The *Corozal* has a center well ladder so that it can make its own flotation, that is, it can dig into a bank ahead, and when the ladder makes an angle of forty-five degrees with the vertical, excavation can be carried on at a depth of fifty feet. It was required by the canal engineers that the dredger should be capable of digging 1,200 cubic yards of soft material per hour at a depth of fifty feet.

The trip from the Clyde to Balboa by the dredger was a memorable voyage. The log showed a total of 12,064 miles covered in the journey, the actual sailing time consuming ninety-six days. The trip was made by way of the Strait of Magellan, and on arriving at its destination the dredger was ready for active service. The digging of the Panama Canal marks an era in dredging work in which the *Corozal* played a most important and successful part.

Disposal of Material from Excavations

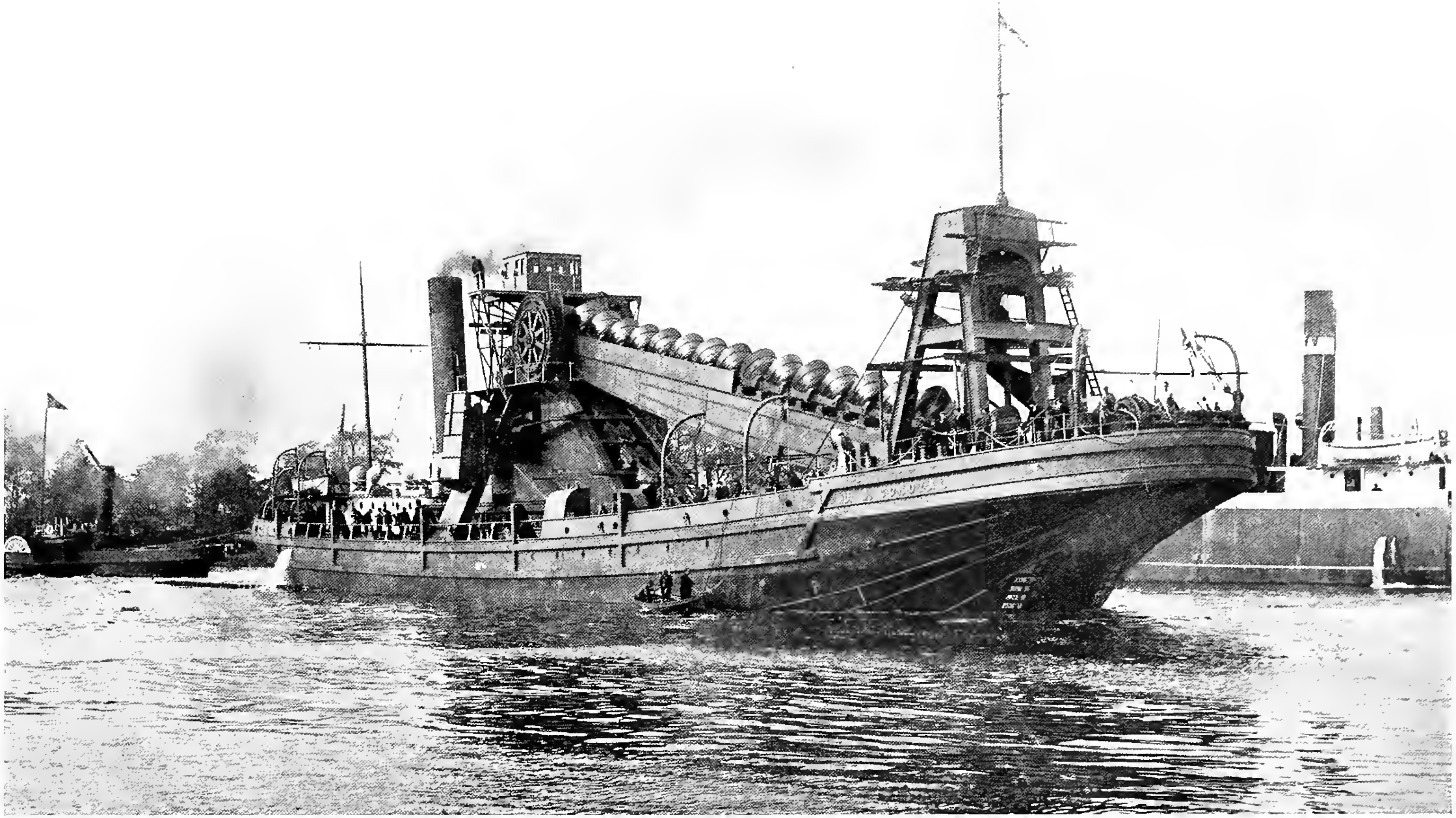
From the foregoing record of the great forces at work in loosening the rocks and earth in the path marked out for the canal, it will be readily seen that one of the most difficult problems to be solved by the canal engineers was that of speedily disposing of the excavated material. With drills, powder, steam shovels and dredges creating an ever-increasing mass to be removed, all the resources of American ingenuity were called upon for a rapid means of getting the débris out of the way as fast as powder loosened it and the machine shovels scooped it up. The original plan of the canal builders seems to have contemplated the use either of the old French type of dump car or standard railroad cars of gondola or platform type. This was soon abandoned for more efficient equipment, and a number of American firms began to supply machinery and cars for the removal of excavated material that quickly solved this difficult feature of canal construction.

One hundred million cubic yards of rock and earth had to be disposed of from the Culebra Cut alone. This means a mass of material 100 feet wide, 100 feet deep, and more than fifty miles long. It means nearly 5,000,000 carloads. Places had to be chosen where this enormous mass of spoil could be deposited, railroad tracks provided to get the cars to and from the dumps, and finally a means for the rapid unloading of the train of cars. What is known in the mechanical and scientific world as "The Lidgerwood System" was among the means chosen for this important work, and thirty "Rapid Unloaders" were purchased.

The Lidgerwood system consists of trains of flat cars, with steel aprons bridging the spaces between the cars, a plow to sweep the load from the cars, a steel cable reaching the length of the train, and the "Rapid Unloader," a powerful winding engine to draw the plow through the train. A long train can be unloaded in five minutes. The unloader is placed on a flat car coupled to the locomotive, and takes steam from the locomotive boiler.

A train for unloading is made up with the locomotive and unloader attached to the head of the train, and with one of the regular Lidgerwood cars carrying the plow coupled to the rear. When the dump is reached the cable is attached to the plow, and the plow rapidly drawn along the cars, unloading earth and rock with a rapidity that is amazing.

In addition to its unloading system the Lidgerwood Company played an important part in another branch of the great work. Tourists and engineers visiting Gatun during construction time were fascinated in witnessing the operation of eight Lidgerwood cableways spanning the Gatun Locks. The supporting cables seemed like mere wire threads in the sky, and the loads appeared to fly. The visitor saw, first, the load being quickly lifted high in the air from a car on the bank; then go spinning along the wire threads, with great speed the carriage hovering a moment over the place of deposit, and finally the load low-



The bucket hopper dredge "Corozal" built for the canal work by William Simons & Company, of Renfrew, Scotland. This firm is distinguished by being practically the only foreign firm that had a large part in the canal construction.

ered and the contents of the bucket deliverered into the wall. Two million cubic yards of concrete were placed in the walls by the cableways.

In the year 1904 the Western Wheeled Scraper Company of Aurora, Ill., submitted a tentative proposition to the Isthmian Canal Commission for twenty-four all-steel, double side-dump cars of twelve cubic yards capacity. This proposition was accepted with a view of giving the cars a thorough test in the actual work and under the conditions as they existed on the Isthmus.

These twenty-four cars were shipped to the canal in the early part of 1905 and on August 9, 1905, the first dirt was moved at Empire by American equipment in the Western air dump cars.

After these cars had been thoroughly tested and their value recognized by the engineers on the Isthmus, the commission ordered seventy-six additional, making 100 in all. This car was designed specifically for the hard service to which equipment was subjected on the canal and was a modification of the Western type of car as used in railroad construction in the States.

In December of the same year 200 more of these cars, all being twelve cubic yards capacity, were shipped. In the latter part of 1906 the commission, finding that it could use to advantage larger cars, ordered 300 Western side-dump cars of 18⅔ cubic yards capacity, which were shipped early in 1907. In 1909, 300 of the Western twelve-yard cars were shipped to the canal. There were also used some four-yard narrow-gauge cars at the Porto Bello crushing plant and some two-yard thirty-inch gauge cars.

All these cars were made exceptionally strong, and their record for standing up under the severe usage to which they were subjected shows the maintenance cost to have been extremely low. Most of them were used under steam shovel dippers of five cubic yards capacity. The impact of a mass of rock contained in a dipper of this size dropped from a considerable height is enormous. This made it necessary to use extra heavy material in the cars so as to avoid all liability of breakage.

