 pounds. The pumps were stopped and a test of the individual holes was made separately. With three exceptions, in the engine-room group, water was forced through each hole with the pressure below 20 pounds and generally below 10 pounds. One of of the exceptions required a pressure of 60 pounds for 30 minutes, the other two blew out as soon as the pressure reached 60 pounds. The flow of water from the individual holes showed conclusively that there were small channels running athwartships and that probably the clay under the entire area covered by the "hole" system was more or less saturated. There was no movement of the wreck during this test other than the gradual righting to starboard which had been going on for some days.

88. By February 3 the removal of wreckage had progressed far enough to allow a further flooding of the cofferdam. The water was then allowed to rise to elevation −24.0, and held at about that level until February 10. The port side of the wreck continued to rise steadily and the starboard side to a less extent, so that the braces between the ship and the cofferdam on the port side had a decided upward slope, tending to assist materially in righting the ship. The effect of partly flooding the cofferdam was quite marked, and between January 26 and February 10, on which last-named date the final flooding began, the port side at frame 41 rose 3 feet, and the starboard side 2 inches, while the stern rose 1 foot. Most of the material had been removed from above the propellers and shafts under the protection of an inner line of steel piling, so as to destroy their anchoring effect.

89. When everything was in readiness for floating the ship, the water was allowed to rise still farther in the dam on February 10, and the pumps connected with the pipe system in the ship described in paragraph 86 were started. The bottom holes in the after or engine-room group were opened first. After the pipe line pressure fell to 10 pounds, the other two groups were opened. For the first group the pressure rose to 20 pounds at the start and fell to 10 pounds in 10 minutes. In the second and third groups the pressures were practically as in the first. The plumb bob in the ship showed a slightly increasing movement to starboard during the first half hour, at which time all of the 29 holes were opened and the pressure on the pipe line was 10 pounds. After six hours the jets on both sides were opened and portable jets were used around the stern and propellers. The pressure on the jets varied from 10 to 40 pounds. As stated in paragraph 68 of this report the after part of the wreck lay with a list to port, the port bilge kneel being about 5 feet lower than the starboard. As the water rose, the ship first showed a tendency to come to an even keel, then a slight rolling of about 2° developed and finally when fully afloat the list to port became nearly the same as when in the mud. This was due to the partly unbalanced weight of the port turret base. The actual "breaking away" from the mud appeared to occur at the bulkhead about 1 a. m. on February 11, when the water level in the dam was about −19 feet and on the ship's side about 1 foot above the final average flotation line at the

