

CHAPTER XI

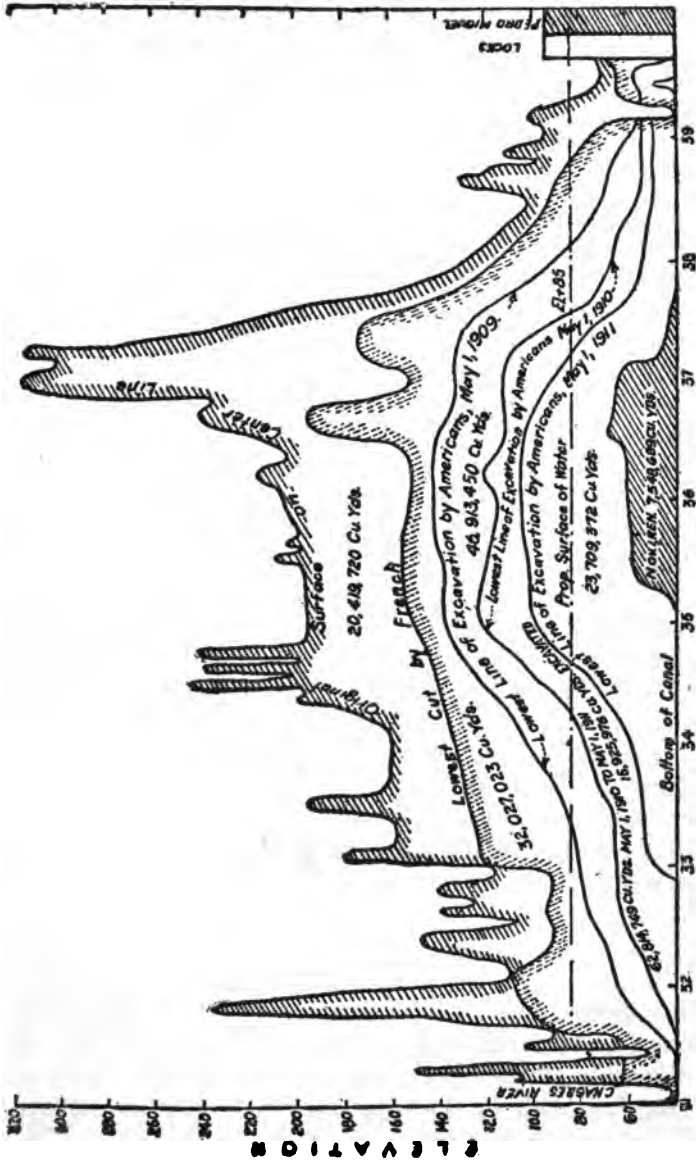
PLAN AND OPERATION OF THE CANAL

During the past twenty years a wondrous transformation has taken place in the narrow strip across the Isthmus over which the United States holds dominion, but most of this change has been wrought since the American occupation began. The French did a great deal of work, but it was mainly of the pioneer sort that makes little appeal to the eye and is fully appreciated only by the technician. Their surveys were of incalculable value to our engineers. The buildings and machinery which they left saved us much trouble and expense. They dug a ditch for a few miles inland from the Atlantic and took an enormous mass of material out of Culebra, but the one was as a scratch in the ground, and the other as a notch in the hill, compared with the full extent of the necessary excavation.

The earlier period of the American tenancy was wisely devoted to preliminary measures of the utmost importance, but unimpressive in their immediate results. Plans were carefully considered in detail. Organization was effected. The railroad was reconstructed, machinery and methods were tested. Civil government was installed. And, most important of all, the field of action was made sanitary and the task thereby rendered possible.

When the army engineers assumed charge of the operation, the period of preparation had just closed. The type of the waterway and its main features had been finally decided upon. The labor supply was assured and life on the Isthmus involved no unusual menace to the health of the white man. In short, the period of construction had begun, the plans were drawn, the tools provided, the foun-

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M I L C S

PROFILE OF CULEBRA CUT FROM THE DIKE AT GOMBOA TO PEDRO MIGUEL LOCKS

enclosing a mixture of sand and clay. The top and upstream slopes are heavily riprapped.

The spillway is a concrete-lined opening, 1,200 feet long and 300 feet wide, cut through a hill in the center of the dam, the bottom of the opening being ten feet above sea level. During the construction of the dam, all the water discharged from the Chagres River and its tributaries was carried through this opening. After construction had sufficiently advanced to permit the lake to be formed, the spillway was closed with a concrete dam, fitted with gates and machinery for regulating the water level of the lake, as described below.

The water level of Gatun Lake, extending through the Culebra Cut, is maintained at the south end by an earth dam connecting the locks at Pedro Miguel with the high ground to the westward, about 1,700 feet long, with its crest at an elevation 195 feet above mean tide.

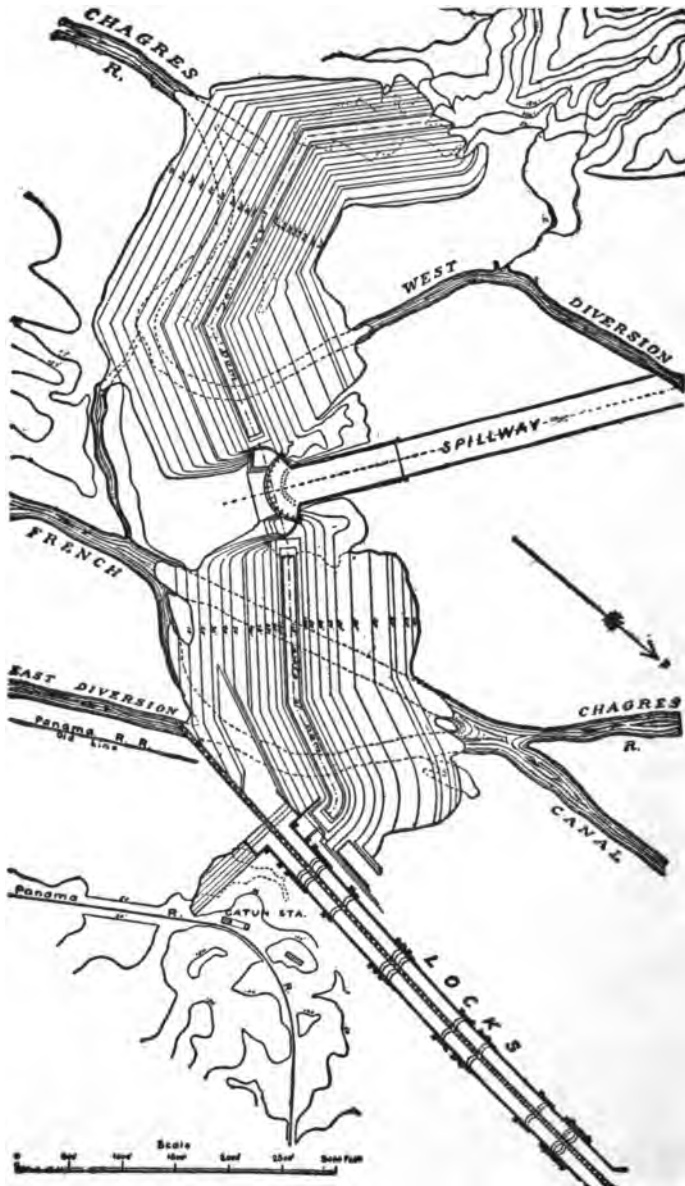
The small lake between the locks at Pedro Miguel and Miraflores is formed by dams connecting the walls of the locks at the latter point with the high ground on either side. The dam to the westward is of earth, about 2,700 feet long, having its crest about 15 feet above the surface of Miraflores Lake. The east dam is of concrete, about 500 feet in length, and forms a spillway for the lake, with crest gates similar to those of the Gatun Dam.

Lake Gatun covers an area of 164 square miles, with a depth in the ship channel varying from 85 to 45 feet. The channel through the lake for the first 16 miles from Gatun is 1,000 feet in width; for the next four miles it is 800 feet, and for the remainder of the distance 500 feet wide. The summit level of the lake extends through the cut and to the Pedro Miguel Locks.

SPILLWAY, GATUN DAM

The Spillway is a concrete lined channel 1,200 feet long and 285 feet wide cut through a hill of rock nearly in the center of the Dam, the bottom being 10 feet above

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GATUN DAM, SPILLWAY AND LOCKS.

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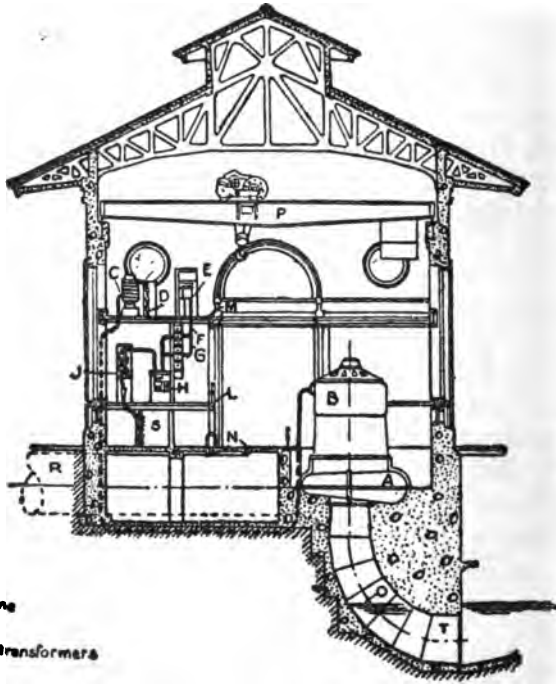
sea level at the upstream end and sloping to sea level at the toe. Across the upstream or lake opening of this channel a concrete dam has been built in the form of an arc of a circle making its length 808 feet, although it closes a channel with a width of only 285 feet. The crest of the dam is 69 feet above sea level, or 16 feet below the normal level of the lake which is 85 feet above sea level. On the top of this dam have been placed 13 concrete piers with their tops 115.5 feet above sea level, and between these there are mounted regulating gates of the Stoney type. Each gate is built of steel sheathing on a framework of girders and moves up and down on roller trains placed in niches in the piers. They have been equipped with sealing devices to make them water-tight. Machines for moving the gates are designed to raise or lower them in approximately ten minutes. The highest level to which it is intended to allow the lake to rise is 87 feet above sea level, and it is probable that this level will be maintained continuously during wet seasons. With the lake at that elevation, the regulation gates will permit of a discharge of water greater than the maximum known discharge of the Chagres River during a flood.

HYDROELECTRIC STATION AT GATUN

Adjacent to the north wall of the spillway has been located a hydroelectric station capable of generating through turbines 6,000 kilowatts for the operation of the lock machinery, machinshops, drydock, coalhandlingplant, batteries, and for the lighting of the locks and Zone towns and, if desirable, operating the Panama railroad. The building is constructed of concrete and steel, and is of a design suitable for a permanent power house in a tropical country. The dimensions are such as to permit the installation of three 2,000-kilowatt units, and provision is made for a future extension of three additional similar units. It is rectangular in shape, and contains one main operating floor, with a turbine pit and two galleries for electrical equipment. The

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building, with machinery and electrical equipment has been laid out upon the unit principle, each unit consisting of



- A- 2,250 k. w. water turbine
- B- 2,000 k. w. generator
- C- Reactance
- D- Generator instrument transformers
- E- Generator switches
- F- Bus 1
- G- Bus 2
- H- Circuit switches
- J- Circuit-instrument transformers
- L- First gallery (el. + 40.85)
- M- Second gallery (el. + 55.35)
- N- Main floor (el. + 33.25)
- O- Low water (el. + 7)
- P- 30 ton crane
- R- Penstock
- S- Cable Vault
- T- Draft Tube

THE HYDROELECTRIC STATION AT GATUN.