The bed of the Western car is pivoted longitudinally in the center over the draft beams and will dump on either side; when dumping, the hinges, riveted to the center sill under the bed, rock on the pedestal castings which are riveted to the draft beams. One of the most important features of the car consists of the patented hinge connection between the bed and trucks. This hinge has two members riveted as above described to the bed and draft beams respectively. Between these members a bar of iron is hung perpendicularly, a horizontal pin passing through the lugs of the upper portion of the hinge and an eye in the perpendicular bar. This bar drops into a socket in the pedestal which forms the lower member of the hinge and which is riveted to the draft beams. Between the upper and lower members of the hinge is a steel wear plate. The bearing comes directly on the wear plate between the upper hinge casting and the pedestal, no strain whatever coming on the horizontal pin which holds the loose bar or hinge connection in place, and the bed and trucks are not fastened together in any way, but the bed rests loosely on the pedestal castings.

The arms which operate the side boards or doors of the Western cars are pivoted on the ends of the beds and at the ends of the side boards, and are operated by a toggle which is attached to the upper arm and to a central point at the end of the car bed. Immediately the bed is tilted, the toggle strikes a rest provided for the purpose, which lifts the door upward and outward from the load, giving the widest possible opening for discharge of the load.

The irons which operate the side doors are not attached to the truck, so that when the side chains are unlatched, the bed and truck are entirely separable. This separable feature of the upper hinge and pedestal is another point of considerable value. In the act of dumping, the bed is not held rigidly to the trucks, but is permitted to rise slightly from the pedestals at the moment of the shock, so that there is no tendency to lift the truck from the rails.

In the event of derailment and rolling down an embankment, the bed and truck automatically separate, causing less damage to the car and making much easier its replacement on the track.

The bearing on which the bed turns in dumping is of such construction and perfect adjustment as to make the dumping and bringing back of the bed to position much easier than on any other make of car, so that the saving in labor by use of the Western is very great.

The height of the Western is less than that of other cars. The dumping angle is forty-seven degrees. On account of the large opening for discharge and the acute dumping angle, anything that can be loaded into the cars will clear the side board in dumping, so that heavy rocks and bowlders or frozen earth in large masses can be easily handled.

The air dumping device used on these cars consists of a cylinder and a set of levers, chains, shafts, and cams for each side. The thrust of the piston rod acts on the lever, which transmits the motion to a shaft through a chain operating over a cam. On the same shaft are two other cams to which the dumping chains are attached, the upper ends of these chains being fastened to the outer angle sills of the bed. The action of the lever causes the shaft to rotate, drawing the bed down to the dumping angle. The return of the bed to carrying position is accomplished by similar action of the device on the opposite side of the car. The air used in dumping the car will serve to return the bed to upright position. The dumping and righting of the car are controlled by the engineer in his cab, operating a special four-way valve designed for this purpose.

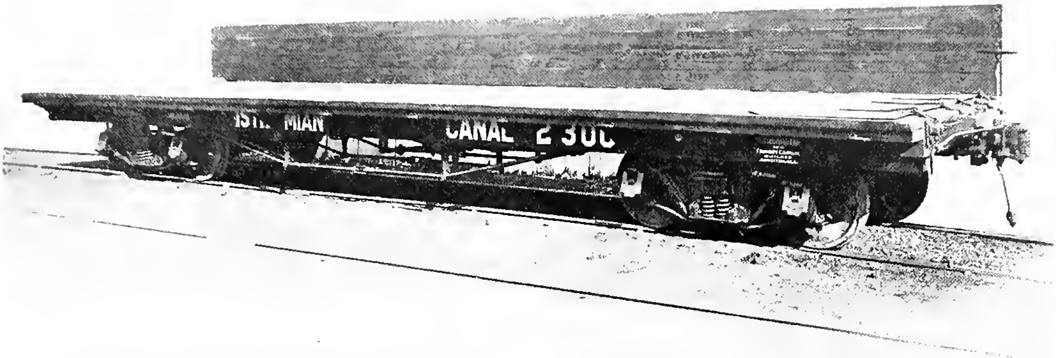
Added to the great saving in the operation of the cars are the fewer repairs required, due not only to their great strength but also to the fact that they stay on the tracks, thus avoiding heavy expenses through derailment and wrecks.

One of the most valuable characteristics is that of rapidity of operation. The dumping of the cars and the bringing back to the upright position require but a few seconds, so that it will be readily appreciated how very great was the importance of this equipment in the saving of time.

The Western dump cars made a remarkable record on the Isthmus, and it is safe to say that had it not been for their use, the cost of handling the material would have been greatly in excess of the actual amount expended.

This type of car has been used on all the gigantic earth-moving enterprises on the American continent within recent date. They have formed an important factor in the construction of practically all railroads in North America in recent years, in the building of the Keokuk Dam, the great Lackawanna Cut-off, the immense stripping operations on the Mesabe Iron Range in northern Minnesota, where more material has been handled than was taken out of the Panama Canal, on the Mississippi levees, in the excavation of the Welland Canal and the approaches to the Selkirk Tunnels in the Canadian Rockies, and other enterprises of more or less importance.

Active operations by the Pressed Steel Car Company (Western Steel Car & Foundry Company), of Pittsburgh, Pa., in the construction work at the Panama Canal began in 1907. At that time it built at its works in Anniston, Ala., a lot of 300 flat cars for the Isthmian Canal Commission. This contract was entered into and completed in fulfilment of an order originally taken out by another company, which was unable to make delivery, in consequence of which the commission called upon the Pressed Steel Car Company to furnish the required material.



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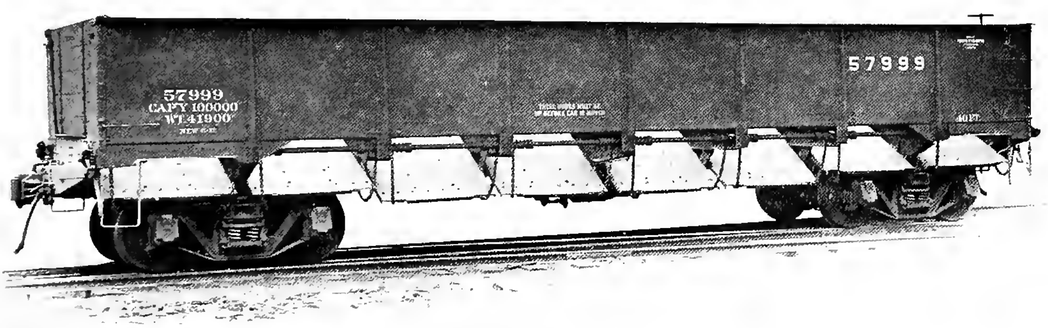

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1. Wooden dirt car with steel sides.
2. Loading dump cars in Culebra Cut.
3. All-steel dump car.
(Made by the Pressed Steel Car Co., Pittsburgh, Pa.)

The cars in question by no means represent the up-to-date steel construction equipment now being turned out by the Pressed Steel Car Company, and therefore poorly illustrate its more modern achievements in car building. However, they were in keeping with the specified requirements, and were built expressly to fill the demands made by the commission. They were of wood construction, having a capacity of 80,000 pounds each, and were built with removable side and side extension so as to be suitable for operation in connection with Lidgerwood unloaders. They were also equipped with a steel apron on one end to cover the space between the cars, as well as with arch bar trucks, and many other approved specialties for cars of this type.

While the cars furnished were, no doubt, in most respects as satisfactory to the commission as more up-to-date cars—at all events, they were what the commission desired—it may be said that the all-wood car is a thing of the past on American railroads. At present, flat cars are built with steel underframes, with either steel or wood floors as may be required. In the general improvement in steel car construction the Pressed Steel Car Company has kept to the front of the rapid advance that has characterized the industry of this country. Among the principal types which it builds at the present time are:

All-steel gondola cars, with high or low sides, and with or without drop doors or hoppers at the bottom, the latest model being so constructed that the drop doors dump the load at either side. When the doors are closed, this car can be used as an ordinary flat bottom car.

The composite gondola cars have steel underframes, while the floors, sides, and ends are of wood. They are used mainly for handling machinery and lengthy material.

The center dumping hopper cars are generally used for hauling coal, coke, and ore. These are built up to seventy-ton capacity, the triple and quadruple cars having a cubical capacity suitable for handling as much as fifty tons of coke.

In the construction of its box cars, the only wood used by the company is in the floors and lining. Many of these cars have large side doors and end doors, to facilitate the loading and unloading of automobiles.

The Pressed Steel Car Company is now building tank cars entirely of steel, the tanks being attached to the center sills at the center, and require no blocking at the ends of the tanks.

Another field of construction in which this company has made marked advance is in its passenger cars, as also in its mining cars. The superiority of steel over wood in both cases is too widely recognized to call for extended comment, especially in the former, where the use of the steel car so greatly reduces loss of life in wrecks, as well as destruction of the material itself through splintering and burning. The steel mining cars are also practically indestructible, and a less number is required to operate a mine or quarry of a given output.

In addition to the manufacture of the various kinds of cars enumerated, this company has a large business in repairs on cars, including the supplying of the various parts, as well as of trucks for engine tenders and cars.