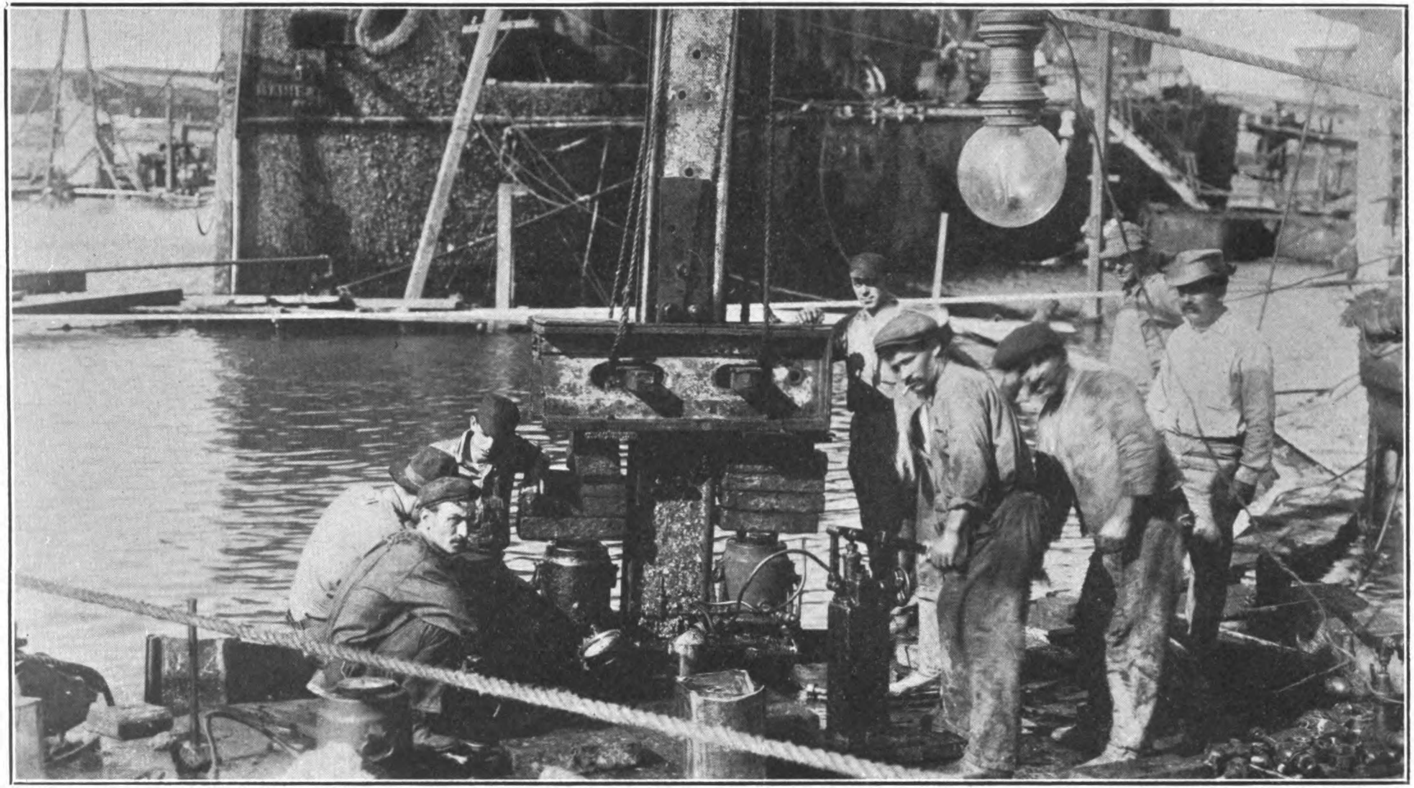


PLATE 61.—STARTING A PILE WITH JACKS, CYLINDER U, WRECK AFLOAT IN COFFER DAM FEBRUARY 21, 1912.

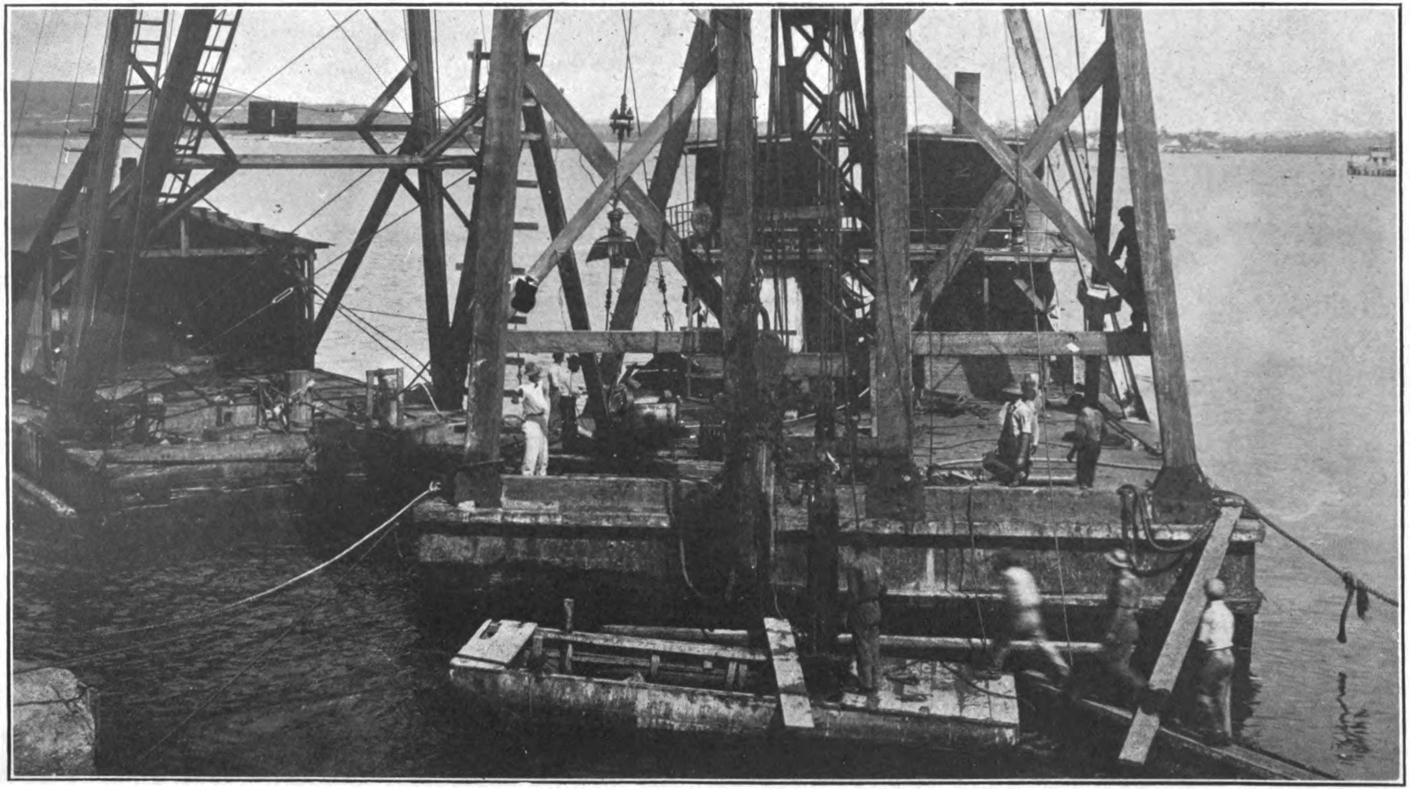
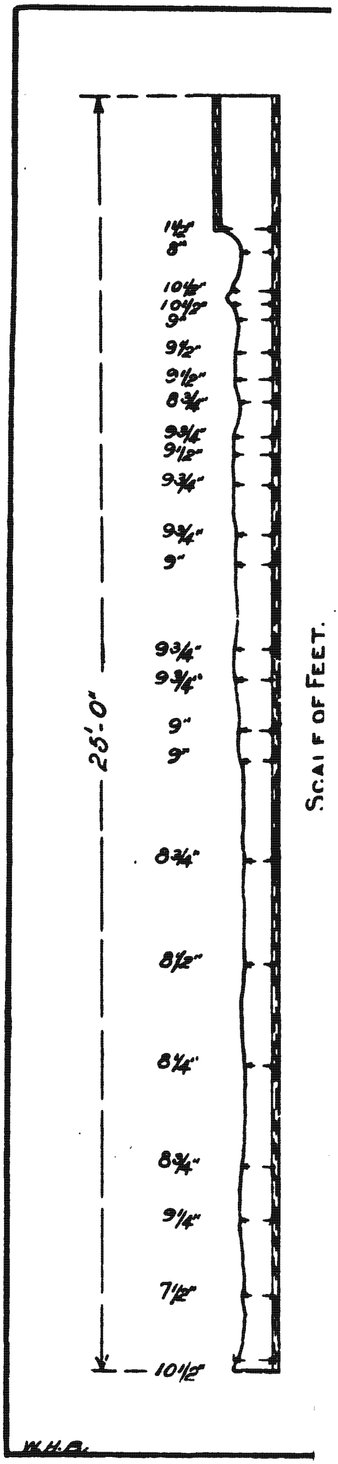