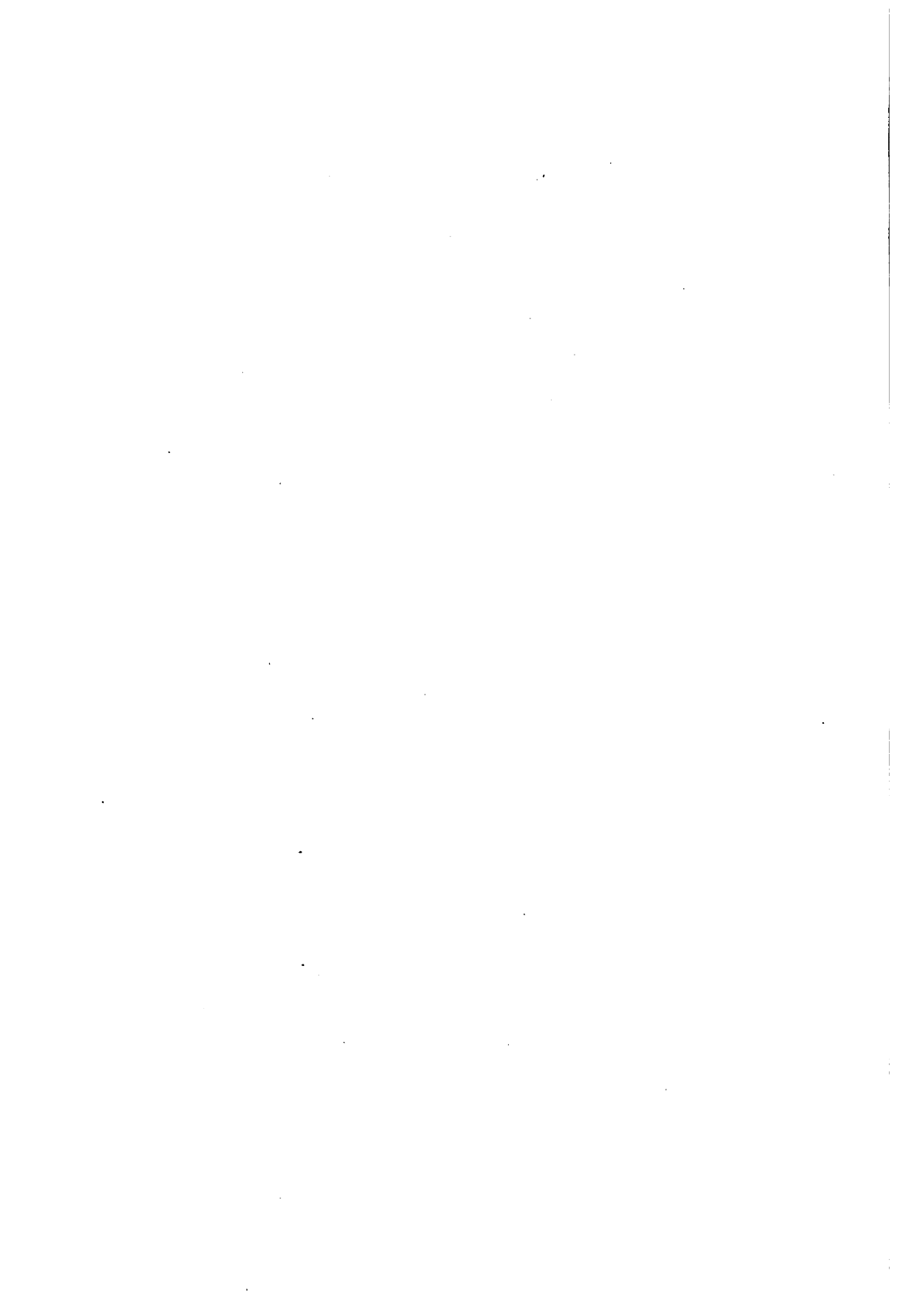
an individual head gate, penstock, governor, exciter, oil-switch and control panel.

Water supply is taken from Gatun Lake, the elevation of which will vary with the seasons from 80 to 87 feet above sea level, through a forebay which is constructed



CULEBRA CUT LOOKING SOUTH FROM BEND IN EAST BANK NEAR GAMBOA.

The train and shovel are standing on the bottom of the cut. The water in the drainage canal is about 10 feet below the bottom of the Canal, or at elevation +30.



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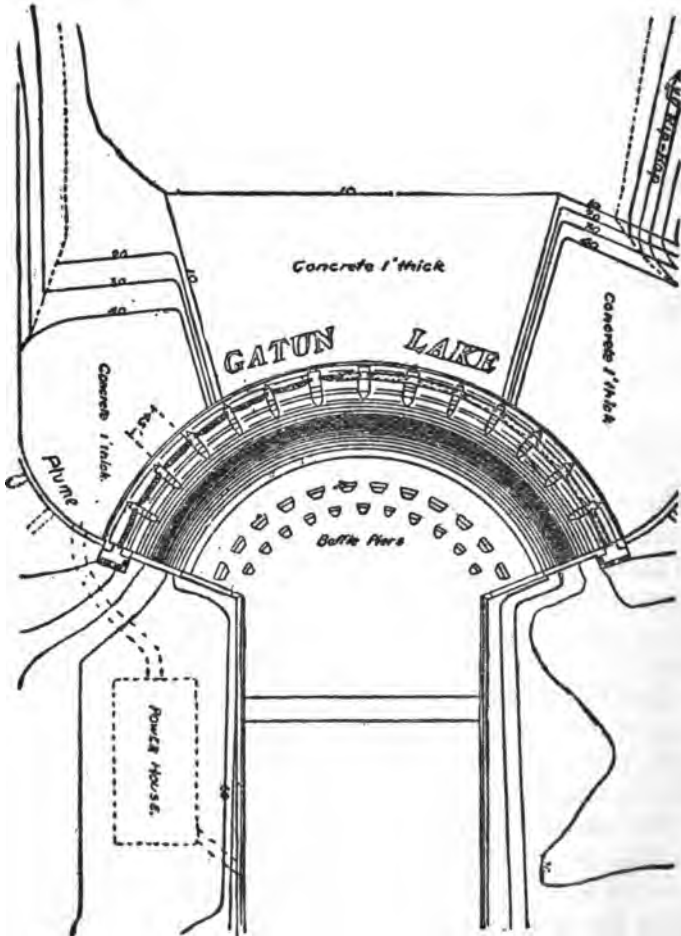
as an integral part of the curved portion of the north spillway approach wall. From the forebay the water is carried to the turbines through three steel plate penstocks, each having an average length of 350 feet. The entrances are closed by cast iron headgates and bar iron trash racks. The headgates are raised and lowered by individual motors which are geared to rising stems attached to the gate castings. The driving machinery and the motors have been housed in a small concrete gatehouse erected upon the forebay wall directly over the gate recesses and trash racks. The gate house has been constructed for the present requirements of three head gates, and provision made for a future addition of three more units.

WATER SUPPLY OF GATUN LAKE

Gatun Lake impounds the waters of a basin comprising 1,320 square miles. (*See Map, p. 162.*) When the surface of the water is at 85 feet above sea level, the lake will have an area of about 164 square miles, and will contain about 183 billion cubic feet of water. During eight or nine months of the year, the lake will be kept constantly full by the prevailing rains, and consequently a surplus will need to be stored for only three or four months of the dry season. The smallest run-off of water in the basin during the past 22 years, as measured at Gatun, was that of the fiscal year, 1912, which was about 132 billion cubic feet. Previous to that year the smallest run-off of record was 146 billion cubic feet. In 1910 the run-off was 360 billion cubic feet, or a sufficient quantity to fill the lake one and a half times. The low record of 1912 is of interest as showing the effect which a similar dry season, occurring after the opening of the Canal, would have upon its capacity for navigation. Assuming that Gatun Lake was at elevation plus 87 at the beginning of the dry season on December 1st, and that the hydroelectric plant at the Gatun Spillway was in continuous operation, and that 48 lockages a day were being made, the eleva-

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tion of the lake would be reduced to its lowest point, plus 79.5, on May 7th, at the close of the dry season, after which



Courtesy of "The Panama Guide"

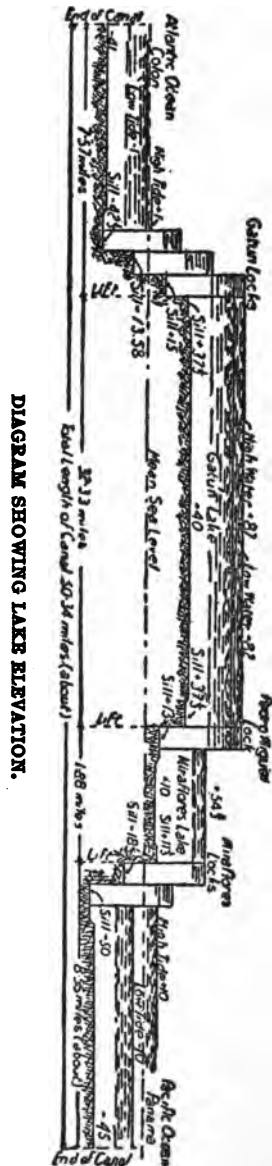
GATUN DAM SPILLWAY.

it would continuously rise. With the water at plus 79 in Gatun Lake there would be 39 feet of water in Culebra

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Cut, which would be ample for navigation. The water surface of the lake will be maintained during the rainy season at 87 feet above sea level, making the minimum channel depth in the Canal 47 feet. As navigation can be carried on with about 39 feet of water, there will be stored for the dry season surplus over 7 feet of water. Making due allowance for evaporation, seepage, leakage at the gates, and power consumption, this would be ample for 41 passages daily through the locks, using them at full length, or about 58 lockages a day when partial length is used, as would be usually the case, and when cross filling from one lock to the other through the central wall is employed. This would be a larger number of lockages than would be possible in a single day. The average number of lockages through the Sault Ste. Marie Canal on the American side was 39 per day in the season of navigation of 1910, which was about eight months long. The average number of ships passed was about $1\frac{1}{2}$ per lockage. The freight carried was about 26,000,000 tons. The Suez Canal passed about 12 vessels per day, with a total tonnage for the same year of 16,582,000.

The water level of Gatun Lake, extending through the Cul-



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ebra Cut, is maintained at the southern end by an earth dam connecting the locks at Pedro Miguel with the high ground to the westward, about 1,400 feet long, with its crest at an elevation of 105 feet above mean tide. A concrete core wall, containing about 700 cubic yards, connects the locks with the hills to the eastward; this core wall resting directly on the rock surface and being designed to prevent percolation through the earth, the surface of which is above the Lake level.

A small lake between the locks at Pedro Miguel and Miraflores has been formed by dams connecting the walls of Miraflores locks with the high ground on either side. The dam to the westward is of earth, about 2,700 feet long, having its crest about 15 feet above the water in Miraflores Lake. The east dam is of concrete, containing about 75,000 cubic yards, about 500 feet in length, and forms a spillway for Miraflores Lake, with crest gates similar to those at the Spillway of the Gatun Dam.

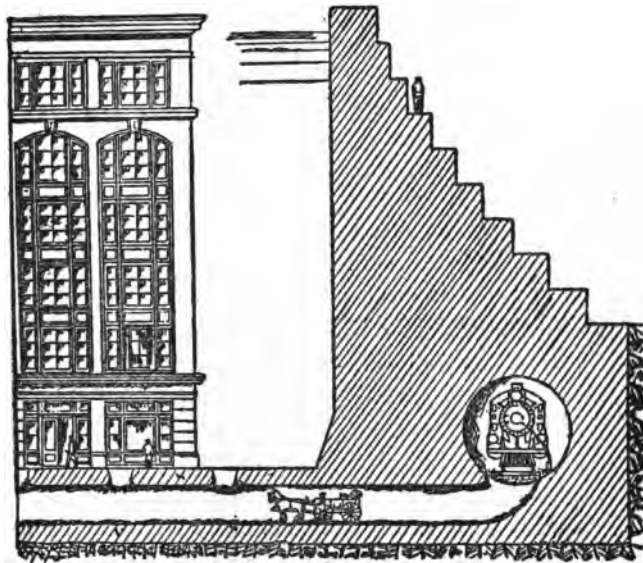
THE LOCKS

There are twelve locks in the Canal, all in duplicate; three pairs in flight at Gatun, with a combined lift of 85 feet; one pair at Pedro Miguel, with a lift of $30\frac{1}{2}$ feet; and two pairs at Miraflores, with a total lift of $54\frac{2}{3}$ feet at mean tide. The dimensions of all are the same—a usable length of 1,000 feet, and a usable breadth of 110 feet. Each lock is a chamber, with walls and floor of concrete, and water-tight gates at each end.

The side walls are 45 to 50 feet thick at the surface of the floor; they are perpendicular on the face, and narrow from a point $24\frac{1}{3}$ feet above the floor, until they are eight feet wide at the top. The middle wall is 60 feet thick and 81 feet high, with vertical faces. At a point $42\frac{1}{2}$ feet above the surface of the floor, and 15 feet above the top of the middle culvert, this wall divides into two parts, leaving a U-shaped space down the center, which is 19 feet broad at

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the bottom and 44 feet broad at the top. In this space is a tunnel, divided into three stories or galleries. The lowest of these divisions is for drainage; the middle for the wires that will carry the electric current to operate the gate and valve machinery, which is installed in the central wall, and the upper division forms a passage-way for the operators. The lock chambers are filled and emptied through



COMPARISON BETWEEN SIDE WALL OF LOCK AND A SIX STORY BUILDING.

lateral culverts in the floors, connecting with main culverts, 18 feet in diameter in the walls, the water flowing in and out by gravity.