The Pressed Steel Car Company began building steel cars in 1897, having been first in the field in a work that has since almost revolutionized the transportation methods of the country, as may be gathered from the foregoing description. The company now operates two plants in the Pittsburgh district, one at McKees Rocks and the other in the former city of Allegheny. A third plant, thoroughly equipped for building steel cars, is located at Hegewisch, Ill., near Chicago. The company has a capacity of 200 cars a day, and employs a force of more than 10,000 men when running full. The plants occupy a total area of 145 acres, of which sixty acres are covered with steel and stone buildings of modern construction. The average consumption of material is 40,000 tons of steel each month, of which 28,000 tons is steel plate, making the company the largest individual consumer of steel plate in the world.

The steel car has done much to improve and increase the carrying capacity of the railroads on which they are used. As late as 1907, a capacity of 100,000 pounds was considered by railroad men to meet the maximum that a freight car could carry. Steel freight cars are now being constructed for general use with capacities up to 140,000 pounds, showing an increase of forty per cent. in six years, and still heavier capacities up to ninety tons and more are being built at the present time.

In January, 1906, the Goodwin Car Company, William H. Taylor, president, with headquarters at 17 Battery Place, New York City, an Illinois office at 10 La Salle Street, in Chicago, and its own car building plant at Clearing, Ill., sent a number of its patent gravity dumping cars, of steel construction, to the Isthmus for service in the construction work on the canal.

The cars of this company were specially adapted, and proved fully equal to the severe service for which they were ordered, in that they combined all of the requisite features found in other dumping, ballasting and gondola cars, together with a number of additional devices that are unique in this particular make of car. One of its most important advantages is that it can be immediately diverted to many required services without alteration or change of parts. The load which it carries is discharged by its own gravity alone, on both sides or on either side, all in the center, or part on either side and part in the center, and it will distribute ballast in any position required without careening the car or moving the car body. This applies to practically every imaginable kind of load, whether tin plate or rail ends, broken stone or hot cinders, large rock or gravel, or any other dumpable materials. These cars are air-dumping, air-replacing, hand-dumping, and hand-replacing, all in one.

The Goodwin car is built entirely of steel plates and angles, and is fitted with malleable iron and steel castings. The capacity of the car is thirty to forty-five cubic yards, with a weight-carrying power limited only by size of journal and from 100,000 pounds upward. Through its new air replacing device, one man, without assistance, can close all of the doors and set the car ready for reloading. These cars are extensively used throughout the United States in railroad building.

Hydraulic Dredges

An important type of dredge used in the canal was the hydraulic, utilized to meet certain extraordinary conditions of wet excavation, where a machine of great power and capacity was needed. At a cost of $158,000 a twenty-inch hydraulic pipe line dredge, built by the Ellicott Machine Company, of Baltimore, Md., was purchased. This dredge had a capacity of excavating 750 cubic yards per hour. It required twenty days to tow the dredge from Baltimore to Colon.

The dredge was of the cutter type with a single sand pumping outfit, and the general dimensions were 150 feet over all, beam moulded forty feet, and extreme depth of hull ten feet and six inches. The hull was constructed throughout of steel, and was divided by four water-tight compartments. The steam plant consisted of four wet back Scotch marine boilers built for a working pressure of 200 pounds per square inch, operated with both oil and coal as fuel. The aggregate indicated capacity of the engines was 1,000 horsepower.

The pumping machinery consisted of a centrifugal pump of the side suction disc-lined type, constructed throughout of steel. It was so designed as to admit of the passage of sand, stones, or gravel without obstruction. The main pumping engine consisted of a three cylinder expansion vertical fore and aft condensing engine.

The material to be dredged, which consisted of coral, sand, and rock, had to be loosened or "agitated" before it could be pumped. For this purpose on the bow of the dredge was located a steel ladder of framework, carrying a revolving cutter, which was of the spiral type and constructed of steel. The depth of the cutting was regulated by raising and lowering the outer end of the ladder, which was capable of making a cut to a depth exceeding forty feet. The suction pipe was carried by the ladder and extended to the outer end where it passed inside of the revolving cutter. The "agitating" engine (it was a double condensing engine especially designed to bear the constant shocks and jars incident to the work) was mounted on the ladder.

The superstructure over the hull was of wood throughout and consisted of a house over the main deck covering all parts of the machinery. Above the main house, provisions were made for the living quarters of the officers and crew, which were specially designed for convenience and comfort, together with the pilot house. In the pilot house were located levers for operating all the machinery except the main engine, so that the operator had full control of the working of the various parts from this point. All the door and window openings of the living quarters were fitted with bronze screens and slatted blinds. Staterooms for the officers and sleeping quarters for the crew with appropriate mess rooms for each were provided.

The dredge was also fitted with an ice plant and an electric plant. The refrigerating plant was provided with ice pans for making ice for drinking water and to cool the refrigerator. By the electric plant the whole interior of the dredge was lighted. It also carried a powerful searchlight.

It is obvious that the canal could not have been dug without the expenditure of many years of time and the labor of hundreds of thousands of diggers had not the most improved dredges operated by the latest machinery been employed.

The equipment of a first-class modern dredge does not end with the machinery necessary to move the dredge from place to place, but must include pumps of great capacity and endurance, and modern experience has demonstrated that the centrifugal pump is the kind best adapted for dredging purposes. In fact the principal part of the equipment of a modern dredge is the centrifugal pump for handling solid material with water. The dredges used in the canal work were equipped with centrifugal pumps manufactured by the Morris Machine Works of Baldwinsville, N. Y.

From the dredging pump a suction pipe leads to the bottom of the river or canal, or other place from which the material is to be pumped. The pump produces a high velocity in the suction pipe, sufficient to draw into the pipe the material, pass the material through the pump, and then deliver it through a pipe line at the point desired. Where hard material is found, revolving cutters are employed for cutting the material before it is drawn into the suction pipe.

A number of the Morris pumps were used in the canal work, one of them being of capacity enough to deliver 300 cubic yards of material per hour, through 1,000 feet of pipe line, while another delivered about 400 cubic yards through a pipe line 4,000 feet in length. One system, consisting of three hydraulic dredging pumps, installed by the Morris Company in 1909 and used in making the Gatun fill, was of peculiar interest. In this work the material had to be elevated as high as eighty feet, through pipe lines varying in length from 6,000 to 8,000 feet. One pump was placed on the hydraulic dredge floating on the water. This pump took the material from the bottom and delivered through the pump and a pipe line into the suction of a second pump, known as a "booster." This booster, in turn, delivered it to another, so that with all these pumps operating in series, one boosting the other, the material was delivered to the elevation desired.

The Morris centrifugal pumps were also brought into play as an aid to sanitation. In a climate such as that of Panama drainage, sewage, and other like refuse cannot be permitted to remain, but must be disposed of in a way to prevent danger to human health and life. Four Morris pumps were used for the purpose of taking drainage and sewage, as collected in pits, and pumping it away to points of safety. These pumps are driven by electric motors, and some of them are of automatic operation.

The Morris Company is the oldest concern in this country building centrifugal pumps, and its experience has covered all classes of this machinery.

When the Canal Commission abandoned its original design of building two dams and two locks at La Boca, near the Pacific terminal, it made necessary the dredging of a sea-level canal from La Boca back to Miraflores. This brought into play the installation of engines and pumps of the International Steam Pump Company, of New York. A vast amount of material was to be removed and it was necessary for the commission to secure the most adequate type of machinery to accomplish the purpose in the shortest time.