PLATE 62.—PULLING A PILE WITH FLOATING DERRICK, CYLINDER U, FEBRUARY 25, 1912.


8"
10½"
9"
9½"
9½"
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9½"
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9¾"
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9"
8¾"
8½"
8¼"
8¾"
9¼"
7½"
10½"
25'-0"
SCALE OF FEET.
W.H.B.

bulkhead. The breaking away at the stern occurred about 1 p. m. when the water in the dam had risen to −16.5 feet and its surface was about 1 foot above the final flotation line at the stern. As the suction was broken with but 1 foot of extra flotation, there was no sudden movement or jar, in fact the movement was not discernible except on the gages. The draft of the ship when floating was about 26.4 feet at the stern, and at frame No. 41, 21 feet on the port side and 17 feet on the starboard side.

90. The braces between the starboard side and the cylinders had been removed one by one, the last ones, from cylinders P, Q, and T, having been cut away on January 28. The brace between cylinders G and O was removed during the day of February 11, and by February 13 the cofferdam was once more full to tidal level. The braces on the port side freed themselves as the ship rose, none of them being cut.

REMOVAL OF COFFERDAM.

91. After the intact portion of the wreck had been floated, in order to take it to sea, the piling and the filling of cylinders A and U were removed. First, the filling in these cylinders was removed by a hired clam-shell dredge, the excavation being carried to a depth of a little more than 25 feet. On February 19, 1912, an effort was made to pull one of the piles on the outer side of cylinder U. None of these piles could be started with any of the hoisting engines available for use, and therefore two of the 150-ton hydraulic jacks were used to start the first pile. One of these jacks was placed on each of the adjoining piles and connection was made with the pile to be pulled by three 1¼-inch bolts passing through the head of the pile and through two splice plates, which were likewise connected with a short length of pile passing through a steel cross girder resting on the plungers of the jacks. Efforts were made to start several piles before succeeding in finding one which could be pulled, and in one of these cases the pull reached 240 tons without moving the pile. Finally one was found which began to come up with a pull of about 160 tons, but it had to be jacked for about 25 feet before it could be pulled by blocks and tackle alone. (See pl. No. 61.) After this pile had been jacked up 10 feet it still required a pull of 70 tons to move it farther, and its removal occupied all of three days.

92. On February 22 the jacks were placed on cylinder A, and a pile was found which began to come up under a pull of 70 tons. It was jacked up for some distance, until it could be removed with blocks and tackle. Near this first pile pulled another pile was found, the top portion of which had split, as shown on plate No. 63. Fortunately this had caused no trouble, and the break was unknown until the pile was removed. This cylinder was the first one filled; its filling had had the greatest length of time to settle and consolidate, and, moreover, the material used for filling had nearly all been excavated by the dipper dredge.

93. After the removal of a single pile from each of these two cylinders the remaining piles were pulled more easily. These piles were pulled by a shear frame rigged on the bow of a steel-hull derrick boat, which was capable of exerting a pull of about 75 tons. (See pl. No. 62.) This pull was sufficient in most cases to pull out the

piles, but occasionally a steam hammer had to be used on the adjoining piles and worked for several minutes in connection with the pulling before its jarring loosened the pile to be removed. In some few instances alternate piles were pulled, but it was found when removing those left in place that almost as much power was required as for the piles first drawn in spite of the fact that nothing but the mud friction remained to hold them. While the opening was being made in the cofferdam, as described above, the wreck had been ballasted so that the draft at the bulkhead was just about 21 feet and at the stern just about 24 feet. All preparations had also been made for sinking the wreck at sea.

SEA GATES IN WRECK.

94. In order to admit water for sinking the wreck, two 4-inch valves and one 6-inch valve were connected to three holes through the bottom, each valve having a stem extending to the main deck. Five gates were placed in the bulkhead, each gate 8 inches wide and 60 inches high, with its bottom 23.5 feet above the bottom of the ship, or about 2½ feet above the water line at this bulkhead. These gates could be opened from the main deck. As an additional precaution, in case it should prove to be impracticable for any reason to open the valves or the gates, charges of explosive were placed near four of the 6-inch bottom hole flanges and also against the wooden bulkhead 10 feet below the water line just about amidships. In order to insure sinking by the head and to prevent rolling, arrangements were made so that the boiler compartment (next the wooden bulkhead) would be flooded 7 feet before any water could flow aft of the magazine bulkhead. This incoming water was also confined to the section between the coal bunkers. The locations of the openings provided through the original bulkheads aft of frame 41 were such that little water would enter the stern compartments until it could come through the afterdeck hatches.