The lock gates are steel structures, seven feet thick, 65 feet long, and from 47 to 82 feet high. They weigh from 300 to 600 tons each. Ninety-two leaves are required for the several locks, the total weighing 57,000 tons. Intermediate gates are being used, in order to save water and time, and permit of the division of each lock into two

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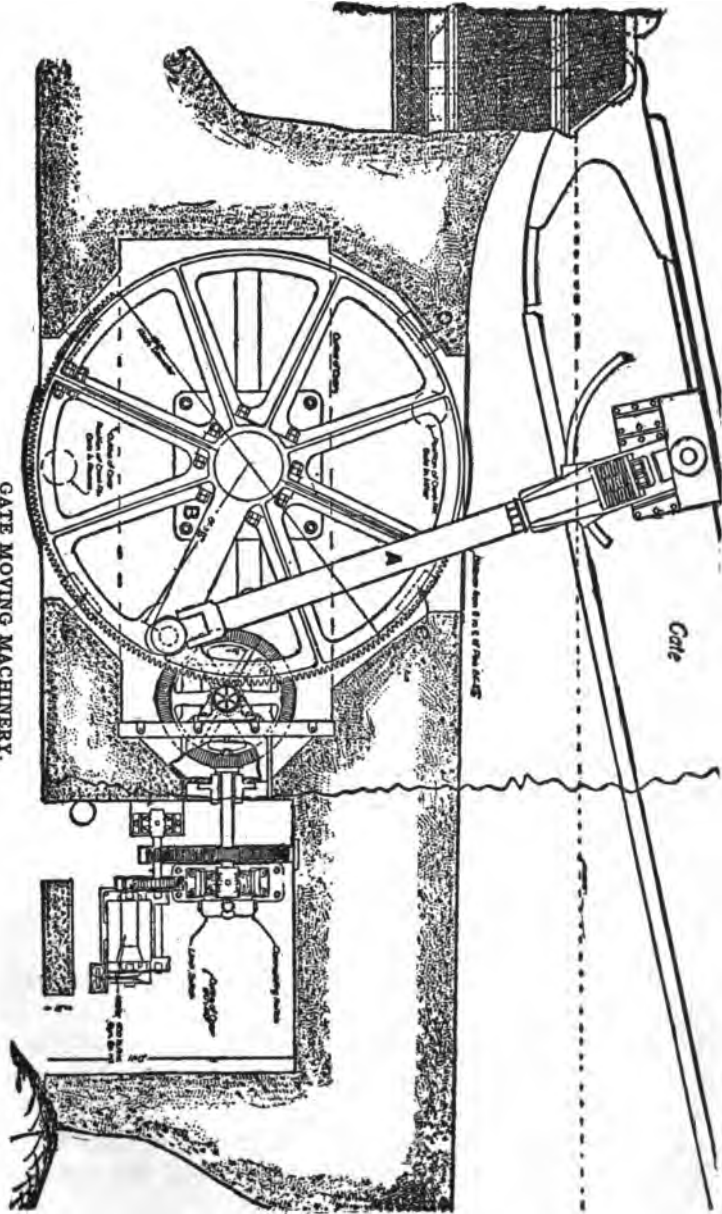
chambers, respectively, 600 and 400 feet long. In the construction of the locks there were used 4,500,000 cubic yards of concrete, which required about the same number of barrels of cement.

The time spent in filling and emptying a lock averages about fifteen minutes, without opening the valves so suddenly as to create disturbing currents in the locks or approaches. The time required to pass a vessel through all the locks is estimated at 3 hours; one hour and a half in the three locks at Gatun, and about the same time in the three locks on the Pacific side. The time of passage of a vessel through the entire Canal is estimated as ranging from 10 to 12 hours, according to the size of the ship, and the rate of speed at which it can travel, since the twenty-four mile passage of Gatun Lake may be made at full speed.

GATE-MOVING MACHINERY

The machinery for opening and closing the miter gates was invented in the office of the Assistant Chief Engineer by Edward Schildhauer. It consists essentially of a crank gear, to which is fastened one end of a strut or connecting rod, the other end of which is fastened to a lock gate. The wheel moves through an arc of 197 degrees, closes or opens the gate leaf, according to the direction in which it is turned. One operation takes 2 minutes. The crank gear is a combination of gear and crank, is constructed of cast steel, is 19 feet 2 inches in diameter, and weighs approximately 35,000 pounds. It is mounted in a horizontal position on the lock wall, turns on a large center pin, and is supported at the rim in four places by rollers. The center pin is keyed into a heavy casting anchored securely to the concrete. The crank-gear has gear teeth on its rim and is driven through a train of gears and pinions by an electric motor in a contiguous room. The motor is remotely controlled by an operator who is stationed at a center control house near the lower end of the upper locks. A simple

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This shows the relation of the bull wheel to strut and gate. A. Strut or connecting rod. B. Bed plate. C. Bearing wheel.

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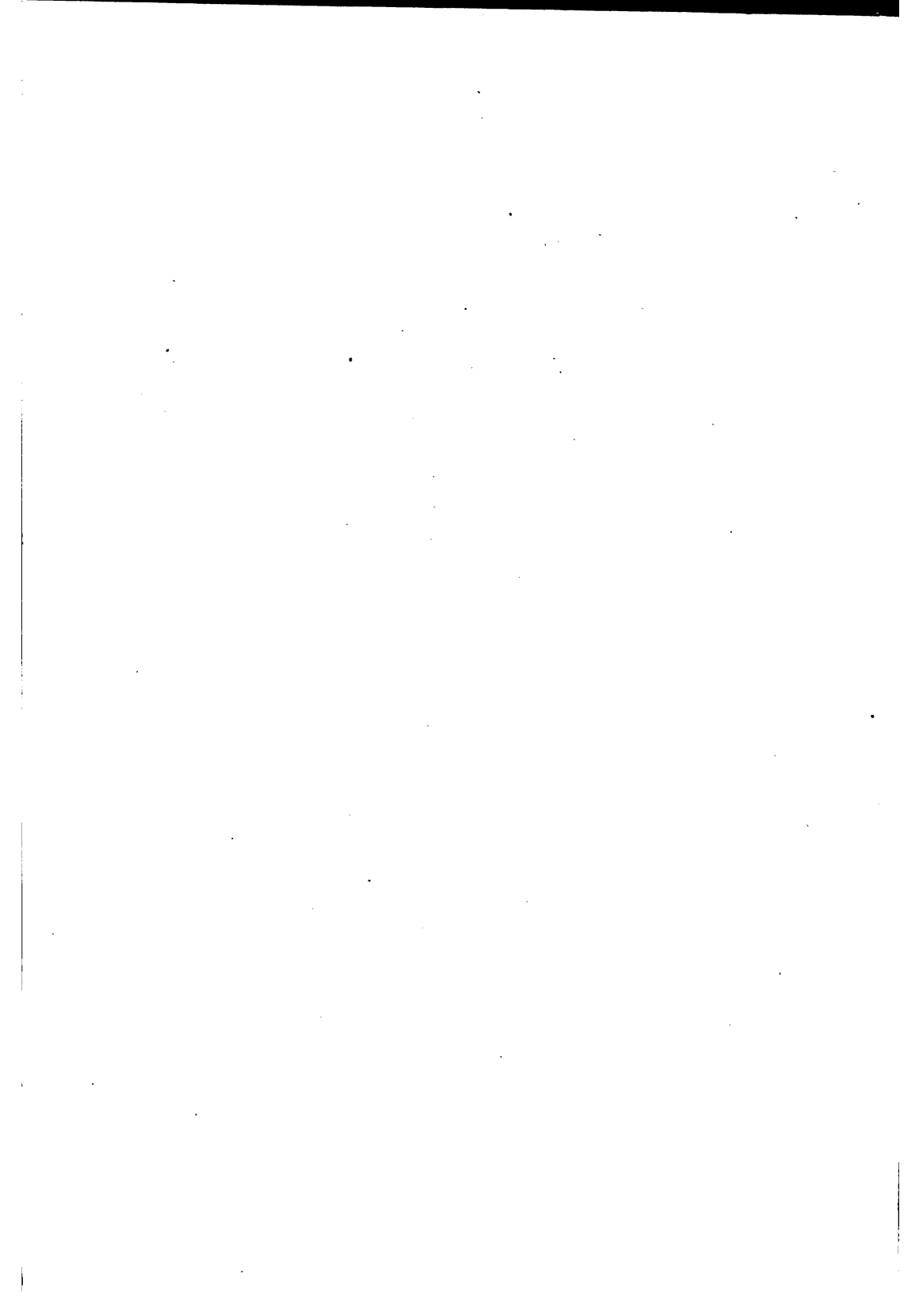
pull of a small switch is sufficient to either close or open a 700-ton gate, the operation being perfectly automatic.

No ship is allowed to pass through the locks under its own power, but is towed through by electric locomotives operating on tracks on the lock walls. The system of towing provides for the passing through the locks of a ship at the rate of 2 miles an hour. The number of locomotives varies with the size of the vessel. The usual number required is 4: 2 ahead, 1 on each wall, imparting motion to the vessel, and 2 astern, 1 on each wall, to aid in keeping the vessel in a central position and to bring it to rest when entirely within the lock chamber. They are equipped with a slip drum, towing windlass and hawser which permits the towing line to be taken in or paid out without actual motion of the locomotive on the track. The locomotives run on a level, except when in passing from one lock to another they climb heavy grades. There are two systems of tracks: one for towing, and the other for the return of the locomotives when not towing. The towing tracks have center racks or cogs throughout, and the locomotives always operate on this rack when towing. At the incline between locks the return tracks also have rack rails, but elsewhere the locomotives run by friction. The only crossovers between the towing and return tracks are at each end of the locks, and there are no switches in the rack rail.

PROTECTIVE DEVICES

Several protective devices have been used to safeguard the gates in the locks.

First. Fender chains, 24 in number, each weighing 24,098 pounds, have been placed on the up-stream side of the guard gates, intermediate and safety gates of the upper locks, and in front of the guard gates at the lower end of each flight of locks. They prevent the lock gates from being rammed by a ship that might approach the gates under its own steam or by escaping from the towing loco-





GATUN UPPER LOCKS, EAST CHAMBER.

The view is looking north from the forebay showing the upper guard gates and emergency dam.

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motives. In operation, the chain is stretched across the lock chamber from the top of the opposing walls, and when it is desired to allow a ship to pass, the chain is lowered into a groove made for the purpose in the lock floor. It is raised again after the ship passes. The raising and lowering is accomplished from both sides by mechanism mounted in chambers or pits in the lock walls. This mechanism consists of a hydraulically operated system of cylinders, so that 1 foot of movement by the cylinder accomplishes 4 feet by the chain. If a ship exerting a pressure of more than 750 pounds to the square inch should run into the fender, the chain is paid out gradually by an automatic release until the vessel comes to a stop. Thus, a 10,000-ton ship, running at 4 knots an hour, after striking the fender can be brought to a stop within 73 feet, which is less than the distance which separates the chain from the gate.

Second. Double gates have been provided at the entrances to all the locks and at the lower end of the upper lock in each flight, the guard gate of each pair protecting the lower gate from ramming by a ship which might possibly get away from the towing locomotives and break through the fender chain.

Third. A dam of the movable type called an emergency dam has been placed in the head bay above the upper locks of each flight for the purpose of checking the flow of water through the locks in case of damage, or in case it is necessary to make repairs, or to do any work in the locks which necessitates the shutting off of all water from the lake levels. Each dam is constructed on a steel truss bridge of the cantilever type, pivoted on the side wall of the lock approach, and when not in use rests on the side wall parallel to the channel. When the dam is used, the bridge is swung across the channel with its end resting on the center wall of the lock. A series of wicket girders hinged to this bridge are then lowered into the channel with their ends resting in iron pockets embedded

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in the lock floor. After the girders have been lowered into place, they afford runways for gates which can be let down one at a time, closing the spaces between the wicket girders. These gates form a horizontal tier spanning the width of the Canal and damming the water to a height of 10 feet. Another series of panels is then lowered, and so on until the dam, constructed from the bottom upward, completely closes the channel. When the dam has checked the main flow, the remainder, due to the clearance between the vertical sides of the gates, may be checked by driving steel pipes between the sides of the adjacent panels. These dams are operated in three movements, and the machinery for operating is, therefore, in three classes, gate-moving, raising and lowering the wicket girders, and hoisting the gates on the girders, all driven by electric motors.

CAISSON GATES

To permit examining, cleaning, painting, and repairing the lower guard gates of the locks, and the Stoney gates of the Spillway dam, and for access in the dry to the sills of the emergency dams, there have been provided floating caisson gates of the molded ship type. When their use is required the caissons are towed into position in the forebay of the upper lock, above the emergency dam, or between the piers of the Spillway, and sunk. The caissons are equipped with electric motor driven pumps for use in pumping out the caissons and for unwatering the locks.

ELECTRIC CONTROL OF LOCK MACHINERY

Principles
The gates, valves, and fender chains of the locks are operated by electricity, and remotely controlled from a central point; that is, there is a central control station for each of the series of locks at Gatun, Pedro Miguel, and Miraflores. In passing a ship through the locks it is necessary to open and close the miter gates weighing from 380 to 730 tons, to fill and empty lock chambers containing

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from three and one half to five million cubic feet of water, to raise and lower fender chains weighing 24,098 pounds each, and to tow the vessel through the locks. All these operations, except that of towing, are controlled by one man at a switchboard.

The control system for Gatun Locks is typical. Water is let into the lock chambers or withdrawn from them by means of culverts under the lock floors, which connect with larger culverts in the lock walls, through which water is carried from the higher to the lower levels. The main supply culverts are 18 feet in diameter, and the flow of water through them is controlled by rising-stem gate valves, which can be completely opened or closed in one minute. In the center wall the culvert feeds both lock chambers, and therefore at each outlet into the lateral culverts there is a valve of the cylindrical type, in order that water may be let into or withdrawn from either chamber at will. A complete opening or closing of these cylindrical valves takes ten seconds. The miter gates are never opened or closed with a head of water on either side of them, the chambers being first emptied or filled by means of the valve and culvert system. The time required either to open or close the miter gate is two minutes.