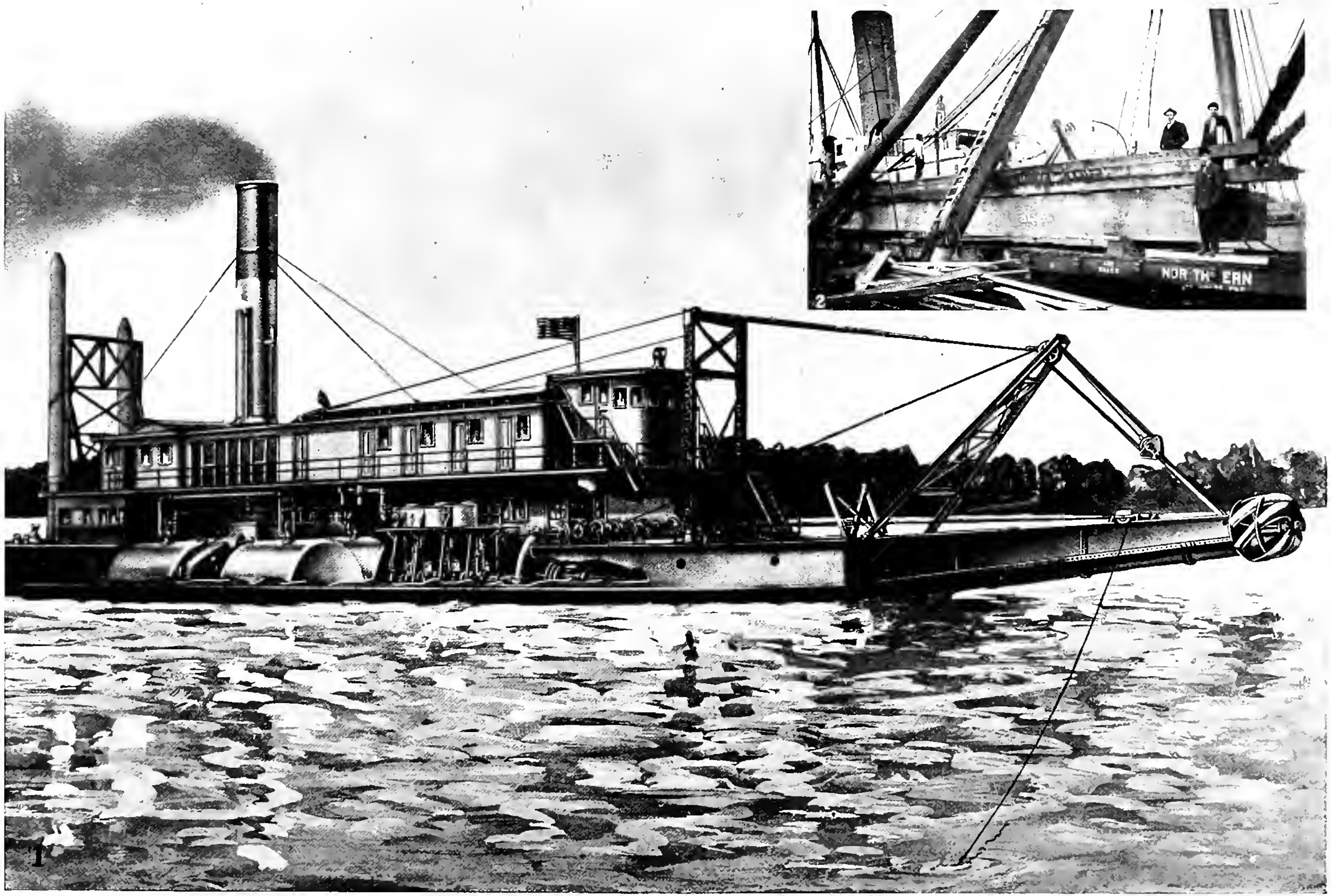
The contract called for complete machinery for a central pumping station of four units, each consisting of one pressure pumping engine, boilers, one dredging pump, one motor, piping and hydraulic monitors, etc. Speed was one of the considerations, and the contract of the International was to deliver the complete plant in 200 days. Such was the capacity of the company to fill all contracts that all the apparatus was delivered in much less time than the contract specified.

The dredging pumps were considered the most powerful of their kind, and were intended to do the work assigned them in one lift of ninety-five feet. The areas to be excavated and filled by means of the equipment installed by the International Company were eight feet above mean tide, and the average depth to be excavated was thirty-five feet. The material to be handled was dark loam, containing fifteen per cent. sand, with a mixture of gravel weighing as much as seventy-five pounds per cubic foot. In some parts of the areas having sand and clay, stones as large as twelve inches in diameter were found weighing ninety pounds per cubic foot, and equal to twenty or twenty-five per cent. of the material in suspension.

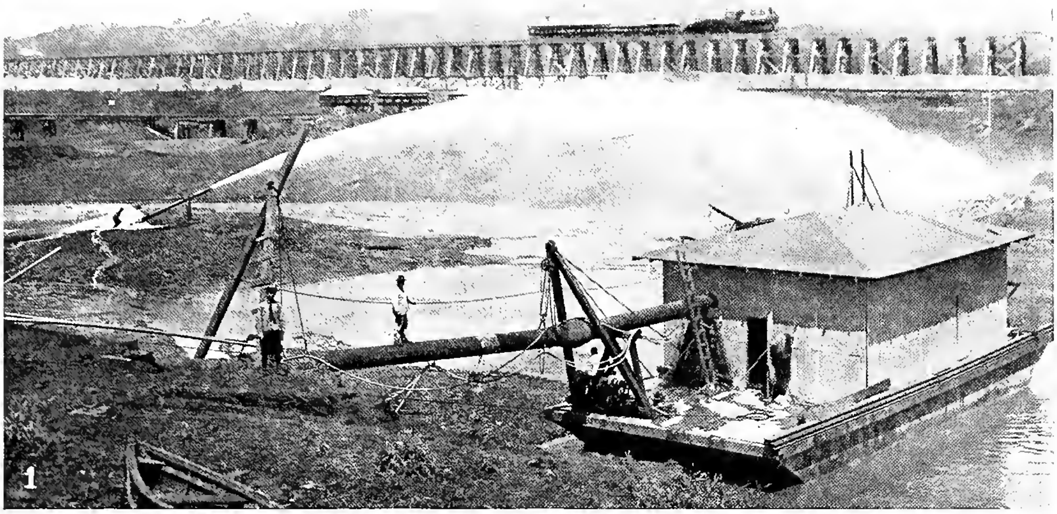
The method of operation was to sink the dredging pumps by stages in the prism to be excavated, until rock was reached, the sedimentary material being mined with the monitors, and sluiced by the dredging pumps. For mining and sluicing, salt water was used through all the pumps. The available power was 3,000 electrical H. P. The plant was designed on this basis for operating the dredging pump motors. The pumping plant had a capacity of 30,000 gallons per minute, pumping the same through 3,600 feet of main pipe, and 500 feet of branch lines.

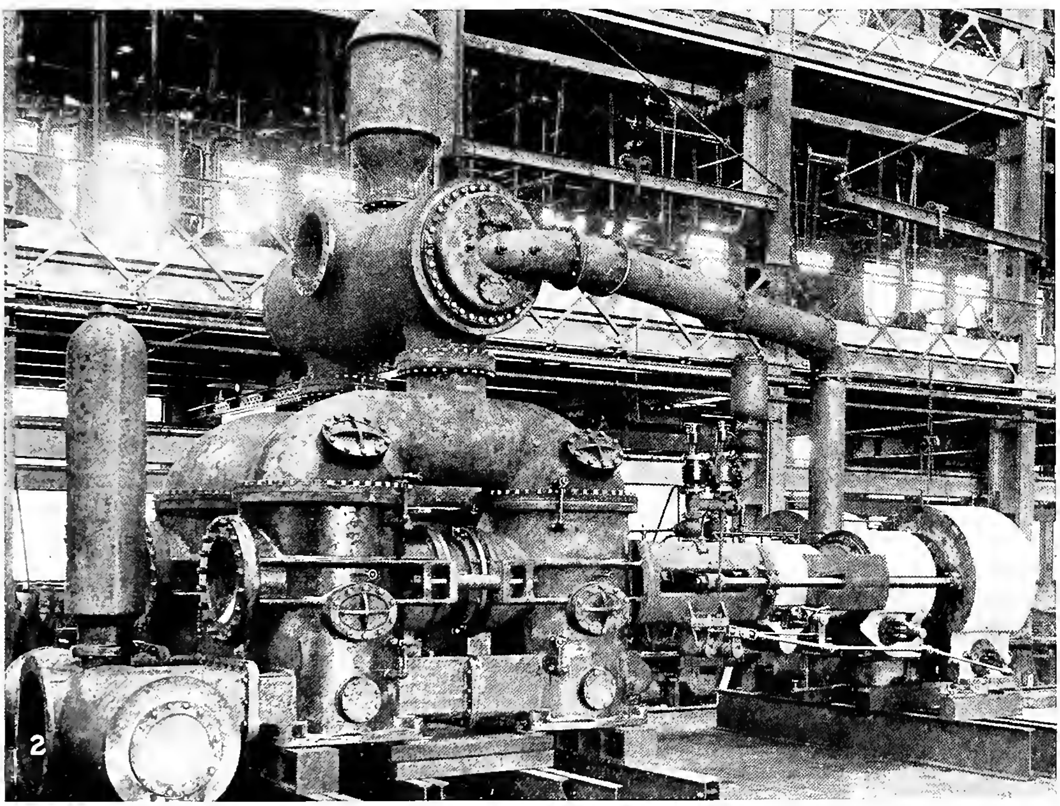
The central pumping station consisted of four units so constructed that they could be operated singly or in multiple, with any or all boilers. The engines took their water from the Rio Grande, having a variation of tide plus ten feet and minus the same distance. The equipment included a complete condensing system, oil and coal burning furnaces and special exhausters for taking care of the priming of the dredging pumps. The fourth or extra dredging pump was used for the excavation of more than 1,000,000 cubic yards of material, delivering the same to a hydraulic dam west of Miraflores locks, making a total lift of ninety-five feet.

The commission made many attempts to remove the vast amount of soft silt, earth, clay, and hard rocks by the use of dredges, and was forced to the conclusion that this material could not be economically handled in any other way than by the hydraulic method; hence came the contract with the International Steam Pump Company. It is one of the wonders of the canal construction that vast amounts of earth, silt, sand, and other materials were lifted from the



1. Hydraulic pipe line dredge.
2. Dredge spuds and dipper handles for the Panama Canal.
(Furnished by the Ellicott Machine Company of Baltimore, Md.)





1. Hydraulic excavation at the canal under pressure from Worthington pumps.
2. One of the giant triple expansion steam pumps used on the canal.
(Supplied by the International Steam Pump Company of New York.)

bed in which they had reposed for countless ages, and pumped, as if water, through thousands of feet of pipe and lifted to a height of nearly one hundred feet and there delivered at the will of the operator. This pumping process shortened the time of construction many months over what would have been required by the old system. A pump capable of handling 300 cubic yards of solid matter per hour almost staggers belief, yet the International Company had four such pumps at work on the canal.