SINKING THE WRECK.

95. On March 16, 1912, at 2 p. m. the wreck was towed to sea, being taken out stern foremost, towed by a United States Navy tug, the *Osceola*, and steadied by two other tugs. (See pls. Nos. 64, 65, and 66.) After having reached a point beyond the 3-mile limit the actual sinking was carried out in exact accordance with the prearranged plan. The party detailed to do this work boarded the wreck at a signal from the towing tug, and—

First. Opened the gates through the athwartship bulkheads aft of the wooden bulkhead at frame 41.

Second. Opened the three valves connected with the bottom holes.

Third. Opened the five sliding gates in the wooden bulkhead, and then abandoned the wreck.

(Pl. No. 67.)

The time consumed in doing this work, from the moment when the signal was received until the party had abandoned the wreck, was just nine minutes.

96. All of the arrangements made for sinking the wreck acted perfectly, and there was no necessity for resorting to the use of explo-

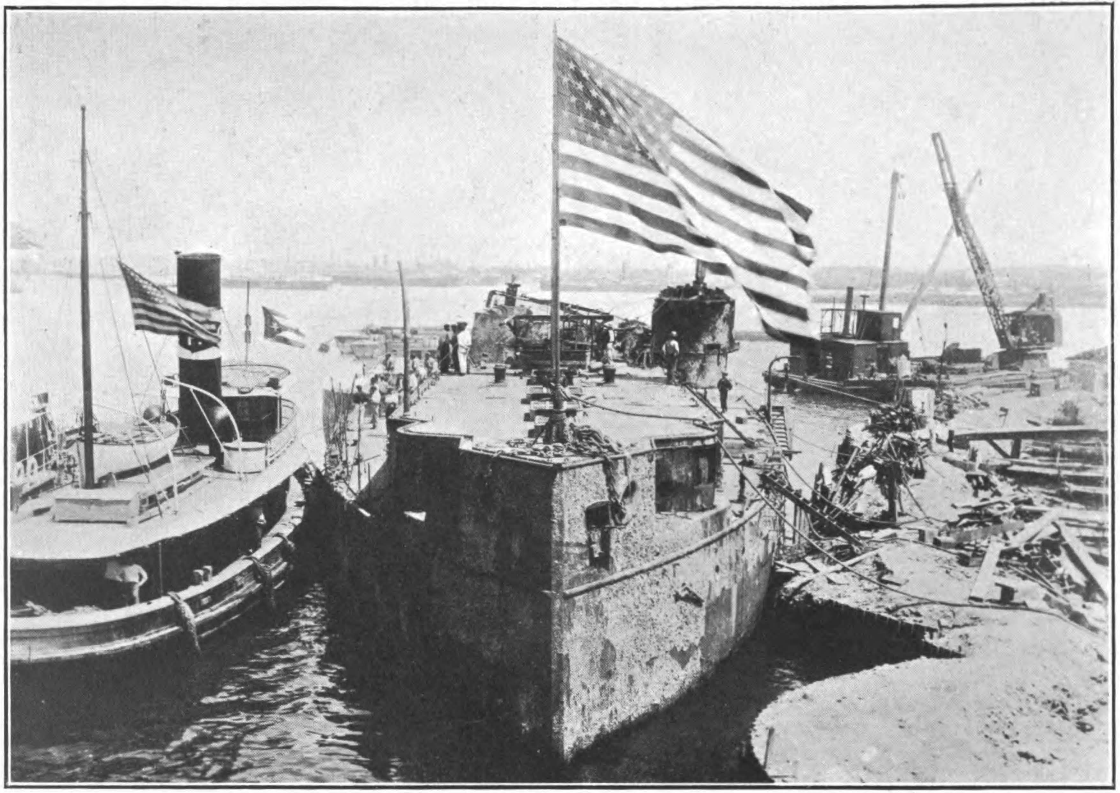

PLATE 64.—WRECK MOORED OUTSIDE OF COFFER DAM FOR REMOVAL TO SEA, MARCH 15, 1912.