A ship to be raised to the lake level comes to a full stop in the forebay of the lower lock, prepared to be towed through one of the duplicate locks by electric towing locomotives. The water in the lower lock chamber is equalized with the sea level channel, after which the miter gates are opened, the fender chain lowered and the vessel passed into the first chamber, where the water is at sea level. Then the miter gates are closed. The rising stem gate valves at the outlet of the main culverts are closed, while those above are opened, allowing water to flow from an upper level into the lower chamber, which, when filled, raises the vessel 28½ feet, to the second level. This operation is repeated in the middle and upper locks until the ship has been raised to the full height of 85 feet above the level of

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the sea. At Gatun, in the passing of a large ship through the locks, it is necessary to lower 4 fender chains, operate 6 pairs of miter gates and force them to miter, open and close 8 pairs of rising stem gate valves for the main supply culverts, and 30 cylindrical valves. In all, no less than 98 motors are set in motion twice during each lockage of a single ship, and this number may be increased to 143, dependent upon the previous condition of the gates, valves and other devices.

Each gate leaf, valve, and fender chain is operated by a separate motor mounted near the machinery in chambers in the lock wall, the motors acting through suitable gears (or pump in the fender chain) upon the various machines. In each machinery chamber is erected a starting panel containing contactors by which current will be applied to the motor and these panels are in turn controlled from a main unit in the central control house. Some of the machinery chambers at Gatun are 2,700 feet distant from the point of control; 90 per cent of them are within 2,000 feet, and 50 per cent of the total within 1,200 feet.

The station from which control is exercised over the movement of all the machines is on the center wall at the lower end of the upper flight of locks at Gatun, and similarly placed at Pedro Miguel and Miraflores. It is in a building raised high enough above the top of the wall to allow a towing locomotive to pass under, a height of 16 feet, and to command an uninterrupted view of every part of the locks. In this house is a double control board duplicated to conform to the duplication in locks. The control board is in the nature of a bench or table, 32 inches above the floor, containing a representation, part model and part diagrammatic, of the flight of locks controlled by the respective series of switches. Standing at his switchboard the operator throws the switches, and sees before him in model or diagram the progress of the fender chains as they rise and fall, the movement of the miter gates inch by inch, the opening and closing of the gate valves in the main cul-

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verts at every stage, the operation of the cylindrical valves, and, in addition, indication of the gradual rise or fall of the water in the lock chambers. The switches controlling the various motors, together with their indicators, are mounted upon the board in the same relative position as the machines themselves in the lock walls. Some distortion of scale will be allowed, to give room for the switches. The board is not over 4 feet in width, in order that the operator may be able to reach beyond the middle of it, and the length of the board is limited to 30 feet at Gatun, and proportionally at the other locks.

The system is interlocking, so that certain motors can not be started in a certain direction until other motors are operated in a proper manner to obtain consistent operation on the whole, and to avoid any undesirable or dangerous combinations in the positions of valves, gates, or fender chains. In this way and by the use of limit switches the factor of the personal equation in operating the machines is reduced to a minimum, almost mechanical accuracy being obtained. Before the operating pair of valves in the main culverts can be opened, at least one pair of valves at the other ends of the locks, both upstream and downstream, must first be closed. This limits an operator to the act of equalizing water levels between locks, and keeps him from allowing water to flow from, say the lake level to the middle lock past the upper lock, thus preventing a possible flooding of the lock walls and machinery rooms. Interlocks, devoted to the control of action between the gate valves in the main culverts and the miter gates, prevent valves being opened a lock length above or below a miter gate which is being opened or closed, and thus prevent an operator causing a flow of water while the miter gates are being moved. Interlocks for the cylindrical valves guarding the openings from the center wall culvert to the lateral culverts keep those of one side or the other closed at all times, except when it is desired to cross-fill the chambers, when they may be opened by special procedure. An

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interlock prevents the operator from starting to open a miter gate before unlocking the miter-forcing machine. The miter gates guarded by a fender chain must be opened before the chain can be lowered, and the chain must be raised again before the gate can be closed, or more exactly the switches must be thrown in this order, but the operations may proceed at the same time. The simple interlocks will prevent such a mistake as leaving the chain down through lapse of memory when it should be up to protect the gate.

LIGHTING THE CANAL

The general scheme of lighting and buoying the Canal includes the use of range lights to establish direction on the longer tangents and of side lights spaced about 1 mile apart to mark each side of the channel. The range lights are omitted in Culebra Cut, where their use is hardly practicable, and on four of the shorter tangents on the remainder of the Canal. In the Cut have been placed three beacons at each angle, and between these intermediate beacons in pairs on each side of the Canal. By keeping his ship pointed midway between these beacons, the pilot is able to adhere closely to the center of the Canal. At each tangent it is necessary to have two ranges of two lights each to prolong the sailing line in order that the pilot may hold his course up to the point of turning. These range lights will be situated on land. There are three types, all of reinforced concrete. The more elaborate structures are used on the Gatun locks and dam and in the Atlantic and Pacific Divisions, where they are closer to the sailing lines of the vessels, while simpler structures have been placed in the Gatun Lake, where they are under less close observation. A light and fog signal on the west breakwater in Limon Bay is also included. The illuminants are gas and electricity, the latter being used whenever the light is sufficiently accessible. For the floating buoys, and for the towers and beacons which are in inaccessible places,

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the system using compressed acetylene dissolved in acetone has been adopted. The buoys are composed of a cylindrical floating body or tank, surmounted by a steel frame which supports the lens at a height of about 15 feet above the water level. The buoys are moored in position along the edge of the dredged channel by a heavy chain and a concrete sinker, and should remain lighted for six to twelve months without being recharged. The candlepower of the range lights varies according to the length of the range, from about 2,500 to 15,000 candlepower. The most powerful lights are those marking the sea channels at the Atlantic and Pacific entrances, they being visible from about 12 to 18 nautical miles. The beacons and gas-buoy lights will have about 850 candlepower. White lights will be used throughout, and, in order to eliminate the possibility of confusing the lights with one another and with the lights on shore, all range lights, beacons, and buoys will have individual characteristics formed by flashes and combinations of flashes of light and dark intervals.

EXCAVATION

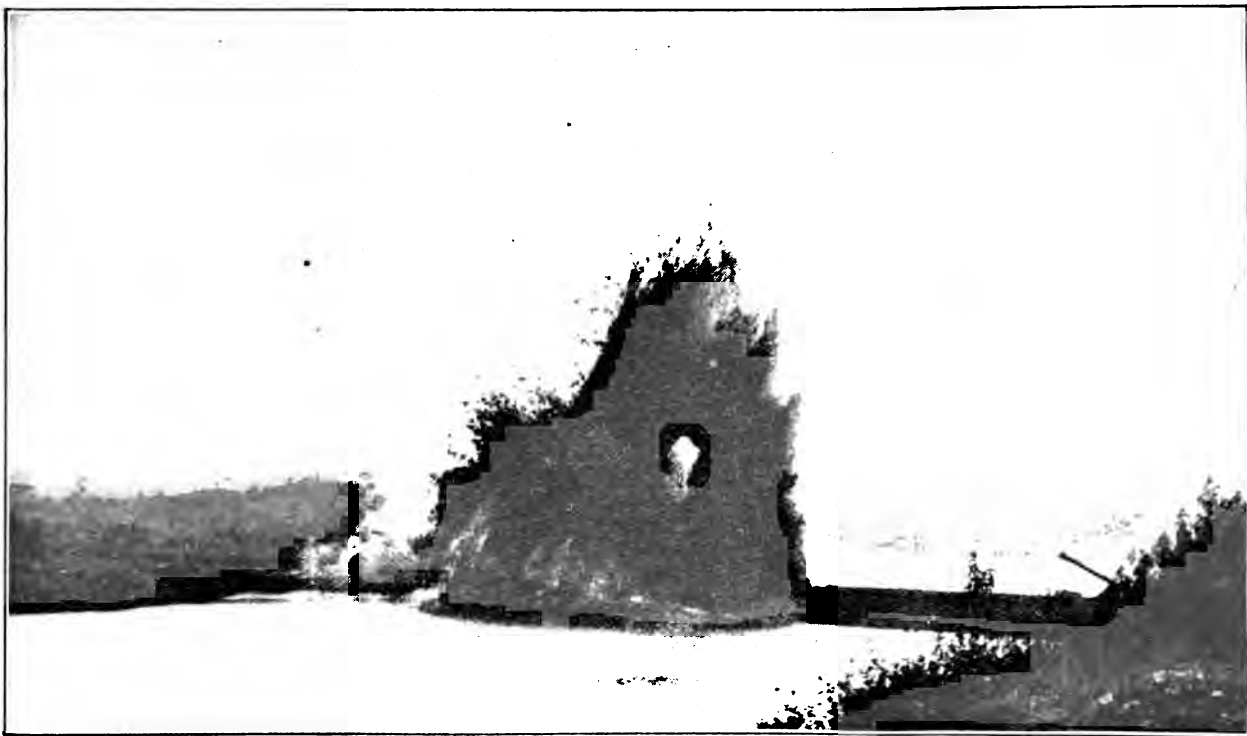
The total excavation, dry and wet, for the Canal as originally planned, was estimated at 103,795,000 cubic yards, in addition to the excavation by the French companies. Changes in the plan of the Canal, made subsequently by order of the President, increased the amount to 174,666,594 cubic yards. Of this amount, 89,794,493 cubic yards were to be taken from the Central Division, which includes the Culebra Cut. In July, 1910, a further increase of 7,871,172 cubic yards was made, of which 7,330,525 cubic yards were to allow for slides in Culebra Cut, for silting in the Chagres section, and for lowering the bottom of the Canal from 40 to 39 feet above sea level in the Chagres section. These additions increased the estimated total excavation to 182,537,766 cubic yards. In 1911, a further increase of 12,785,613 cubic yards was made,

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of which 5,257,281 cubic yards was for slides in Culebra Cut, and the remainder for additional excavation and silting in the Atlantic and Pacific entrances, raising the grand total of estimated excavation to 195,323,379 cubic yards. In 1912 an increase of 17,180,621 cubic yards was made, of which 3,545,000 cubic yards was for slides in Culebra Cut and the remainder for dredging excavation at Gatun locks, silting in the Atlantic entrance, and for the Balboa terminals, and in 1913 came a still further increase of 20,126,000 cubic yards, of which 9,067,000 cubic yards was due to slides and breaks in Culebra Cut, bringing the grand total of estimated excavation to 232,353,000 cubic yards. Deducting Balboa terminal excavation, the total for the Canal proper, according to the estimate of 1913, is about 223,559,000 cubic yards, or nearly double the amount of the original estimate made in the minority report of the International Board of Consulting Engineers in 1906. The points of deepest excavation are in Culebra Cut, 495 feet above the bottom of the Canal at Gold Hill, and 364 feet above at Contractor's Hill opposite. The widest part of the Cut is opposite the town of Culebra, where owing to the action of slides on both banks, the top width is about half a mile. Active excavation work on a large scale did not begin until 1907, when 15,765,290 cubic yards were removed. In 1908, over 37,000,000 cubic yards were removed, and in 1909, over 35,000,000 making a total for the two years of over 72,000,000 yards, or a monthly average for those two years of 3,000,000 cubic yards. In 1910, 31,437,000 cubic yards were removed; in 1911, 31,603,000; in 1912, 30,269,000; and to July 1, 1913, 18,324,637 cubic yards, including both wet and dry excavation, and leaving a total of 25,748,051 yet to be taken out.

SLIDES AND BREAKS

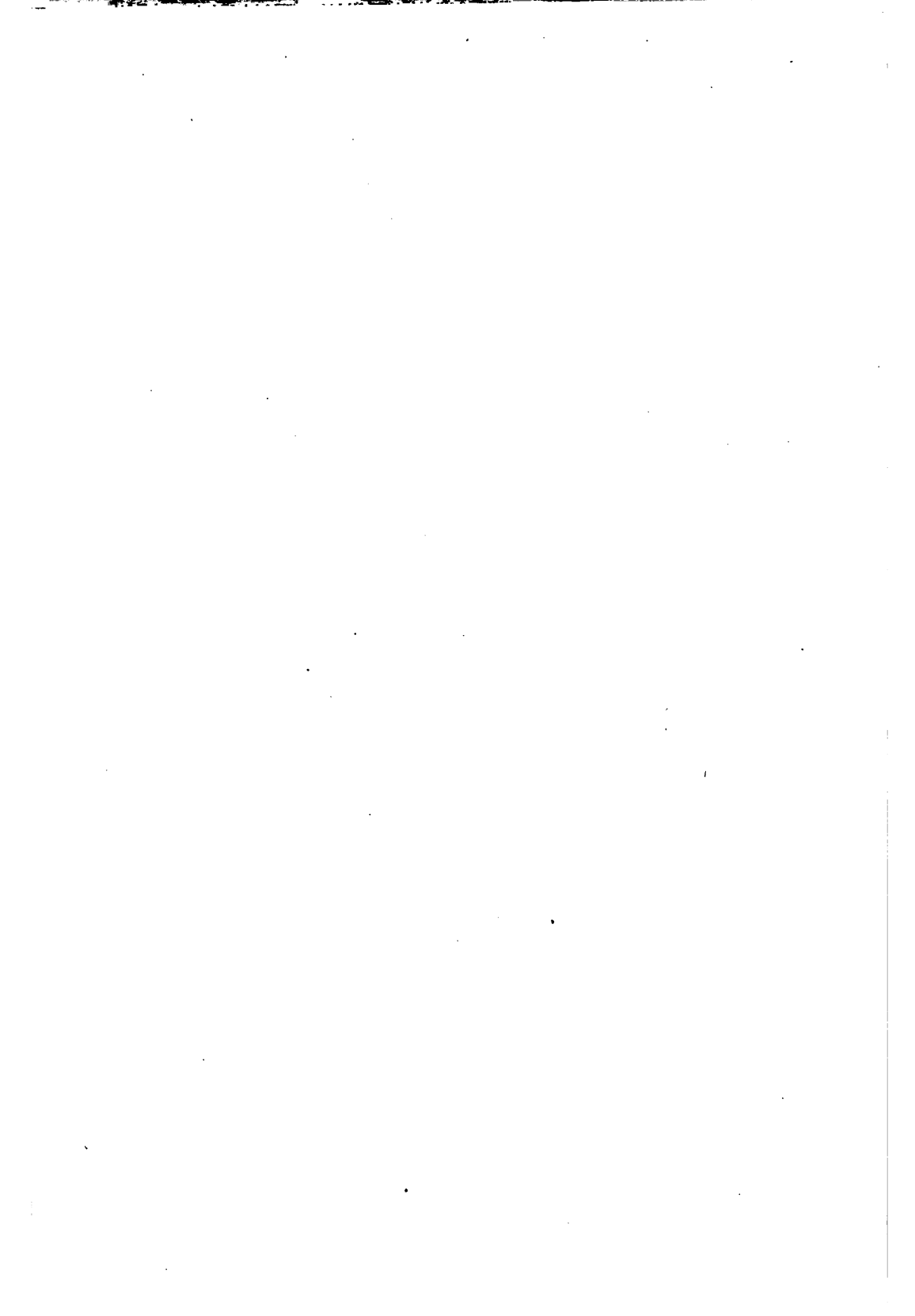
There have been in all 26 slides and breaks in Culebra Cut; 17 covered areas varying from 1 to 75 acres and 9



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FORTY TONS OF DYNAMITE DESTROY THE LAST BARRIER BETWEEN THE OCEANS.