In the excavation work, especially for deep foundations, wells, and for caissons, vast amounts of gravel and sand had to be taken out. To expedite this work sand pumps were employed, the Nye new model high-pressure pump being the one selected. These pumps were built by the Nye Steam Pump and Machinery Company, of Chicago, Ill. The pump is a small, compact machine designed especially for mining, railroad, draining, irrigation, cofferdam and well sinking work. The pump creates a very high vacuum, thus being able to lift water to a great height. One of the smaller size, requiring a space of only twenty inches square for installation, is capable of delivering water to a height of one hundred and fifty feet. The pumps used on the canal for sand pumping were capable of pumping seventy tons of sand per hour. Thus with a small expenditure of steam, 700 tons of sand could be pumped from an excavation in a day of ten hours. One of the advantages of these pumps for the purposes of the canal construction was that they could be worked suspended from a beam, or when placed upon a stand.

The earth fills and embankments of the canal were rolled in layers with Buffalo Pitts special embankment rollers, manufactured by the Buffalo Steam Roller Company, of Buffalo. These machines were so constructed that the corrugations could be removed from the rolls and the machines used for building streets and highways in the Canal Zone.

Buffalo Pitts rollers were selected because they are the result of twenty years' development of this machine by this company and have an unequaled record for efficiency and durability. Their record in the service of the various departments of the United States government and the government of the Philippine Islands was carefully scrutinized by the purchasing officials, and was found to justify their selection, regardless of the fact that they were somewhat more expensive than other rollers obtainable.

Another feature of these machines that recommended them to the engineers was the peculiarity of their construction, which enabled them to be utilized as hauling engines for drawing graders and wagon trains of road building or other material, over routes where it was impracticable to lay a temporary railway.

Construction Equipment

In the construction work of the Panama Canal the immense amount of heavy material to be handled made necessary the use of modern locomotive cranes. The principal cranes selected for the canal work were manufactured by the Browning Engineering Company, of Cleveland, Ohio. These locomotive cranes were self-propelling, and could rotate and hoist either independently or simultaneously. They were capable of lifting from one to 100 tons, and were fitted with booms 100 feet in length. They not only hoisted great stones and immense blocks of iron and heavy pieces of timber to their proper places in the work, but were also employed in digging; using, for this work, what is technically known as the "orange peel bucket." Blocks of stone and structural iron weighing many tons were handled with the greatest ease, some of them being hoisted to a height of nearly 100 feet.

Among the manufacturers who furnished machinery designed to expedite heavy work on the canal was the Brown Hoisting Machinery Company, of Cleveland, Ohio, designer and maker of patent automatic hoisting and conveying appliances.

In the autumn of 1905 this company shipped to the Isthmus one five-ton Brownhoist fast plant unloader and one five-ton cantilever crane. These machines were used on the docks at Cristobal. The unloader was used for unloading coal from the barges and transferring it to the railroad cars and the storage pile, and continued its work after the completion of the canal.

The unloader is equipped with a raisable apron 67½ feet long, which extends out over the boat, and at the rear of the unloader there is a cantilever extension of eighty feet. The Brownhoist trolley travels on the runway the entire length of the apron and cantilever extension. With this machine the company furnished a seventy cubic-foot Brownhoist coal grab bucket and four Brownhoist tubs. The grab bucket is suspended from the trolley, decends into the hold of the boat, automatically picks up its load, and carries it back to the storage pile or to the sixty-ton bin placed on the machine, from which the coal is dumped into the railroad cars. The tubs are used in cleaning up when the coal is to be shoveled by hand.

The unloader travels along the face of the dock with a speed of seventy-five feet a minute. It is steam operated, the boiler and engine house being placed on the pier. The trolley travels in its runway from 1,000 to 1,200 feet a minute, and has a hoisting speed of 500 to 600 feet a minute.

The cantilever crane was used for unloading general merchandise. It consisted of a steam operated pier running upon two tracks of thirty-seven-foot gauge, and had a cantilever extension on each side of 153 feet, one extension being out over the boats. This was also provided with a runway for a Brownhoist trolley, the entire trolley travel being 343 feet. With this appliance, heavy merchandise of all kinds was unloaded from the boats and deposited on railroad cars or a storage platform. These cantilever cranes were originally constructed for work on the Chicago Drainage Canal, and were the first of their kind in the world.

Brownhoist locomotive cranes for handling sand, crushed stone, coal, machinery, large block stone and other miscellaneous material were used in large numbers in the work on the Isthmus. These cranes were of fifteen to twenty-ton capacity. Brownhoist grab buckets of various capacities were used on the Lidgerwood cableways for handling crushed stone and other materials. Some remarkable records were made by the buckets in this work, and the appliances of this company, designed particularly to speed the handling of material of all kinds, counted heavily in the rapid completion of Uncle Sam's task at Panama.

The fact that on completion, all the power required for the operation of the canal as a whole was to be electrical, generated by water power from the spillways, gave to the selection of boilers to be used during construction—for the generation of steam required as power for various purposes connected with the construction work—an aspect essentially different from that ordinarily found in a work of such magnitude.

The numerous plants erected for construction work had to be considered as being of a temporary character. Further, a number of the plants had to be moved from point to point as the work of construction progressed, which made it advisable to utilize small and inexpensive boiler units. The result of such conditions was the installation of cylindrical, or return tubular, boilers in the greater number of the smaller plants.

In certain of the plants, however, which could be considered of more than a temporary character, that is, plants designed to operate several years, the added efficiency and general service of the water tube boiler was considered desirable despite the greater first cost. In plants of this kind boilers of the Babcock and Wilcox Company's manufacture were installed.

A number of these boilers were used, the first being installed at Panama in 1906 for the Union Oil Company. This company furnished the government with oil for a number of its plants, all the way across the Isthmus. Oil was brought from California in tank steamers and distributed to various points by pipe lines.

In 1907 the Babcock and Wilcox Company installed two boilers, rated at 500 horsepower each, for the Isthmian Canal Commission at the Balboa compressor plant. These boilers supplied steam for two air compressors, and for a small electric lighting load. Two years later two more of these Stirling boilers were installed for the commission at the Porto Bello power plant, where the steam generated was used mainly for stone crushing.

The same year four Babcock and Wilcox boilers were installed in the Central pumping station for hydraulic excavation and sluicing. This plant was designed to take care of the dredging and pumping work from San Miguel to the Pacific. This contract was awarded because of the superior merit of the steel-cased semi-marine type of boilers which were sold under a rigid guarantee of efficiency. The steel-cased feature of this boiler played an important part in its selection by the government officials. Much trouble had been experienced with boiler-setting brickwork, because of the blasting over the whole length of the canal. The blasts were very heavy and it was almost impossible to keep boiler settings in place. As brick on the Isthmus cost in the neighborhood of $100 a thousand laid, the upkeep of the ordinary boiler settings was excessive. The steel casings of the boilers installed at this plant did away almost entirely with this difficulty. Another interesting feature of these boilers is the duplex furnace. By this arrangement either oil or coal can be used as fuel. The boilers installed at the Central pumping station were of wrought steel construction throughout, and nominally rated at 2,100 horsepower.

Among the contractors for permanent machinery to be used in operating the canal was the D'Olier Engineering Company, of Philadelphia. The entire boiler plant equipment for the power house at both Gatun and Miraflores was furnished by this firm, and was installed by them. Each plant contains 600 horsepower, horizontally inclined, water tube boilers. The boilers are set in batteries of two, and have steel casings instead of the usual brick setting. They were built for 205 pounds absolute pressure, and a superheat of 150 degrees Fahrenheit.

Each boiler is equipped with shaking grates for the use of coal by hand firing and also with a complete system of oil burners, for the use of California fuel oil. The smoke flue is of steel, lined inside with a two-inch non-conducting lining. Each plant is equipped with a motor driven and a steam driven induced draft exhaust fan for drawing the gases through the boilers and sending them up the chimney. The arrangement of the dampers is such that either the motor driven or the steam driven fan may be used.

The contracts of this company also included the induced draft equipment, piping, boiler feed pumps, feed water heaters, and other boiler rooms auxiliaries, all of which were installed by the company. The piping system is very complete and consists of the highest grade of pipe and fittings. The high pressure steam pipe is extra heavy, with steel flanges welded on, long bend connections being used. The fittings are of cast steel and the valves are made with cast steel bodies, bronze fitted. The high pressure piping is covered with a magnesia covering two inches thick. Hot water meters are provided for measuring the amount of water supplied to the boilers. The cost to the government for the equipment furnished by the D'Olier Company was $175,000. All the safety appliances known to modern science were used both in the construction and installation of the two power plants, and to secure the greatest efficiency.

As speed in the completion of the great work was an important feature in the calculations of the Canal Commission it was sought, even in the smallest appliances to the machinery, to secure the appliance best adapted to the work it would be called upon to perform, and under the severe climatic conditions prevailing on the Isthmus. Many boilers were to be used in various parts of the work, and it was sought to have every appliance necessary for continuous work of the most complete kind. In looking for an injector for supplying the boilers with water, the choice fell on that manufactured by the Penberthy Injector Company, of Detroit, Mich. The superiority of this injector was its thorough automatic qualities, simple construction, and durability, operating with equal efficiency in any location or climate. The injectors excel in grading the amount of water delivered to the boilers, and lift water vertically twenty-three feet.