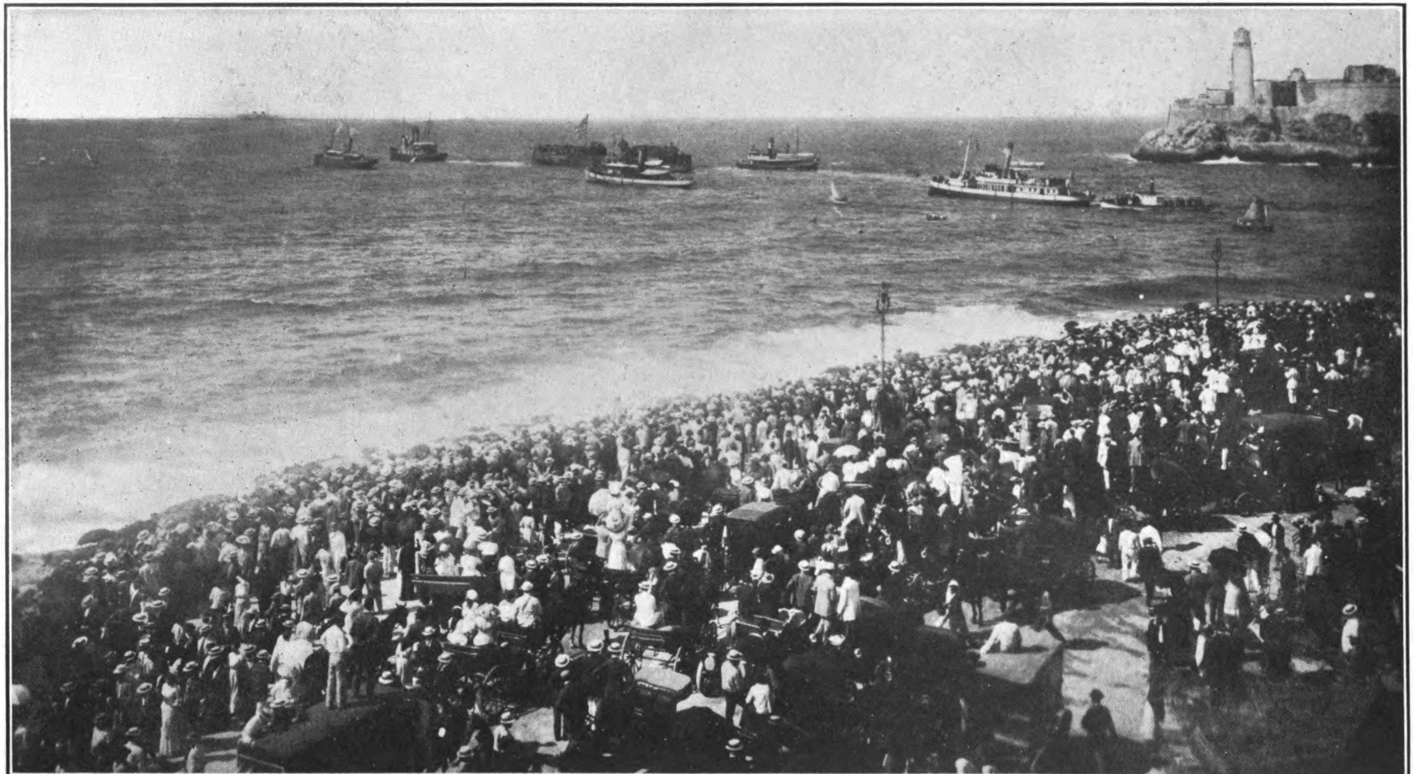

PLATE 65.—WRECK LEAVING MOUTH OF HAVANA HARBOR MARCH 16, 1912, 3 P. M.