The blowing up of Gamboa Dike, the last of the dikes in the Panama Canal. This dike separated the water in the Gatun locks from Culebra Cut. The removal of the dike by a discharge of 40 tons of dynamite set off by President Wilson, was the last stage in the completion of the great waterway. Dredges were put to work immediately widening the channel at Cucaracha slide in Culebra Cut so that within a short time the Canal was ready for use throughout its entire length.



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covered areas of less than 1 acre each, making in all a total of 225 acres. One variety of slide is caused by the slipping of the top layer of clay and earth on a smooth sloping surface of a harder material. The largest slide of this character is that known as Cucaracha on the east bank of the Canal just south of Gold Hill. This gave the first French company trouble during the final years of its operations. It first gave the Americans trouble in 1905, and between that date and July 1, 1913, over 12,000,000 cubic yards of material were removed from the Canal because of it. It broke nearly 1,900 feet back from the axis of the Canal and covers an area of 47 acres. Another variety of slide, properly called break, is due to the steepness of the slopes and the great pressure of the superincumbent material upon the underlying layers of softer material. The largest slide or break of this type is on the west side of the Cut at Culebra just north of Contractor's Hill and covers an area of 75 acres. Over 7,000,000 cubic yards of material have been removed from this slide. On the east side of the Cut a similar slide covers an area of about 50 acres, breaking back about 1,300 feet from the center of the Canal. About a half million cubic yards have been taken out of this slide and more remains to be removed. It is estimated that the total amount of material removed from the Canal because of the slides will aggregate between 21,000,000 and 22,000,000 cubic yards.

DRILLING AND BLASTING

Most of the material excavated in Culebra Cut has consisted of rock varying from very soft, which readily disintegrates on exposure to the atmosphere, to very dense rock of great hardness. It has been necessary before excavating this material to drill and blast it. Two kinds of drills have been used—tripod and well—both obtaining their power from a 10-inch compressed air main on the west bank of the Cut which is supplied by three batteries of

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air compressors placed at equal distances along the 9 miles of the Cut. The usual depth of drill holes has been about 27 feet, three feet deeper than the steam shovels have excavated. The drill holes, placed about 14 feet apart, are loaded with 45 per cent potassium nitrate dynamite in quantities depending upon the character of the rock, and are connected in parallel and fired by means of a current from an electric light plant. The maximum number of drills in use at any one time in Culebra Cut was 377, of which 221 were tripod and 156 well. With these over 90 miles of holes have been drilled in a single month. A pound of dynamite has been used to about every $2\frac{1}{2}$ cubic yards of material blasted, and the quantity used in Culebra Cut during several years has averaged about 6,000,000 pounds a year.

CAPACITY OF STEAM SHOVELS AND DIRT TRAINS

There have been several classes of steam shovels engaged in excavating work, equipped with dippers ranging in capacity from $1\frac{3}{4}$ cubic yards to 5 cubic yards, and a trenching shovel, which has a dipper with a capacity of $\frac{3}{4}$ of a cubic yard. In Culebra Cut excavation the 5-yard dippers have been used almost entirely.

Each cubic yard, place measurement, of average rock weighs about 3,900 pounds; of earth, about 3,000 pounds; of "the run of the Cut," about 3,600 pounds, and is said to represent about a two-horse cart load. Consequently, a five cubic yard dipper, when full, carries 8.7 tons of rock, 6.7 tons of earth, and 8.03 tons of "the run of the Cut."

Three classes of cars were used in hauling spoil—flat cars with one high side, which were unloaded by plows weighing from 14 to 16 tons, operated by a cable upon a winding drum, and two kinds of dump cars, one large and one small. The capacity of the flat cars is 19 cubic yards; that of the large dump cars 17 cubic yards, and that of the small dump cars, 10 cubic yards. The flat car train was

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ordinarily composed of 20 cars in hauling from the cut at Pedro Miguel, and 21 cars in hauling from the cut at Matachin. The large dump train was composed of 27 cars, and the small dump train of 35 cars.

The average load of a train of flat cars, in hauling the mixed material known as "the run of the Cut," was 610.7 tons (based on a 20-car train); of a train of large dump cars, 737.68 tons, and of a train of small dumps, 562.5 tons.

The average time consumed in unloading a train of flat cars was from 7 to 15 minutes; in unloading a train of large dump cars, 15 to 40 minutes; and in unloading a train of small dump cars, 6 to 56 minutes. The large dump cars were operated by compressed air power furnished by the air pump of the locomotive, while the small dump cars were operated by hand.

The record day's work for one steam shovel was that of March 22, 1910, 4,823 cubic yards of rock (place measurement), or 8,395 tons. The highest daily record in the Central Division was on March 11, 1911, when 51 steam shovels and 2 cranes equipped with orange peel baskets excavated an aggregate of 79,484 cubic yards, or 127,742 tons. During this day, 333 loaded trains and as many empty trains were run to and from the dumping grounds.

The greatest number of shovels in use at one time in the Cut was 43, and the greatest monthly excavation in any single month, in the Cut, was obtained in March, 1911, when 1,728,748 cubic yards of material, mostly rock, were excavated.

To handle this amount of material required the services of 115 locomotives and 2,000 cars, giving about 160 loaded trains per day to the dumps, which on the average were about 12 miles distant, the haul one way varying from about one mile to 33 miles. To serve properly the trains and shovels employed in excavation work in the Cut, although it is less than nine miles in length, about 100 miles of track have been required, or an average of over nine parallel tracks at all points.

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BREAKWATERS

Breakwaters have been constructed at the Atlantic and Pacific entrances of the Canal. That in Limon Bay, or Colon harbor, extends into the bay from Toro Point at an angle of 42° and $53'$ northward from a base line drawn from Toro Point to Colon light, and is 10,500 feet in length, or 11,700 feet, including the shore connection, with a width at the top of fifteen feet and a height above mean sea level of ten feet. The width at the bottom depends largely on the depth of water. It contains approximately 2,840,000 cubic yards of rock, the core being formed of rock quarried on the mainland near Toro Point, armored with hard rock from Porto Bello. The purpose of the breakwaters is to convert Limon Bay into a safe anchorage, to protect shipping in the harbor of Colon, and vessels making the north entrance to the Canal, from the violent northers that are likely to prevail from October to January, and to reduce to a minimum the amount of silt that may be washed into the dredged channel.

The breakwater at the Pacific entrance extends from Balboa to Naos Island, a distance of about 17,000 feet, or a little more than three miles. It lies from 900 to 2,700 feet east of and, for the greater part of the distance, nearly parallel to the axis of the Canal prism; varies from 20 to 40 feet in height above mean sea level, and is from 50 to 3,000 feet wide at the top. It contains about 18,000,000 cubic yards of earth and rock, all of which was brought from Culebra Cut. It was constructed for a two-fold purpose; first to divert cross currents that would carry soft material from the shallow harbor of Panama into the Canal channel; second, to furnish rail connection between the islands and the mainland.

CHANGE OF LOCATION OF LOCKS

A brief explanatory review of the changes referred to may facilitate a clear understanding of the final plan.

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It has been asserted that the abandonment of the Sosa site was in response to a new idea acted upon without due consideration. The facts in the matter are these: In 1905, the present chief engineer visited the Isthmus in the capacity of a member of the Board of National Defenses. In a relevant report, he made the following statement:

"The great objection to the locks at Sosa Hill is the possibility of their destruction by the fire from an enemy's ship. If, as has been suggested to me by officers of this department entitled to speak with authority on the subject, these locks can be located against and behind Sosa Hill in such a way as to use the hill as a protection against such fire, then economy would lead to the retention of the lake. . . . If, however, Sosa Hill will not afford a site with such protection, then it seems to me wiser to place the locks at Miraflores."

Mature study of the question led to the conclusion that locks at Sosa would not be sufficiently secure, and it was further evident that their transfer to Miraflores would be accompanied by a saving in cost. The latter point, it should be remembered, was that decided upon by the Walker Commission for the site of the tide lock at the Pacific end. So that it appears that this, like all the other features of the plan, has been the subject of the most exhaustive investigation and thought.

CHANGES IN DIMENSIONS

The increase of channel width through one-half the length of Culebra Cut from 200 feet to 300 feet at the bottom, which will enable ships to pass each other in any part of the Cut, was not made on the recommendation of the Commission, but by executive order.

The usable dimensions of the locks were changed at the instigation of the President and on the recommendation of the General Board of the Navy from 900 feet and 95 feet, to 1,000 feet and 110 feet.

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On this point Colonel Goethals has said: "It is objected that the size of the locks limits the Canal to vessels which can use them. This is true. The present lock designs provide intermediate gates dividing the locks into lengths of 600 and 400 feet. About 98 per cent of all ships, including the largest battleships now building, can be passed through the 600-foot lengths, and the total lock length will accommodate the largest commercial vessels now building, which, I believe, are 1,000 feet long and 88 feet beam. It is true that ships may increase in size so as to make the present locks obsolete, but the largest ships now afloat can not navigate the Suez Canal, nor the proposed sea level canal at Panama. It must also be remembered that the commerce of the world is carried by the medium-sized vessels, the length of only one of the many ships using the Suez Canal being greater than 600 feet."

It is undoubtedly fortunate that Colonel Goethals' judgment in this matter was not accepted, since during the past two years a great increase in the size of both commercial and war vessels has come about, chiefly noticeable in width. Our new battleships have a beam of 97 feet and upwards, which will leave a clearance in the lock chambers of less than 13 feet in all, or about 6 feet on either side. Commercial vessels now built, and others whose keels have been laid, have a beam of 96 feet, so that it is quite possible that the locks may prove to be too narrow before they are found too short.

The height of the Gatun Dam was decreased, so that its crest stands 30 feet, instead of 50 feet, above the normal level of the lake, which is 85 feet.

This change was made because, with the progress of time and more thorough knowledge of the foundation material, it became quite evident that the larger dimensions were unnecessary, and to build in accordance with them would be a wasteful expenditure of time and money. The reduced weight is sufficient to meet the utmost demands of stability, and the reduced height is ample for the com-

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plete retention of the lake, which can never, under any conceivable circumstances, rise to 100 feet above sea level.

COST OF THE CANAL

The present estimated cost of the Canal, which it is improbable that any future conditions will materially affect, is about \$375,000,000. No unknown factors, nor hypothetical calculations entered into the preparation of these figures. This estimate is largely in excess of that which formed part of the report of the Board of Consulting Engineers, but which was based on data much less complete than that since rendered available. During the last six years of the work there was an increase in the wage scale and in the cost of material. Wages on the Isthmus exceeded those in the United States from 40 to 80 per cent for the same class of labor. The original estimates were based on a ten-hour day, but Congress afterward imposed upon the Commission the observance of an eight-hour day. The various changes already noted, and others of a minor character, but considerable in the aggregate, increased the quantity of the work to be done by 50 per cent. Despite all this, the unit costs increased no more than 20 per cent. Furthermore, no such system of housing and caring for the employees as was maintained was anticipated by the Board.

In addition, municipal improvements in Panama and Colon, together with advances to the Panama Railroad, approximated \$15,000,000, a sum which will eventually be returned to the Treasury of the United States.