Keeler water tube boilers, manufactured by the E. Keeler Company, of Williamsport, Pa., were and are used at several points on the Canal Zone. In connection with the Gatun and Miraflores handling plants for the Gatun and Miraflores locks, these boilers were put through a series of rigid tests in which they made a remarkable showing.

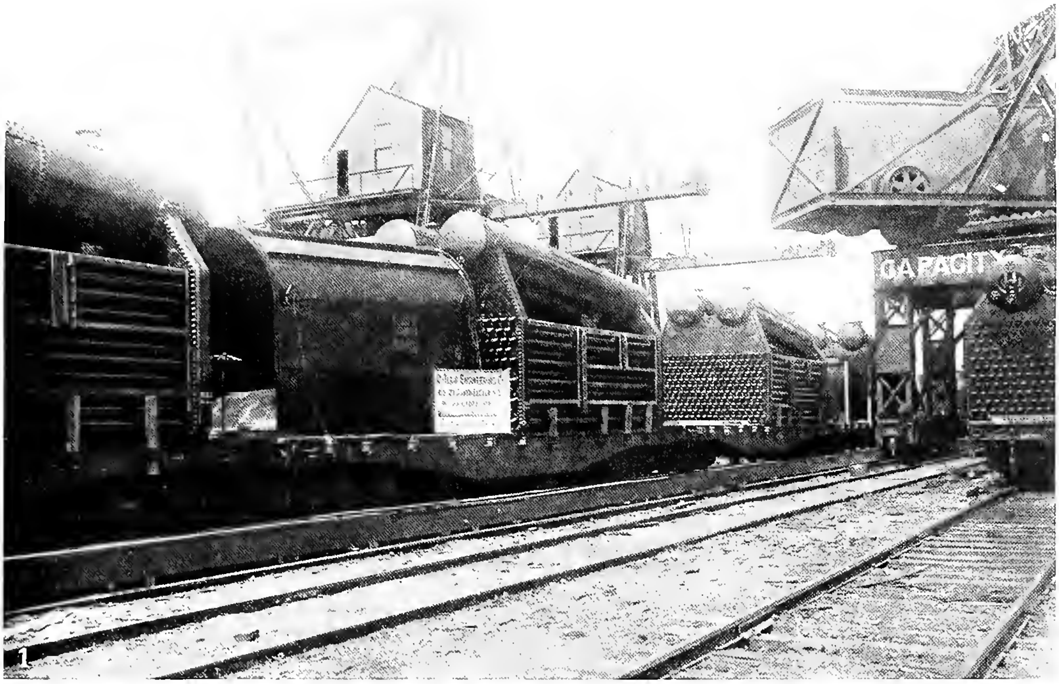
The Keeler water tube boilers include an unusually complete combination of features. They are designed to secure simplicity and durability, together with the highest safety and economy. The boiler consists of one or more steam and water drums to which are securely riveted a front and rear water leg or header. The tubes are expanded into these headers in straight horizontal and staggered vertical rows with an inclination of one inch to a foot. The drum is horizontal, providing a maximum steam disengaging surface. The steam outlet is from the center of the drum.

Vertical baffle walls of a special grade of fire brick with a backing of cast iron direct the gases three times through the bank of tubes. The tubes are staggered and the gases move at right angles to them, thus being continually divided and reunited, and brought into intimate contact with the tube surfaces. Horizontal baffles are provided if required by special conditions, and other special arrangements of baffle walls are made when desirable. Wrought steel is used for every part of these boilers under pressure, and the highest class of skill and material is used in their construction.

Prominent among the power plants in connection with the construction work of the canal were the batteries of Robb boilers built by the Robb Mumford Boiler Company, at South Framingham, Mass., now owned and operated by the International Engineering Works of the United States and Canada. For the machine shop and air compressor plant at Gorgona, twenty-four large Robb boilers were built at the South Framingham plant. These boilers were set in batteries of six each, and each battery formed a unit, consisting of six boilers discharging into a horizontal flue which had provision for cutting out any boilers for cleansing, and thence into a self-supporting steel stack 100 feet high and seven feet in diameter. The boilers were of the standard horizontal return tube type, each eighty-four inches in diameter and nineteen feet ten inches in length. The Robb boilers are constructed according to the rules formulated by the Massachusetts Board of Boiler Rules, the most rigid requirements of any State in the Union.

The question of water for use in running the hundreds of boilers required on the canal work was one of the greatest importance. It was well known that the water on the Isthmus is particularly bad for boiler purposes, and to enable the engineers to succeed in procuring the proper efficiency from their boilers, it was necessary to use chemicals to properly neutralize the water. The government looked about for the best material obtainable for the purpose, and adopted the chemicals of the Bird-Archer Company, of New York, purchasing thousands of pounds to be used in the marine, stationary, and locomotive equipment from the Atlantic to the Pacific.

The materials, made in liquid and powdered form for stationary purposes (accord-



1. Shipping D'Olier boiler plant equipment to the canal.
2. The boilers installed at Miraflores power plant.
(D'Olier Engineering Company, Philadelphia, Pa.)

ing to analysis of water), in extract and solid form (the latter in zinc containers) for marine purposes, and a new material in solid form in sticks one-inch square and nineteen inches long, known as polarized mercury for locomotives, are as effective in their way for locomotive use as the canal will be for shipping.

In supplying a compound suitable for the conditions existing along the great waterway between the Atlantic and Pacific, owing to the many different conditions arising from the vast difference in scale-forming salts found in waters, it was necessary to consider both chemical and metallurgical conditions.

It being almost impossible to secure analyses of the different waters, there being so many, it was necessary to make a compound in extract form, combining along with chemical reaction, an addition of polarized quicksilver made under special process known only to the Bird-Archer Company, and covered by letters patent.

Owing to the use of different types of boilers, working under different conditions, it was necessary to depend largely upon mechanical action of the mercury in throwing off scale and preventing the formation of new scale, and also in the stopping and prevention of any galvanic or corrosive action which might arise from acidity in the water, or through the negative and positive action of metals, one against another, under heat and pressure.

The Bird-Archer Company supplied a very large quantity of these special chemicals, which proved to be the most efficient of any boiler chemical ever used. It was also necessary to put up this extract, on account of the tropical conditions, in a special form to allow for expansion, a condition not found in the colder climates.

The Bird-Archer Company manufactures special chemicals for locomotive, marine, and stationary boilers. It has in its employ the most skilled officials, in its chemical, metallurgical and engineering departments, and has among its engineer corps some of the best known master mechanics, chief engineers from the marine service, and superintending engineers in stationary lines. It is now the largest manufacturer of boiler chemicals in the world, having a trade with nearly every country, and supplies at least ninety per cent. of the chemicals used by the marine trade in the United States.

For over thirty years the Ball Engine Company, of Erie, Pa., has been exclusively engaged in the manufacture of high speed steam engines, and it was but natural that it should have an important part in the work of furnishing engines for use in the construction of the Panama Canal.

Seven Ball engines were used in connection with the work on the canal. The combined power of these engines amounted to 800 K.W. in direct connected electric generator units, and 900 horsepower in rope drives. The largest unit was of the Cross Compound Corliss type, operating at 150 R.P.M. and driving a sixty-cycle Alternator of 400 K.W. capacity. The other units were of the tandem compound type, equipped with Sweet balanced valves.

All of these engines were of the side crank construction, which has been adopted by this company because of its superior adaptation to the conditions met in service. The construction eliminates the necessity for three bearings in engines direct connected to generators, and avoids the undesirable feature of an overhanging wheel, which is particularly objectionable in the case of belt or rope drives, and in alternating current work.

The engines furnished for service in the Canal Zone were of standard construction throughout, and represent the result of years of constant study and care in an effort to produce a machine superior to all others of its kind.

The single valve engines are equipped with a flat balanced valve, having a minimum amount of clearance. The valve, valve seat, and pressure plate are finished to a high degree of accuracy, permitting the valve to work freely, but being steam tight. Means are provided by which the valve may be readily adjusted to take up any wear that may occur. This is accomplished with a simple micrometer adjustment which allows the pressure plate to be minutely adjusted without removing the valve chest cover. This device is used exclusively on Ball engines.

On the Ball non-releasing gear Corliss engines the non-detaching valve gear is enclosed in a tight case which is partly filled with oil. This ingenius device makes possible a high speed engine of the genuine Corliss type because it keeps the valves completely at rest for more than one half the stroke, when the pressure on the valve is very much unbalanced, and when movement is detrimental.

In the latter part of 1907, the canal officials awarded to the Buckeye Engine Company, of Salem, Ohio, a contract for supplying one of its high-grade automatic steam engines, at a cost of $3,245, for work at the Isthmus. The award was based on the well-known merits of the machinery manufactured by this company, the government having previously purchased a number of its engines for use in construction work at other points.