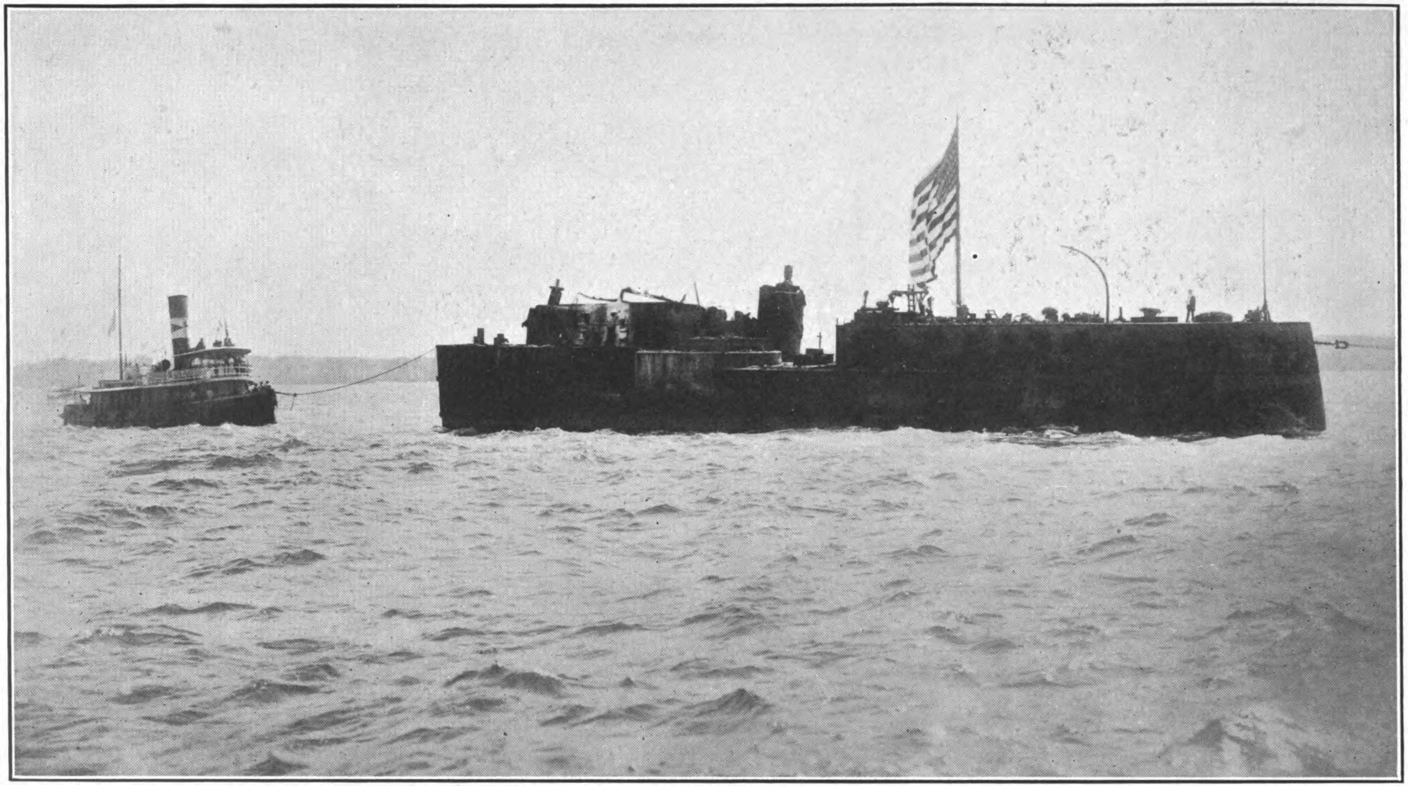

PLATE 66.—WRECK AT SEA, UNDER TOW, MARCH 16, 1912.

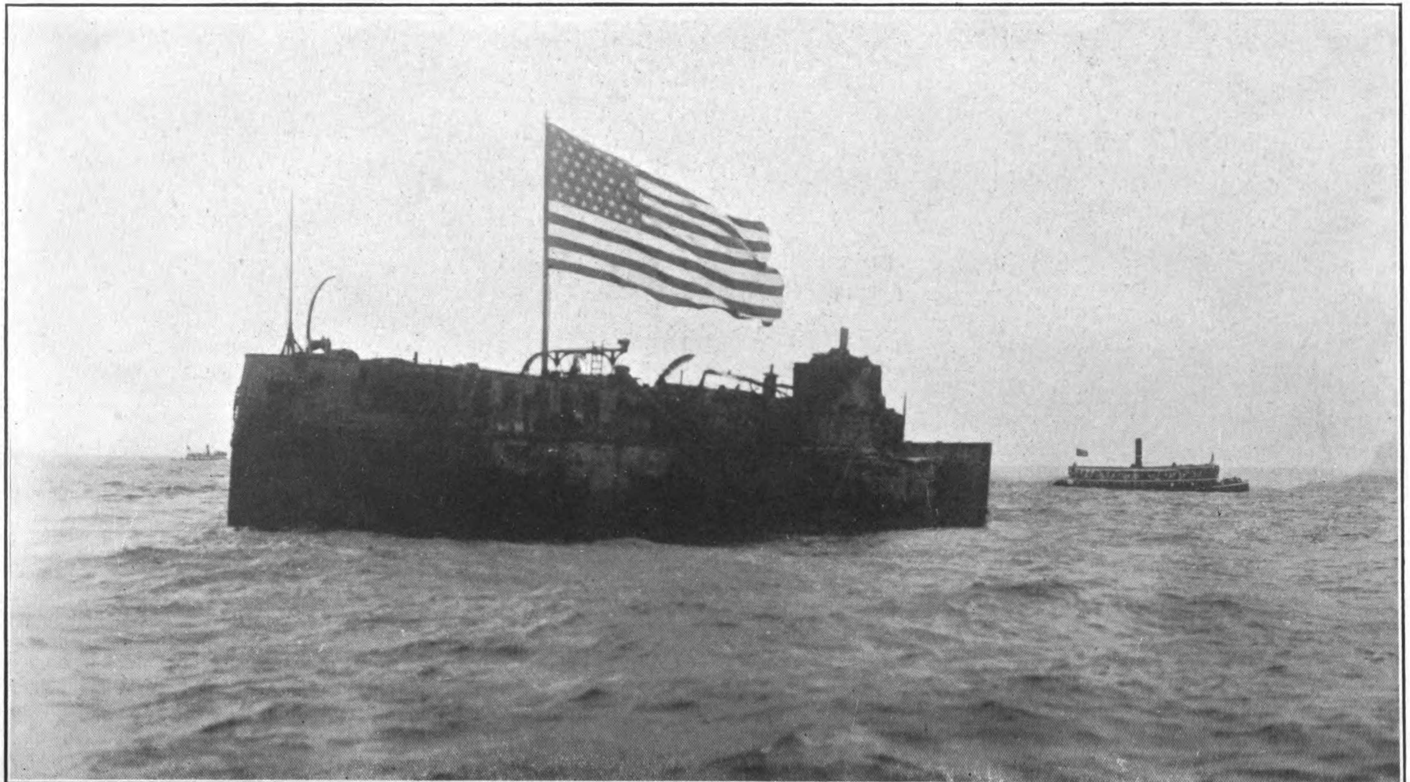

PLATE 67.—WRECK ABANDONED AT SEA BEYOND 3-MILE LIMIT 4.50 P. M. MARCH 16, 1912.