APPROPRIATIONS

Payment to the New Panama Canal Company.....	\$40,000,000.00
Payment to Republic of Panama.....	10,000,000.00
Appropriation, June 28, 1902.....	10,000,000.00
Appropriation, December 21, 1905.....	11,000,000.00
Deficiency, February 27, 1906.....	5,990,786.00
Appropriation, June 30, 1906.....	25,456,415.08
Appropriation, March 4, 1907.....	27,161,367.50
Deficiency, February 15, 1908.....	12,178,900.00

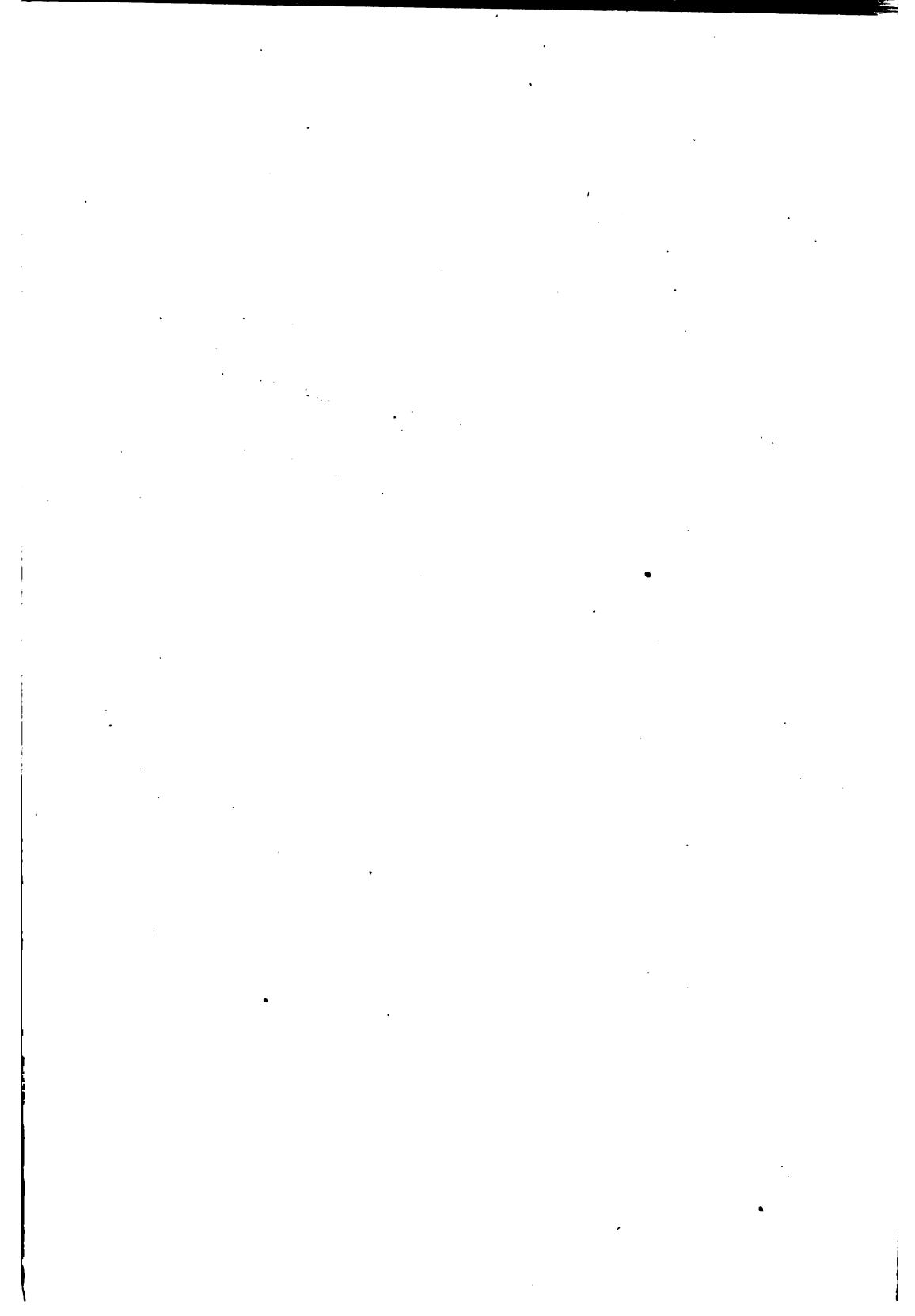
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Appropriation, May 27, 1908.....	\$29,187,000.00
Deficiency, March 4, 1909.....	5,458,000.00
Appropriation, March 4, 1909.....	33,638,000.00
Deficiency, February 25, 1910.....	76,000.00
Appropriation, June 25, 1910.....	37,855,000.00
Appropriation, March 4, 1911.....	45,560,000.00
Appropriation, August 24, 1912.....	28,980,000.00
Private Act. Relief of Elizabeth G. Martin.....	1,200.00
Private Act. Relief of Marcellus Troxell.....	1,500.00
Private Act. Relief of W. L. Miles.....	1,704.18
Private Act. Relief of Chas. A. Caswell.....	1,056.00
Private Act. Relief of Alexandro Comba.....	500.00
Private Act. Relief of Douglas B. Thompson.....	1,500.00
Private Act. Relief of Robert S. Gill.....	2,520.00
Total.....	<u>\$322,551,448.76</u>
Appropriation for Fortifications, March 4, 1911.....	3,000,000.00
Appropriation for Fortifications, August 24, 1912.....	<u>2,806,950.00</u>

CLASSIFIED EXPENDITURES TO NOVEMBER 1, 1912

Department of Construction and Engineering.....	\$159,411,558.14
Department of Construction of Engineering Plant.....	2,868,362.47
Department of Sanitation.....	15,319,882.40
Department of Civil Administration.....	5,961,599.68
Department of Law.....	30,887.52
Panama Railroad, Second Main Track.....	1,123,477.93
Panama Railroad, Relocated Line.....	8,866,392.02
Purchase and Repair of Steamers.....	2,680,112.01
Zone Water Works and Sewers.....	5,140,506.45
Zone Roadways.....	1,579,724.67
Loans to Panama Railroad Company.....	3,247,332.11
Construction and Repair of Buildings.....	10,188,813.63
Purchase from New Panama Canal Company.....	40,000,000.00
Payment to Republic of Panama.....	10,000,000.00
Miscellaneous.....	4,207,175.37
Total.....	<u>\$270,625,624.40</u>
Expenditures for Fortifications to Nov. 1, 1912.....	<u>1,685,315.75</u>

The balances carried in expenditure accounts, which are included in the last item above, for water works, sewers, and pavements in the cities of Panama and Colon amounted





PEDRO MIGUEL LOCKS.

The south end of the East Chamber, showing construction of safety and lower gates.

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altogether to \$2,395,358.79. The unexpended balance in the appropriation for sanitation in the cities of Panama and Colon, available for expenditures on water works, sewers, and pavements, was \$97,465.64, including transfer of appropriations for quarter ended September 30, 1912.

A careful official estimate has been made by the Canal Commission of the value to the Commission at the present time of the franchises, equipment, material, work done, and property of various kinds for which the United States paid the French Canal Company \$40,000,000. It places the total value at \$42,000,000, divided as follows:

Excavation, useful to the Canal, 29,708,000 cubic yards.	\$25,389,240.00
Panama Railroad Stock.	9,844,320.90
Plant and material, used, and sold for scrap.	2,112,063.00
Buildings, used.	2,054,203.00
Surveys, plans, maps, and records.	2,000,000.00
Land.	1,000,000.00
Clearings, roads, etc.	100,000.00
Ship channel in Panama Bay, four years' use.	500,000.00
Total.	\$42,799,826.00

The Canal Zone contains about 436 square miles, about 95 of which will be under the waters of the Canal and Gatun and Miraflores Lakes. It begins at a point 3 marine miles from mean low water mark in each ocean, and extends for 5 miles on each side of the center line of the route of the Canal. It includes the group of islands in the Bay of Panama named Perico, Naos, Culebra, and Flamenco. The cities of Panama and Colon are excluded from the Zone, but the United States has the right to enforce sanitary ordinances in those cities, and to maintain public order in them in case the Republic of Panama should not be able, in the judgment of the United States, to do so.

Of the 436 square miles of Zone territory, the United States owns about 363, and 73 are held in private ownership. Under the treaty with Panama, the United States has the right to acquire by purchase, or by the exercise of

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the right of eminent domain, any lands, buildings, water rights, or other properties necessary and convenient for the construction, maintenance, operation, sanitation, and protection of the Canal, and it can, therefore, at any time acquire the lands within the Zone boundaries which are owned by private persons. The United States will also control the area to be covered by Gatun Lake which extends beyond the lines of the Canal Zone.

The population of the Canal Zone, official census, is 62,810; of Panama City, 35,368; of Colon, 17,749.

The permanent administration and Canal headquarters building will be on a knoll west of Ancon quarry where it will overlook both the terminal piers and the Canal entrance. It is to have 75,000 square feet of floor space and is to cost not more than \$375,000, including \$25,000 for that part assigned to permanent records. The quarters for employees attached to the administration building will be erected in the general area adjacent to and northeast of it, and employees connected with the shops, docks, and other terminal facilities at Balboa will be housed in quarters erected in the area surrounding the slope of Sosa Hill and on the fill adjoining the Ancon-Balboa highway. There will be a permanent settlement at Pedro Miguel for employees of the Pacific locks, and one at Gatun for employees of the Atlantic locks. The settlement at Cristobal will be maintained, and possibly the settlement at Ancon. No necessity is apparent for any other than the above five settlements, except for the military forces which will be stationed on the Isthmus.

The piers for commercial use at Balboa are built at right angles to the axis of the Canal, with their ends about 2,650 feet from the center line of the Canal channel. They are about 1,000 feet long, and 200 feet wide, with 300-foot slips between, and with landings for small boats at the head of each slip for the full width between piers. The old French steel wharf, about 1,000 feet long, will be retained for some time in the future, for commercial purposes.

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Two wharves and one pier have been constructed at Cristobal, behind a mole and breakwater, built out from shore toward the Canal channel, and paralleling the boundary line between Canal Zone and Panamanian waters. Primarily, these docks are to meet the commercial requirements of the Panama railroad, but should there be enough traffic after the Canal is completed to justify it, four other piers, each about 1,000 feet long, and 209 feet wide, with 300-foot slips between, will be constructed.

The main drydock will be situated at Balboa, and will be capable of accommodating any vessel that can pass through the Canal locks. It will have a usable length of 1,000 feet, a depth over the keel blocks of 35 feet at mean sea level, and an entrance width of 110 feet. The entrance will be closed by miter gates, similar to those used in the locks. The drydock will have a rock foundation, and its sides will be lined with concrete. Its equipment will include a 40-ton locomotive crane, with a travel on both sides.

For vessels of smaller type, an auxiliary drydock will be built at Balboa, in lieu of the marine railways originally contemplated. It will have a usable length of 350 feet, a width at entrance of 71 feet, and a depth over the keel blocks of $13\frac{1}{2}$ feet at mean sea level. It will be provided with a floating caisson. The 40-ton locomotive crane on the main drydock will be utilized for this dock also. The work of providing space for these drydocks, as well as for the new shops, is now under way, and requires the excavation of about 300,000 cubic yards of material from the northwest face of Sosa Hill. The excavated material is used in filling the site for the shops and terminal yard.

On the Atlantic side it is proposed to retain the old French drydock at Mount Hope, which has a usable length of 300 feet, a width at entrance of 50 feet, and a depth over the sill of 13 feet at mean sea level. It was the opinion of the board in charge of the dock projects, that the commercial requirements in sight would not warrant the construction of a drydock at Cristobal capable of accommodating

large vessels, in view of the building of a drydock at Balboa, to which any large vessel on the Atlantic side could be taken and returned, in case it was found necessary to dock it for repairs.

The plans contemplate furnishing vessels with fuel, fresh water, and supplies of all kinds. The main coaling plant will be situated on the north end of the island, opposite dock No. 11, Cristobal. It will be capable of handling and storing 200,000 tons of coal, with a possible increase of 50 per cent. One hundred thousand tons of the total normal storage is subaqueous. The plant will have railroad connection with the mainland over a bridge of the bascule type, which will cross the French canal at a point about half a mile south of the Mount Hope drydock. The preliminary work on this plant has been begun by the Panama railroad.

A subsidiary coaling plant will be situated at Balboa, at the outer end of the southeast approach wall of the drydock, having a frontage of 500 feet thereon, adapted for discharging vessels. This plant will be capable of handling and storing 100,000 tons of coal, with a possible increase of 50 per cent. Fifty thousand tons of the total normal storage is subaqueous.

In addition to coal, facilities will be provided at Cristobal and Balboa for supplying shipping, and the Canal works, with fuel oil. In line with this plan, four steel tanks of 40,000 barrels capacity each, have been contracted for in the United States.

The main repair shops will be built at Balboa, and are designed to maintain the following equipment:

1. Lock, spillway, and power plant machinery.
2. Water and land equipment retained for the maintenance of the Canal.
3. Rolling stock and equipment of the Panama railroad.
4. Mechanical apparatus connected with the coaling plants, fortifications, cold storage plant, wireless stations, etc.
5. The making of repairs, etc., required by commercial vessels, and by private individuals and corpora-

tions. 6. The making of such repairs as may be required by vessels of the United States Navy.

In addition to these, a number of subsidiary buildings will be erected. All of the structures will be of permanent construction, with steel frames. The sides and ends will be left open for ventilation and light, protection from sun and rain being afforded by overhanging sheds.