The engine furnished was of the latest improved type as built by the company. It was of exceptional weight and strength, and so constructed as to insure the greatest possible durability and the most perfect adjustment of all its parts. Through its perfectly fitting valves ample travel at all adjustments was secured, thus eliminating untrue wear. The governor, being of the shaft type, is secured to the engine shaft, driving valves through an eccentric rod, rock shaft, and valve stem as positively as the main shaft is driven. This type gives the closest regulation under all conditions, and cannot become detached and wreck the engine. The Buckeye Engine Company has built more than 6,000 of these machines, besides being engaged in the manufacture of gas engines, and its latest product, the "Buckeye-mobile." This is a remarkably efficient engine and boiler unit for the effective utilization of superheated steam, a modification of the German type of locomobile, developed and adapted to American conditions.

One of the firms whose products were interwoven with many phases of the canal work was the Abendroth and Root Manufacturing Company, with its main offices and works at Newburgh, N. Y. This company, which manufactures the Root spiral riveted pipe, machinery and foundry supplies, plate metal construction, Root sectional water tube boilers and other like equipment, has been established since 1867, and its products were known in Central and South America long before canal construction was undertaken.

Many years ago, the company's pipes were used in installing the water pipe line at Tegucigalpa, Honduras, the line being over twelve miles long, with its head 2,000 feet above the city. An interesting illustration of the difficulties of shipments to this territory before the completion of the canal is shown by the roundabout way in which this pipe reached its destination. It was shipped by steamer from New York to the Isthmus of Panama, transferred to the railroad across the Isthmus, then on a steamer again up the coast to Amapala, and finally by barges to the mainland. It was then carried in carts ninety miles to Tegucigalpa.

With the completion of the canal, such a shipment could now be carried direct from New York to Amapala, and with the impetus given commerce, harbor and interior improvements by the example set by the United States at Panama, shipments to these remote destinations will meet few of the difficulties of years gone by.

Despite its rough journey, this pipe reached its destination in perfect condition, and a report fifteen years after it was laid down showed that it was working as perfectly as when the water was first turned in. The only damage the pipe sustained in that period was when it was twice cut during revolutions, but a length or two of new pipe soon made the whole as good as new.

Several miles of this company's asphalted

One of the great Brownhoist Cantilever Cranes at work in the Chicago Drainage Canal. Their efficiency there led to their extensive use on the Panama Canal.
(Supplied by the Brown Hoisting Machine Company, Cleveland, Ohio.)

spiral riveted pipe was used for hydraulic excavation work on the Pacific division of the canal, together with two of its hydraulic giants. On other portions of the canal, miles of pipe ranging from eight inches to twenty-six inches were used for exhaust steam, compressed air and water supply lines. The pipe was found suitable for all phases of the work where such piping was needed because of its light weight, great strength, and simplicity of connections.

A number of the Root water tube boilers manufactured by this company were purchased for power purposes at the canal. These boilers have a superior circulation that permits the highest degree of maximum fuel economy, easy steam qualities, low cost of repair and large capacity for overload.

The pipe furnished the canal by this company was made by its specially designed machinery, and coated inside and out by its special asphaltum composition or galvanizing process, insuring the longest possible life to the material by protecting it from corrosion. The spiral riveted construction gives the pipe a continuous helical rib, giving it great strength and rigidity combined with corresponding lightness in weight. It furnished one of the best examples of the thoroughness of American manufacture in the list of general equipment used in the canal's construction.

In the preparation for actual construction of the canal, to say nothing of construction work, large quantities of wrought steel and iron pipe were required. The water and sewer systems of Colon and Panama were made over, or rather created anew; the sanitation work throughout the Canal Zone called for piping of all kinds; the preliminaries for the housing and feeding of laborers included the construction of quarters, storehouses, ice plants, laundries, hospitals, etc., all of them fitted with modern plumbing and lighting plants.

The question of standardizing construction materials was an important one as affecting pipe, just as it affected all other equipment. The Isthmian Canal Commission found that rapid and thorough preliminary and construction work required both standardization and a formula that would insure the best of materials. A board was appointed to consider this matter, and tests were applied which were calculated to bring out the best points in American methods of manufacture. The Youngstown Sheet and Tube Company of Youngstown, Ohio, submitted a formula and specification for iron pipe and tubes which were finally adopted by the commission as a standard, and all material of that nature subsequently used at Panama either in preliminary work or in canal construction conformed to this standard.

The Youngstown Company received awards for over $400,000 worth of black and galvanized wrought steel and iron pipe, constituting shipments embracing practically every size and character. These shipments were made from the factory, after inspection by an engineer appointed by the Isthmian Canal Commission. As the operations on the Isthmus depended upon the promptness with which material was forwarded from the United States, it fell upon the Youngstown Company to expedite its shipments of pipe, and the manner in which this duty was performed drew forth praise from the government officials at Panama. The co-operation of American manufacturers was, in fact, a vital factor in the prompt and orderly evolution of the work at Panama. The history of the construction of the canal is also a history of American manufacturing efficiency—of good material honestly put together and systematically forwarded. The list of important manufacturers who contributed to the construction of the Panama Canal has become a roll of honor, and among the first to give cordial recognition to the efforts of American manufacturers were the engineers in the Canal Zone.

Cement and Concrete

Soon after the construction of the Panama Canal was commenced the Isthmian Canal Commission bought from the Allis-

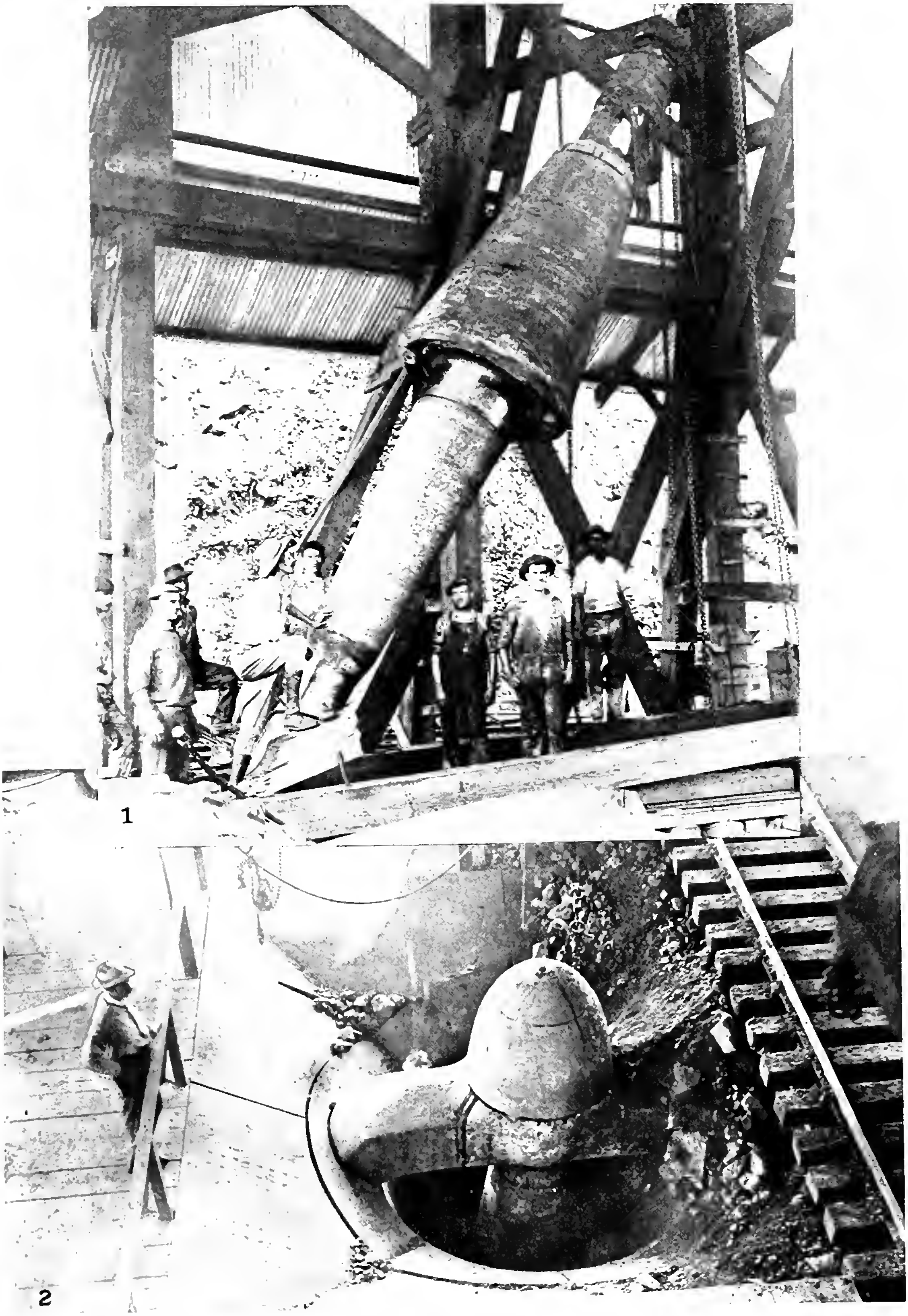
Chalmers Company the first stone crushing plant used in the production of crushed stone for concrete work. This plant consisted of one No. 8 Style "K" and two No. 5 Style "K" Allis-Chalmers "Gates" Crushers, and the necessary auxiliary equipment. The plant was designed by the Allis-Chalmers Company and erected by the Isthmian Canal Commission near Ancon. Its capacity was about 1,000 cubic yards per day of eight hours.