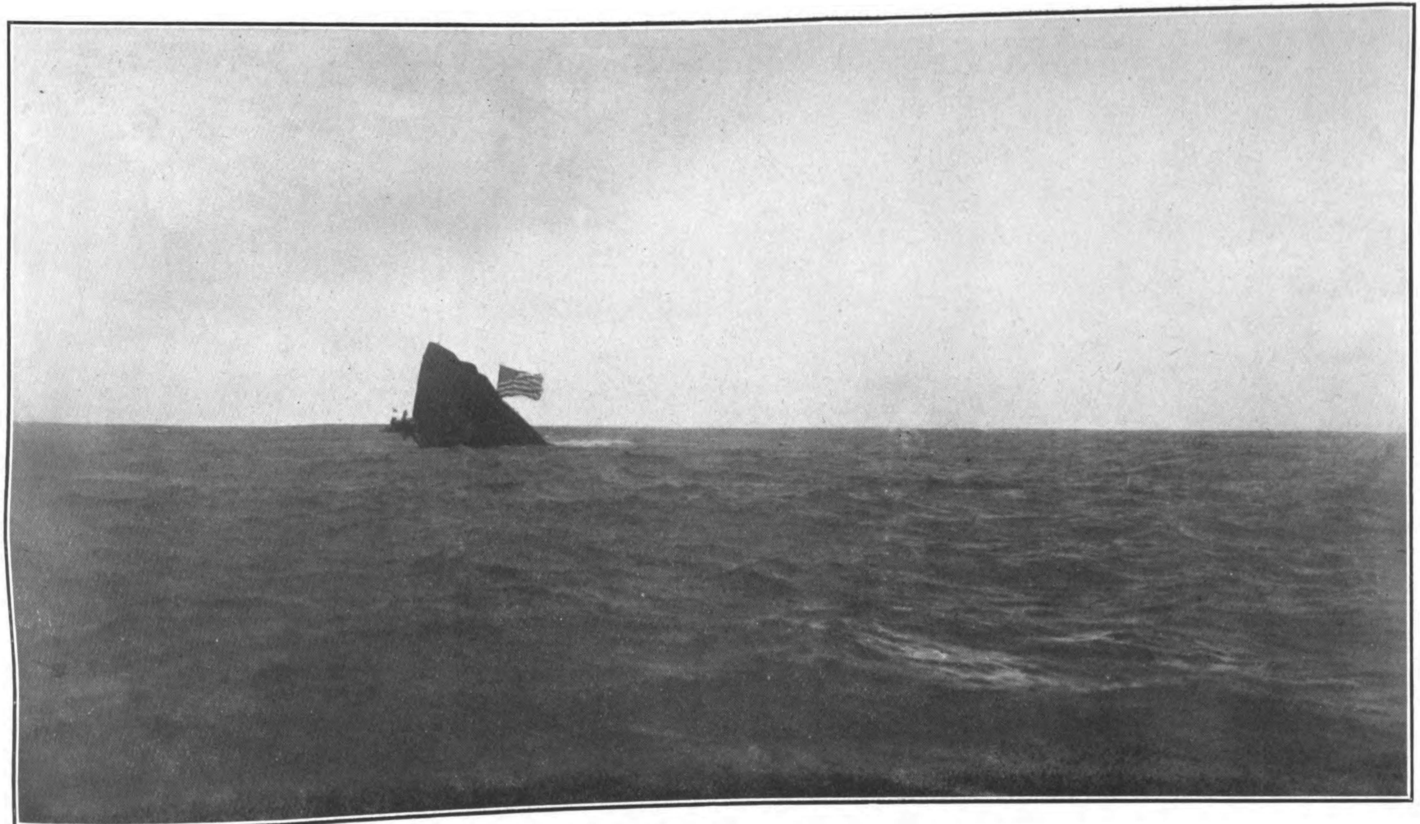

PLATE 68.—LAST VIEW OF WRECK 5.21 P. M. MARCH 16, 1912.

sives in order to admit the water. The wreck disappeared from sight 41 minutes after the opening of the valves and gates was completed. (Pl. No. 68.) The depth of water at the site where the wreck disappeared is given by the charts as 620 fathoms.

REMOVAL OF REMAINDER OF THE COFFERDAM.

97. The same difficulties as those encountered in pulling the piles from cylinders A and U were experienced in removing the first pile from each of the other cylinders, and the same methods were employed to overcome them. From all of these cylinders a portion of the filling material was dredged prior to pulling the piling, and after the first pile in each had been taken out the remaining piles were pulled by the derrick boats, special shear frames having been rigged on two of them. (See pl. No. 69.) All of this piling which had remained even approximately straight pulled very easily. All of it which had been bent, and especially some of it near the points of tangency which had been bent edgeways as well as flatways, proved to be hard to pull. Until April 13 derrick No. 2 alone was engaged on this work. After that date derricks 1 and 2 were kept at this work, and the piles were unloaded from the scows and stored on the wharf by derrick No. 5.

98. To June 30, 1912, a total of 3,146 piles had been pulled in 112 days, or an average of 28.1 piles per day. The greatest number pulled in one day was 79. The greatest daily average for June was 36.85. The last pile was pulled July 27. During the operation of pulling the dredge was kept at work in advance of the derricks removing the fill from the cylinders and the banks placed inside and outside the dam.

99. There had been left in the bottom, when the cofferdam was removed, a considerable quantity of wreckage, which had been thrown so far from the keel line of the wreck as to be too close to the cylinders for removal until after the cylinders were taken out. This included the wreckage of the end of the bow section and of the forward turret. The exact position of the bow was not discovered until the cofferdam had been unwatered. The barbette of the forward turret was found deep in the mud shortly before the dam was flooded. The turret itself was not discovered until October 28, 1912, while dredging for the removal of the fill of the cofferdam. The bottom sections of 17 piles which had separated in pulling were also left. The sections of the bow wreckage which could be reached, but which were too close to the cylinders for removal, were cut in pieces and buoyed before the dam was flooded.