The main metal working shops, including machine, erecting and tool shops, the forge and pipe shop, and the boiler and shipfitters' shop, together with the shed for the storage of steel, will be placed end on between the drydock and repair wharf. The general storehouse, foundry, wood-working shops, subsidiary buildings, and office building, will be erected parallel to the line of the drydock and water front, northeast of the main shops. Two lines of railroad tracks will extend past each end of the main metal working shops, and one track through their center. The main shops will be provided with overhead traveling cranes, the crane runways being extended through each end of the buildings over the railroad tracks. As far as possible, the present machinery will be utilized in the new shops. All of it will be electric driven, including both individual and group drive.

It is proposed to retain the drydock shops, for making repairs on the Atlantic side, until sufficient experience is had to determine the extent and character of repair facilities necessary.

For the handling of the lock gate leaves, as well as for other Canal requirements, and commercial and general wrecking purposes, one, or two, powerful floating cranes will be purchased. For handling vessels of the largest size at Cristobal and Balboa, two high power harbor tugs will be provided, and for the transportation of coal, fuel oil, and fresh water alongside of vessels, a sufficient number of barges and lighters will be placed in service. The steel barges, now in use by the Canal Commission, can be used to good advantage, after the necessary modifications have been

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made, in the barge and lighter service. A tender for passengers and mail will be furnished at each terminus also, provided the business justifies it.

Some idea of the stupendous nature of the undertaking may be gained by a glance at the following table of statistics of the equipment in use during the construction period:

CANAL SERVICE	
Steam shovels:	
105-ton, 5 cubic yard dippers.....	15
95-ton, 4 and 5 cubic yard dippers.....	30
70-ton, 2½ and 3 cubic yard dippers.....	33
66-ton, 2½ cubic yard dippers.....	10
45-ton, 1½ cubic yard dippers.....	11
26-ton.....	1
Trenching shovel, ¼ cubic yard dipper.....	1
Total.....	101
Locomotives:	
American—	
106 tons.....	100
105 tons.....	41
117 tons.....	20
Total.....	161
French.....	104
Narrow gage, American, 16 tons.....	33
Electric.....	9
Total.....	307
Drills:	
Mechanical churn, or well.....	196
Tripod.....	357
Total.....	553
Cars:	
Flat, used with unloading plows.....	1,760
Steel dumps, large.....	596
Steel dumps, small.....	1,207
Ballast dumps.....	24
Steel flats.....	487
Narrow gage.....	209
Motor.....	6
Pay Car.....	1

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Pay Certificate.....	1
Automatic, electric.....	45
Decauville.....	224
Special, shops.....	12
Total.....	4,572
Spreaders.....	26
Track shifters.....	9
Unloaders.....	30
Pile drivers.....	14
Dredges:	
French ladder.....	7
Dipper.....	3
Pipeline.....	7
Sea-going suction.....	2
Clam shell.....	1
Total.....	20
Cranes.....	47
Rock breaker.....	1
Tugs.....	11
Tow boat.....	1
House boats.....	3
Clapets.....	12
Pile driver, floating.....	3
Crane boat.....	1
Barges, lighters and scows.....	72
Launches.....	29
Drill boats.....	2
Floating derricks.....	2

PANAMA RAILROAD

Locomotives:	
Road (12 oil burners).....	36
Switch.....	26
Total.....	52
Cars:	
Coaches.....	57
Freight.....	1,434
Total.....	1,491

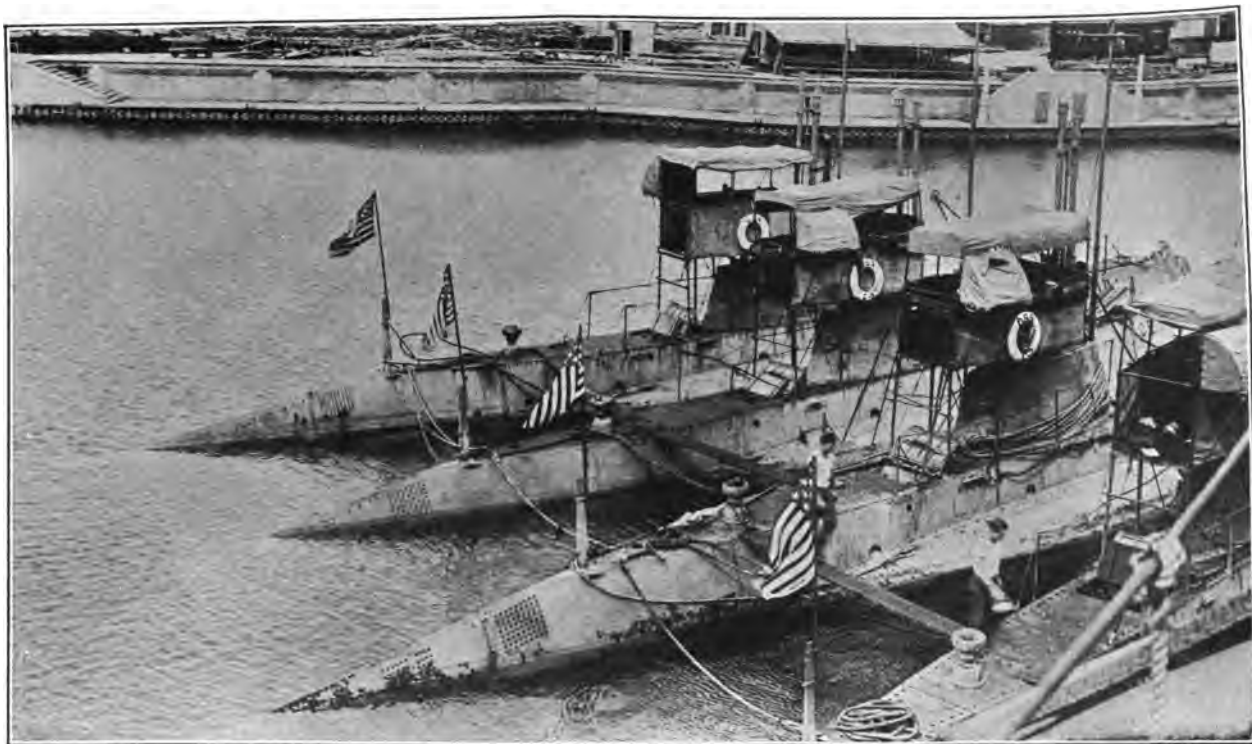
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Cranes:	
Locomotive.....	2
Wrecking.....	2
	4
Total.....	
	4
Piledrivers:	
Track.....	1
Floating.....	1
	2
Total.....	
	2
Tugboat.....	1
Lighters:	
Coal, all steel.....	5
Cargo, steel and iron.....	8
	13
Total.....	
	13
Motor boats.....	2
Steam ditcher.....	1

SUCCESS OF THE MILITARY MANAGEMENT

The writer confesses to having been one of the sceptics who viewed with misgiving the transfer of the Canal operation to military management, and he acknowledges with pleasure that in every important respect the results have been contrary to his predictions. The work could not have been in better hands. It has been carried on without any hitch or subsidence, and the progress made has excited the admiration and astonishment of engineers throughout the world.

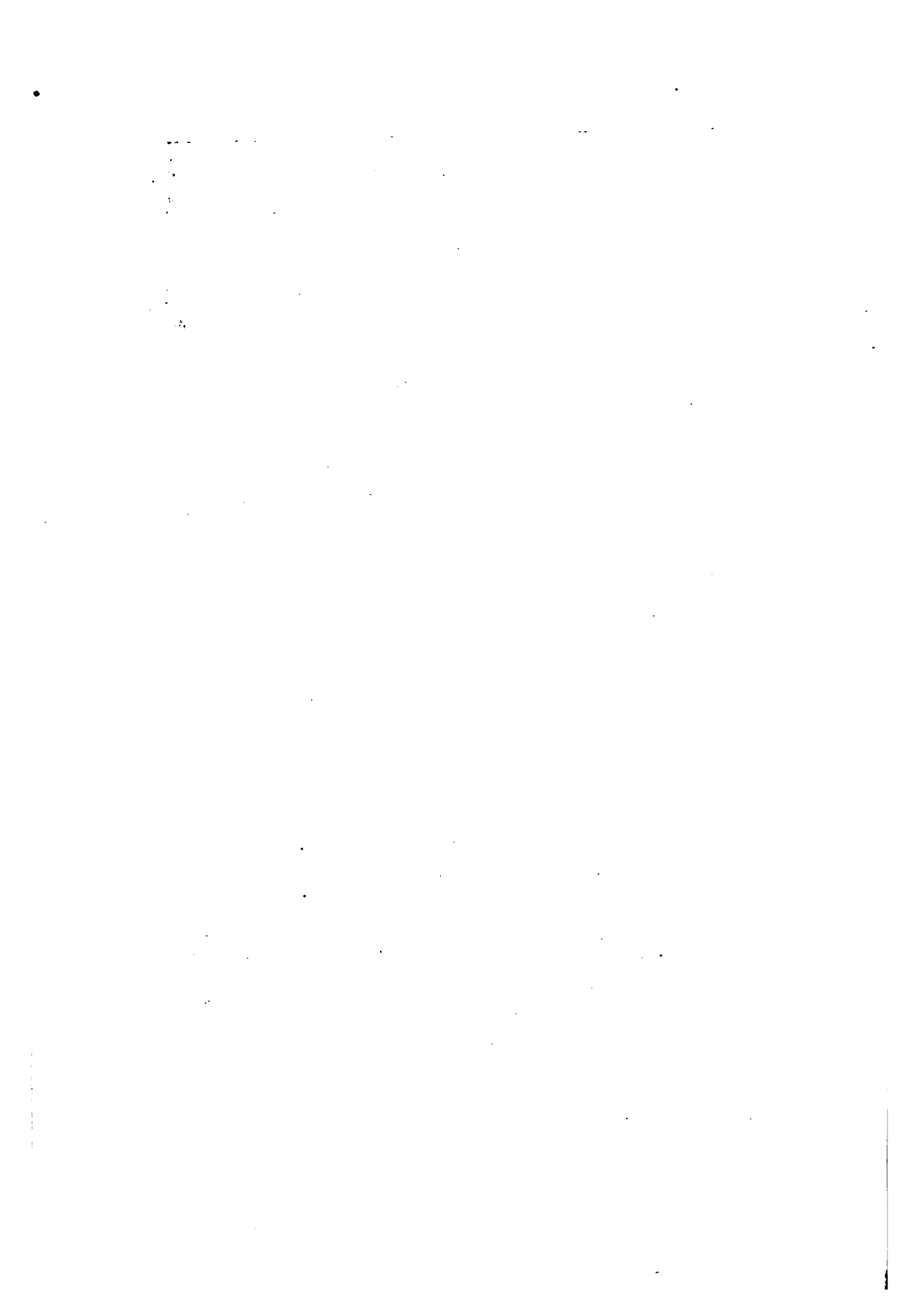
An excellent organization has been established and a strong *esprit de corps* maintained. Health conditions were steadily improved and a gradual increase in the efficiency of labor effected. All classes of employees have been imbued with confidence and courage by the knowledge that their chiefs were moving along clearly cut lines, with well-defined purposes in view. For the first time



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SUBMARINES TO BE USED IN DEFENDING THE PANAMA CANAL

The vessels here shown are to be used in defense of the Pacific side of the Canal. They appear as anchored in the new concrete docks at Colon, preparatory to their passage through the Canal, after having made the longest sea voyage on record for submarines.



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since the enterprise was entered upon, the responsible heads of it were in complete accord with the controlling authorities at Washington.

The plan of organization of the Engineering Department divided all construction work into three topographical districts, each under the charge of an Assistant Engineer with full control and responsibility. These divisions are: The Atlantic Division, extending from deep water to Gatun Lake, and including the Gatun Dam and locks; the Central Division, extending from Gatun to Pedro Miguel, and including the Culebra Cut; the Pacific Division, extending from Pedro Miguel to deep water in the Pacific, and including the dams and locks at the former point and at Miraflores.

CHAPTER XII

MILITARY AND POLITICAL ASPECTS

For more than two hundred and fifty years the various nations of the world have been wrangling over the project of building a canal on the Isthmus of Panama. Diplomats have fought wordy battles and concocted wily schemes to secure a foothold on the Isthmus which would place their governments in an advantageous position either for building a canal or acquiring a strategic position in case one was built by another nation. Spain, England, France, Colombia and the United States have figured as the principals in these diplomatic negotiations. Although there have been other nations involved none have played a part sufficiently noteworthy for mention.

Of course Spain, as the first nation on the ground, was chiefly concerned with the canal project in its early days. Next England, whose traders and freebooters had obtained a foothold on the Spanish main, became a factor in Isthmian politics. The Englishmen had settled in Nicaragua and Honduras, Jamaica and others of the West Indian islands. Of these settlements, perhaps the most important, from a diplomatic point of view, was the English colony in that part of Nicaragua known as the Mosquito Coast. This colony was established in 1740, and some time later became a dependency of Jamaica. This foothold was gradually strengthened by treaty and otherwise, until England was enabled to organize a province there called British Honduras. Diplomatic discussion of this matter between England and Spain again and again resulted to the advantage of England, and her hold upon this territory grew stronger and stronger. In 1860 England was able to obtain an acknowledgment

from Nicaragua of the validity of her claim to British Honduras, and became a powerful factor in that part of the Isthmian country.