Later on as the work progressed and the Gatun Locks were being constructed the government engineers decided to erect a plant at Porto Bello to produce the crushed stone required for this work. The rock in the Porto Bello quarry was very hard and abrasive, closely resembling that found in the Palisades on the Hudson River, New York. The operations at the quarry being of necessity very large, and the additional fact that the peculiar formation of the rock caused it to blast out in pieces of immense size, made the installation of a large preliminary crusher necessary to obtain maximum operating economies. The engineers of the Isthmian Canal Commission decided upon a No. 21 Allis-Chalmers "Gates" Gyratory Crusher for this work as the most modern machine.

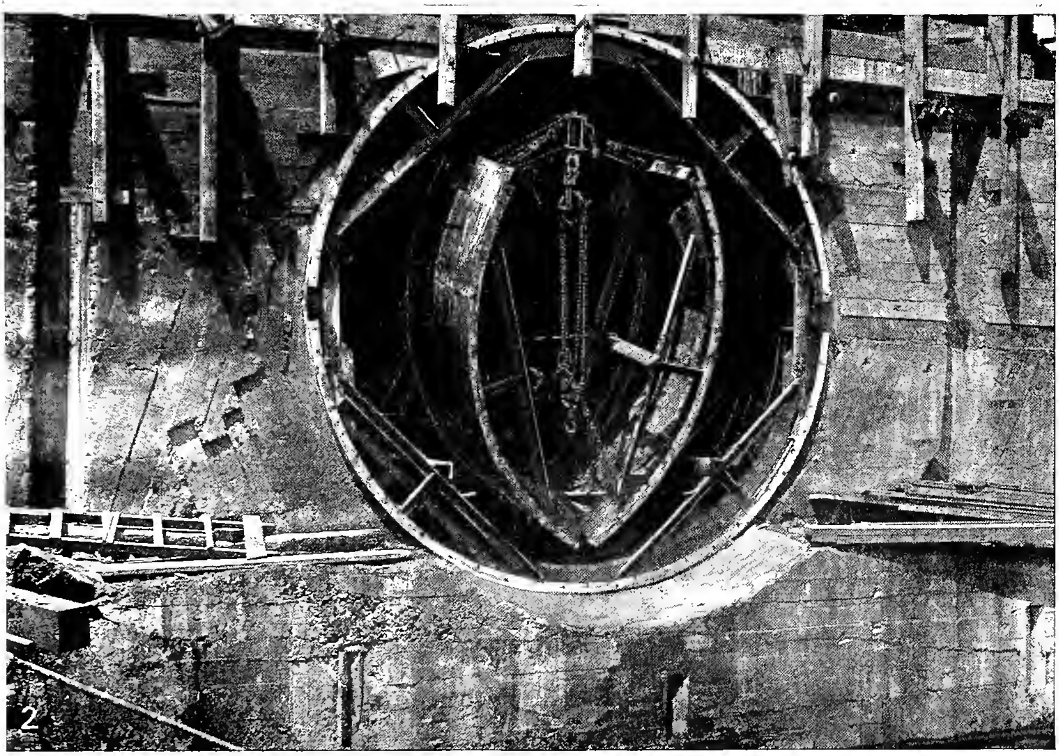
The great and rapid advance made in crushing machinery is shown by the size of the receiving openings of the No. 8 crusher installed at Ancon as compared with the No. 21 installed at Porto Bello. The No. 8 crusher has two receiving openings eighteen inches by sixty-eight inches, whereas the No. 21 has two receiving openings forty-two inches by 114 inches, the former machine weighing approximately fifty tons and the latter about 235 tons. To give some idea of its immense size it should be noted that it will take pieces weighing four to five tons, breaking them down to about seven inches in one operation. This large crusher is capable of easily crushing 5,000 cubic yards of rock in eight hours, although it was never extended to its fullest capacity as only 3,500 cubic yards were used at the Gatun lock daily. The enormous size and weights of the individual pieces that go to make up this machine made the transportation and installation (the plant being located several hundred feet above water level) a difficult one, and much credit is due the management and engineers of the Isthmian Canal Commission in successfully mastering these problems.

The rock in the quarry was loaded with large steam shovels into six to eight-ton side dump cars, and trains of ten cars were brought by locomotive to the crusher and discharged into the feed hopper. After being crushed in this preliminary breaker to about seven inches the material dropped into a sixty-inch Allis-Chalmers pan conveyor and elevated to additional crushers which further reduced it to about three and one-half inches. The material used in the concrete work at Gatun locks being "crusher run," no sizing screens were necessary at the crushing plant. Its location being on a hill-side, all the crushed material flowed by gravity to a final conveyor located at the foot of the hill which carried it to the storage bins. These bins were located on Porto Bello harbor, and the material was loaded directly from these bins into barges having a carrying capacity of about 700 cubic yards. The barges were towed to Gatun, a distance of about thirty-five miles, and there unloaded with clam shell buckets.

By the middle of 1909 work on the locks had reached the stage when concrete construction began in earnest, and immense quantities of material were accumulated at Gatun, Miraflores and Pedro Miguel. The extraordinary size of the culverts and other conduits connected with the locks make it necessary that specially designed forms should be employed for the deposit of concrete. Experience in the construction of such works as the New York subways had demonstrated the superiority of collapsible steel forms over the old wooden forms. Although the first cost was higher, the steel forms proved much more economical in large operations, because of



1. Main shaft for crushing plant at Porto Bello.
2. Stone breaker.
(Supplied by the Allis-Chalmers Company, Milwaukee, Wis.)



1. Twenty-two-foot horseshoe shaped Blaw Steel Form for culvert construction, Panama Canal.
2. Eighteen-foot round Blaw Steel Forms showing telescopic features used for culvert construction in the canal locks.
(The Blaw Steel Construction Company, Pittsburgh, Pa.)

the rapidity with which work could be done.

After considerable study of the problem, the commission adopted a design furnished by the Blaw Steel Construction Company, of Pittsburgh, as being best adapted to canal work. Contracts were awarded to this company, and the forms were shipped to the Isthmus in July, 1909, and July, 1910. The accompanying illustrations give a clear idea of the manner in which the forms were used for culvert construction in the locks. The forms were of great size, measuring in some cases twenty-two feet in diameter, and were the largest in existence at that time. In the tropical climate of Panama wood forms would have warped and caused no end of trouble by losing their shapes, but the steel forms retained their rigidity under all conditions, and, of course, were not affected by tropical heat.

Instead of setting up a temporary form which would have been knocked down again with each completed section of the work, as is necessary when wood forms are used, the steel forms were merely telescoped and moved forward to a new section. No repairs or renewals were required, there was no waste labor or material, and valuable time was saved on account of the ease with which forms were set up and removed, and also on account of the accurate adjustment.

Since these steel forms were employed at Panama they have become a factor in other important concrete construction projects, notably in the aqueduct conveying Catskill water to New York City, and in the New York subways.

The steel forms furnished for the culverts through Miraflores and Pedro Miguel locks by the Blaw Steel Construction Company were ten, eighteen, twenty and twenty-two feet in diameter.

The heavy loads of concrete which these forms had to carry and the requirement that one section be passed through the others in position made it necessary to use the most advanced ideas in the design of a collapsible telescopic form.

The full round forms were made in five-foot sections, each section being divided into quadrants. The quadrants were rigidly braced with angles, making it impossible to distort the forms when handling or loading with concrete. The joint lines of the quadrants were on the horizontal and vertical planes. The horizontal joints were reinforced with lap plates spanning the joint from one quadrant to the other. At the vertical joints, top and bottom, hinges were provided for holding the quadrants together.

The moving of the forms was accomplished by means of a special traveler which ran on a track attached to the bottom quadrants. This traveler was provided with vertical jacks and side collapsing arms which engaged the top quadrants. The jacks and arms after being fastened to the top quadrants were collapsed, drawing in the quadrants to a position of less cross-sectional area than when in full position, so they could be passed through the sections in place. The bottom quadrants were collapsed by a rope and block and raised by a chain hoist to a position which would allow them to be telescoped.

The horseshoe-shaped forms were of the three hinges type. The sections were five feet long and divided into four parts called side sheets and wing plates. The side sheets were hinged together at the top and to the lower ends of the side sheets were hinged the wing plates. The collapsing and moving of these forms was done on a traveler constructed to run on a track which was laid on the finished invert of the culvert. The traveler was provided with vertical jacks and side collapsing arms. The vertical jacks engaged the forms at the top hinge joint and the collapsing arms engaged to side sheets above the joint of the wing plates. After the traveler was made fast to the forms, the wing plates were raised and folded in next to the side sheets. The side sheets were then drawn away from the concrete by the collapsing arms and the entire form lowered by the vertical