100. The approved project of the Cuban Government for the improvement of the harbor contemplates excavation to a depth of 11 meters at the site of the wreck. Much of the wreckage remaining when the dam was flooded was below this depth, and with the assent of the Cuban authorities it was decided that the site should be cleared completely to a depth of 11 meters. This was done by dredging over the entire area to a depth of 37 feet and removing all obstructions found, either by lifting them to a scow for removal to sea or by cutting off the projecting parts with dynamite, or by sinking a mass too heavy to be lifted by dredging around it and exploding charges of dynamite on its upper surface. The work proved difficult

and tedious, but was finally completed on December 2, 1912. On December 3 the site was carefully swept to a depth of 37.5 feet in the presence of representatives of the Cuban Government and declared free of obstructions.

Statement of expenditures made in connection with the work of raising the U. S. S. "Maine" from the harbor of Habana, Cuba, and the balance of amounts appropriated for that work.

Total of appropriations		$900,000.00
Expenditures:		
Establishing office and collecting force	$1,374.64	
Purchase and repair of plant	52,826.94	
Preliminary surveys and work	8,652.31	
Clearing site for cylinders	10,376.23	
Material and labor, shell of cofferdam	257,629.24	
Material and labor, filling cofferdam	72,787.89	
Bracing cylinders	33,535.73	
Stone fill	50,819.13	
Unwatering and removal of mud and wreckage, June 1 to Oct. 30, 1911	40,263.33	
Removal of wreckage and building bulkhead frame 41, Nov. 1 to Feb. 10, 1912	75,090.73	
Opening dam and removal of after portion of wreck, Feb. 10 to Mar. 16, 1912	30,368.57	
Removal of cofferdam and clearing site, Mar. 17 to July 10, 1912	90,699.69	
Clearing site and returning plant, July 10, 1912, to Mar. 31, 1913	64,857.82	
		789,282.25
Outstanding liabilities		783.55
Total for removal of wreck		790,065.80
Care and removal of bodies		4,090.50
Total expended		794,156.30
Allotment made Feb. 20, 1913, in accordance with act of Congress approved Aug. 22, 1912		5,000.00
Total		799,156.30
Balance available		100,843.70
Total expenditures and liabilities, removal of wreck		790,065.80
Deposit in Treasury from sale of plant		4,290.97
Net cost removal of wreck		785,774.83

Respectfully submitted.

W. M. Black,
Colonel, Corps of Engineers.
Mason M. Patrick,
Lieut. Col., Corps of Engineers.
H. B. Ferguson,
Major, Corps of Engineers.

O

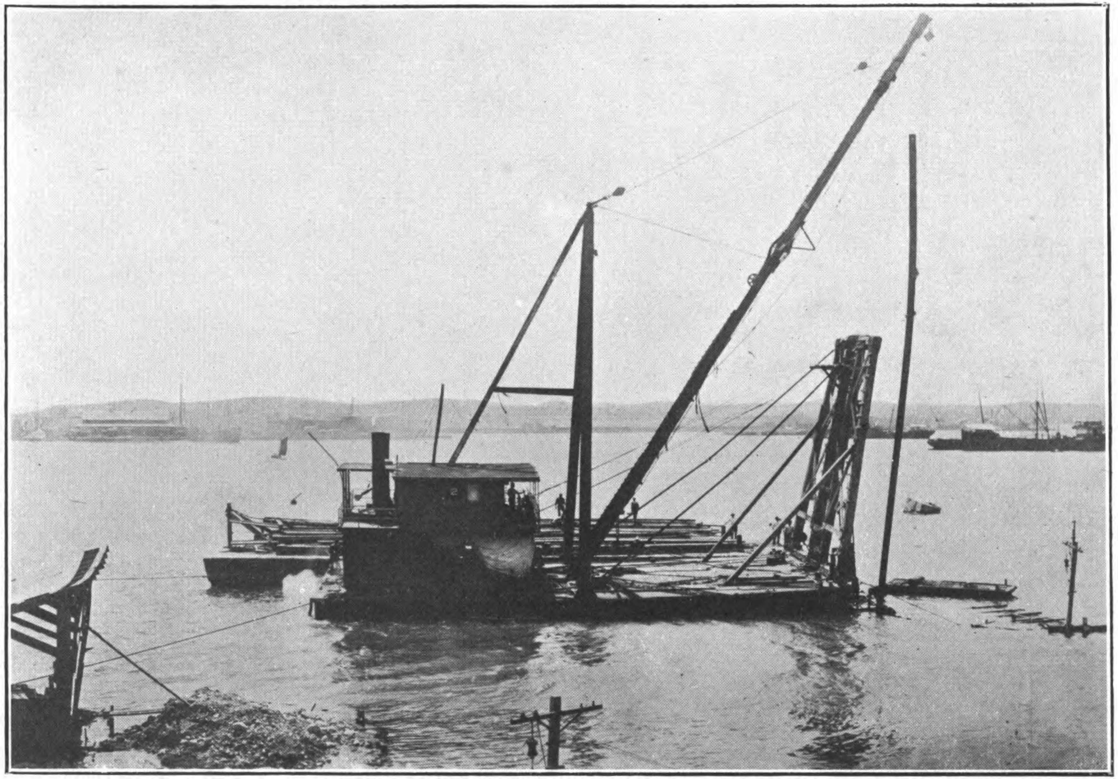

PLATE 69.—DERRICK BOAT PULLING COFFER DAM PILES, APRIL 8, 1912.