THE UNITED STATES TAKES A HAND

The United States, although naturally the logical builder of a canal on the Isthmus, was very slow to take advantage of the necessity and opportunity. It was not until about 1835 that any interest in such a project was manifested in this country. In that year the question of a canal was brought up in the Senate, with the result that an emissary was sent to the Isthmus to make an investigation of the matter. This move had no definite results until 1846, when a treaty was negotiated with New Granada by which the United States was given the sole right of transit across the Isthmus between the Atrato River and the Chiriqui Lagoon, either by road, railroad or canal. The limits of this treaty were sufficiently wide to provide a basis for the Panama Railroad concession, secured a few years later.

An attempt was made shortly afterward to negotiate the same privileges with Nicaragua, but complications were immediately encountered because of the fact that England was powerfully entrenched there. Various agents were sent to this country in an effort to conclude a satisfactory treaty. Finally, the negotiations resulted in the signing of a treaty with Nicaragua, guaranteeing that country sovereignty over the territory occupied by the canal which it was proposed to build. As this rather left England out in the cold, she immediately took steps to maintain her strategic position by threatening the seizure of Tiger Island in the Gulf of Fonseca, at the Pacific terminus of the proposed canal.

To block this move the United States, through its agent in Nicaragua, negotiated a treaty with that Republic by which Tiger Island was ceded to the United States, thus creating a difficult situation with England. A diplomatic

wrangle immediately ensued, which was settled in 1850 by the unfortunate Clayton-Bulwer Treaty, under which both governments agreed to forego the right to build or fortify an Isthmian canal, or to ally themselves with any Isthmian country for that purpose. Both countries offered protection to any other country which would undertake to build the canal, and guaranteed the freedom of a port at either end of the canal.

This treaty did not apply to British Honduras, and resulted greatly to the disadvantage of the United States.

This state of affairs maintained until after the Civil War in the United States, since that struggle occupied the attention of this country to so great an extent that the matter of building a canal was naturally held in abeyance. In 1866, however, the project again came up for discussion, and the people of the United States came to a clearer realization of the irritating features of the Clayton-Bulwer Treaty, and to desire a greater latitude of action upon the Isthmus of Panama. Various propositions were made looking to the abrogation of the treaty with England, among them being a project to buy Tiger Island. But these came to no definite end. President Grant was the first to advocate the clear-cut policy of an American canal under American control, and negotiations were entered into with Nicaragua in 1869 and 1870 with a view to building a canal across the Isthmus.

Soon afterward France entered the field of Isthmian diplomacy, Ferdinand de Lesseps making an attempt to secure an abrogation of our treaty with New Granada, in order that France might have the right to build a canal entirely under French control. The United States applied the Monroe Doctrine and adopted so firm an attitude on this subject, however that the attempt was abandoned.

GROWTH OF DEMAND FOR A CANAL

From this time on the American people turned their eyes more and more strongly to Panama and to the vital

necessity of this country for a canal under American ownership. The strong desire for this dates back to 1849 with the rush of the gold miners to California during the great gold strike in that State. Difficulty was experienced in crossing the continent because of a lack of transcontinental railroads and the length and tediousness of the journey by wagon train. A great many of the "forty-niners" chose to take ship to the Isthmus and brave the perils of the jungle and to pay the high rates exacted for crossing there. From this date our Far West grew rapidly in importance, and the necessity for some means of quick transportation, both for the purpose of defense and trade became more and more apparent, until, in 1898, the famous voyage of the Oregon around the Horn brought the crying necessity for a canal before the American people in such a way that public sentiment was aroused and became insistent that a canal should be built and owned by the United States as soon as possible.

THE VOYAGE OF THE "OREGON"

The American people will not soon forget the voyage of the Oregon. At the opening of the war with Spain, when the great Spanish fleet under Admiral Cervera was reported to be speeding across the Atlantic to make an attack upon the American coast, the Oregon, one of the finest ships in our none too large navy, was on the Pacific side. Need of her on the other side of the continent was felt so strongly that orders were telegraphed to her captain to make the long voyage around the Horn at the utmost possible speed. Never before had such a voyage at top speed been made by a battleship. Day by day the people hastened to open their newspapers to see where the Oregon was, and to wonder whether she would be able to make the long voyage without accident and arrive at the scene of action in time. The Oregon did make this memorable voyage without accident and in record-breaking time, and arrived in time to

take part in the battle of Santiago. Nevertheless, the lesson taught by the anxiety and suspense endured throughout many days was not soon to be forgotten, and the determination became stronger and stronger that such an emergency must never again arise and that some rapid means of communication between our coasts must be provided. Within two years a new treaty with England called the Hay-Pauncefote Treaty was negotiated, and ratified on December 16, 1901. By the provisions of this treaty the troublesome and annoying Clayton-Bulwer Treaty was abrogated. The United States was empowered to build and control a canal, both in times of peace and war. By this treaty we were forbidden to blockade the canal, but were not forbidden to fortify it, and thus all obstacles to the construction and ownership of a canal across the Isthmus of Panama were cleared away, and a way opened for the enterprise.

SELECTING A LOCATION

The next three years were occupied in selecting a location. Two routes were suggested, one on the location of the French attempt at Panama, and the other through Nicaragua. After careful study and investigation, however, it was decided to adopt the Panama route, as has been set forth at greater length in another portion of this volume.

The negotiations with Colombia, looking to the right to build a canal, have also been detailed at length, as have the dramatic revolution in Panama and the treaty with that country, which closed the diplomatic wrangling of centuries and left the United States free to build a canal under the conditions which we desired.

FORTIFICATIONS

Prominent among the international questions involved by the consideration of the canal has been the question of fortifications. By the Hay-Pauncefote Treaty we were not forbidden to place fortifications on the canal, and in

fact no mention of the matter was made. After the signing of the treaty, however, there was a great deal of discussion as to whether or not we had this right. The matter was not definitely settled until 1911, however, when an appropriation of \$3,000,000 was made by the House of Representatives for this purpose. Work was begun immediately, and the huge forts which guard the waterway, armed with the latest and largest type of mortars and disappearing rifles, have settled this question for all time.

The questions raised on this subject involved not only our right to fortify the canal, but also the expediency. As on many other questions which have arisen concerning methods of policy connected with the canal, the people of the United States were divided into rival camps on this subject. The opponents of fortifications presented many arguments in support of their position. In the first place it was claimed that no fortification was necessary, inasmuch as the canal could be protected by our fleet. This argument was met by a consideration that in that case our fleet in time of war would be largely tied down to a defense of this important avenue of communication, and would lack the freedom of action which would be most favorable to its success. Further argument along this line was that this would be a far more expensive method of defending the canal than the proposed fortifications, since it would be necessary to provide a fleet of sufficient size to take care of the defense of the canal, in addition to the ships necessary for the defense of our extensive coast line. Many other arguments were brought up by those opposed to fortifications, but these were disposed of along the same logical lines.

The doctrine of non-militarism is the one chiefly expounded by those opposed to canal fortification. Up to the present time our theory of national defense was largely based on the belief that no enemy could successfully attack us because of the ocean lying between. In these days of high speed ships, however, the long stretch of South America,

reaching far below us, is practically the only remnant of that isolation. The great length of the voyage around the Horn, together with the fact that no European nation has a foothold in any part of the continent which it could use as a naval base, offers a formidable obstruction to the passage of a hostile fleet. Should the enemy, however, obtain control of the Panama Canal the distance would be shortened by some 8,000 miles, and a powerful fleet would be able to threaten both coasts of the United States at one time, a thing which is now impossible.

Of course, we must be protected from such a possibility. Our army is too small to adequately protect both coasts at the same time, and our land fortifications are too widely separated for adequate defense. With the control of the canal insured to us by powerful fortifications and garrisons, we can concentrate our land forces on that side of the continent which is threatened by an enemy. Thus by means of the Panama Canal we are once more enabled to resume the attitude that we are naturally defended from foreign attack, and that the opening of the Canal is a long step away from militarism instead of in that direction.

Many means of insuring possession to us of the Canal in time of war have been suggested, such as treaties with foreign countries which would assure us that the Canal would not be used against us at such time. These, however, would not be sufficiently trustworthy to satisfy us. A strict neutralization of the Canal would make it possible for the enemy to use the waterway as well as ourselves, an even more unsatisfactory state of affairs. The only possible solution of the problem is that the Panama Canal must be kept open always to our fleet and closed to the fleet of our enemy, and that it must be entirely under our control, unhampered by any other nation. To accomplish this, every possible step must be taken to promptly construct fortifications and military defenses of all kinds, and to establish a garrison sufficiently powerful to insure an adequate defense of this vital point.





PANAMA, PAST AND PRESENT.

Scene showing the repaving of one of Panama's old muddy streets with vitrified brick. Sewers and waterpipes have been laid throughout the city resulting in a great reduction of disease.

The fact that we have fortified the Canal does not in any way conflict with our treaty obligations to maintain a neutral commercial waterway, but we must insist on considering the Canal a part of our coast line, and as such falling under our rightful control as the great highway between our Atlantic and Pacific shores. The sentiment to this end has been growing ever since the Canal project became a concrete one. If a precedent were needed, we have it in the precautions taken by England to guard the approaches to India by means of fortifications at Gibraltar, Cyprus and at Malta, which guard the entrance to the Mediterranean. The Red Sea is protected by fortifications at Aden and on the Island of Perin, and to make matters doubly sure England owns a controlling interest in the Suez Canal. Other nations, furthermore, have pursued similar tactics. Germany has securely fortified the Kiel Canal, and there are other instances of a similar nature.

The control of the Panama Canal is, however, far more necessary to our national security than that of the Kiel Canal to Germany or the Suez Canal to Great Britain, since it is the key to the protection of our many thousands of miles of coast line and the seaports which dot it, and it is only right that we should adopt similar precautions to insure our safety by its adequate defense. One of the chief difficulties with the Clayton-Bulwer treaty was the clause which guaranteed to England a free passage through the Canal in case she was at war with this country, and it was largely on this account that pressure was brought to bear for a repeal of this treaty.

There are two branches of defense which must be considered, namely:—sea and land. The sea defenses will be provided for in the enormous fortifications with their powerful artillery, which are situated at the Atlantic end on both sides of Limon Bay. At the Pacific end the fortifications are placed on the islands which guard the entrance to the Canal. These fortifications serve a double purpose, as they will be the means of keeping a hostile fleet at a distance

too great for any bombardment of the locks and machinery of the Canal. They will also serve to protect the exit of our fleet in case it should be necessary to send it through the Canal in the face of a hostile fleet. The second branch of defense of the Canal must provide against an attack by a land force. This will be accomplished by the mobile land garrison, which will be employed to defend the Canal against a landing force from an enemy's fleet, or from an army which would approach to the attack through one of the South American republics.

In the first instance, the proposed garrison of six or seven thousand men would probably be ample to repel any such attack, and the further consideration that it would be very difficult to land any force on the Isthmus in the face of a defending fleet makes this item of little consequence. In case, however, of the expedient of bringing a large army to attack the Isthmus by land, we are in a particularly favorable position to reinforce the garrison by either one of the two oceans, and we can probably put a sufficient force there to insure adequate defense before a hostile army would be able to reach and attack the Canal.

As now planned the land garrison will consist largely of infantry with full artillery, and a small body of cavalry. These men will maintain a permanent garrison, and thorough and detailed plans will be worked out for a complete defense of the Isthmus. With the completion of the Canal the entire Zone, with the exception of the stretch occupied by the Canal itself, together with a few military roads, will be allowed to relapse into the original jungle, and as growth is very rapid in the tropics it will be but a short time until this is again in the wild state and will thus form one of the best defenses against a land force. For this reason the Isthmus will not be open to settlement, but will be maintained strictly as a Government reservation; and no one will be allowed to land there without the express permission of the Government.

In addition to the defenses of the Canal itself, the

enormously strong naval base which we are constructing at Pearl Harbor in the Hawaiian Islands may be counted upon to assist materially in the defense of the Pacific end of the Canal.

CHAPTER XIII

THE RESULTS OF OPENING THE CANAL

Ever since the project of cutting an Isthmian canal has begun to be talked of in the United States, the question of what the results attained by it would be has been a matter for serious discussion.

As the enterprise neared completion this discussion became more general and of deeper interest to the people at large, especially to those interested in shipping and in transcontinental and foreign commerce. Congressional investigations have been made, and special reports prepared on the subject, until now we are in a position to predict along fairly definite lines what the net results of the opening of the canal will be.

The benefits which will accrue to this country fall into two major classes:—military and commercial. It has long been said that a Panama canal is a commercial convenience and a military necessity. But to the people at large the commercial aspects of the canal are pre-eminent, and they look to it for great results in the reduction of the risks and expenses of commerce.

FROM A MILITARY POINT OF VIEW

From a military point of view the canal will prove of the greatest value. The United States is in a most peculiar position as a world power, on account of the enormous extent of our coast line and the fact that it fronts upon both the Atlantic and the Pacific, upon both of which oceans it is necessary to maintain a powerful naval force. Without the Panama Canal the Atlantic and Pacific fleets are nearly



MAP OF ROUTES TO THE ISTHMUS.

This shows the directness of the routes from New York and New Orleans to Colon.



