jacks sufficient to pass through the forms in position.

The water passages under the floors of the locks were made with a full round form. At regular intervals an opening occurs from these water passages up into the locks. This opening was formed by a special collapsible steel form which fitted on the full round form and projected up to the floor line of the lock.

These forms were built by the Blaw Steel Construction Company from their own designs, which were approved by the United States engineers. The forms were erected in the shops and inspected before shipment. No skilled labor was required to handle them, as all parts were interchangeable, thus avoiding any cutting or fitting after the forms were erected.

The Alpha Portland Cement Company, which from time to time furnished the Isthmian Canal Commission with large quantities of cement, is one of the largest Portland cement concerns in the United States, as well as one of the pioneers in the American manufacture of Portland cement.

When the Alpha Company started operations in 1891, there was but little Portland cement used in this country. The first equipment of the company consisted merely of two forty-foot kilns, and the yearly production amounted to only 100,000 barrels—a quantity that the six great plants of the Alpha can now produce in four days.

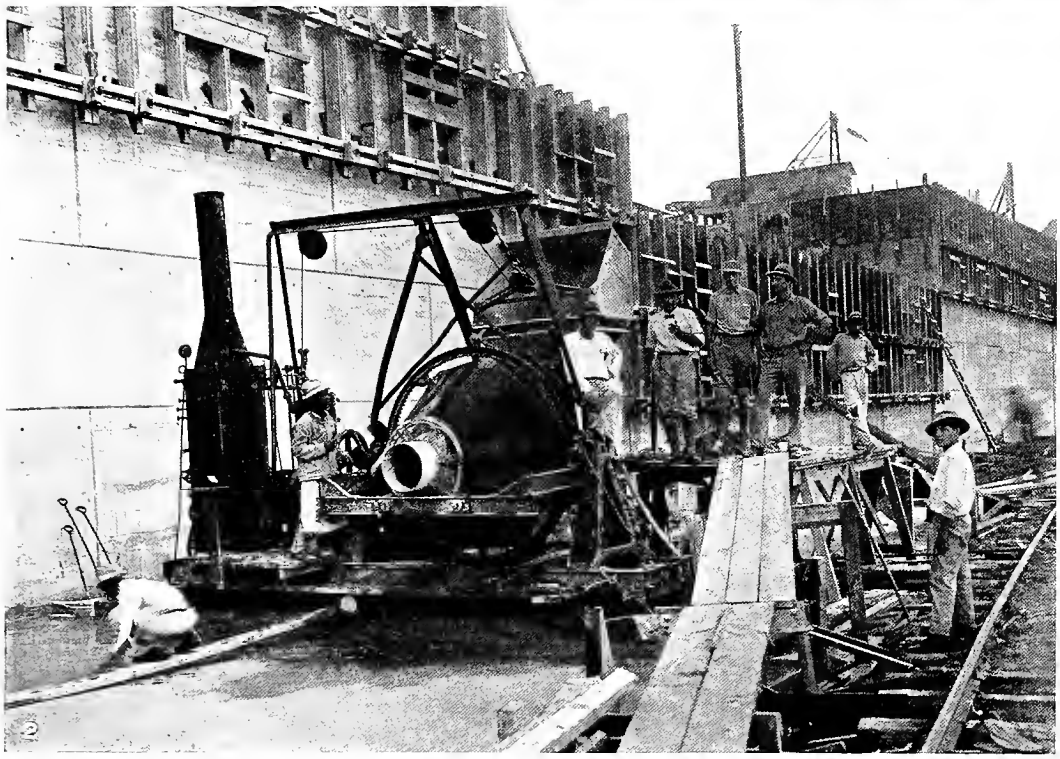
The mills of the Alpha Company are located at Martin's Creek, Pa., Alpha, N. J., Manheim, W. Va., and Cementon, N. Y. There are six great plants on six trunk line railroads. The Catskill plant, with its private docks, is also directly on the Hudson River and ideally situated for shipments along the coast, the barge canal, and for export purposes.

The product of the Hudson River Alpha plant has a characteristic that fortunately fits with its location, that is, the low percentage of alumina in the rock, which adapts the cement particularly to use in sea-water. Extensive investigations show that a cement of low alumina content gives the best results where concrete is exposed to salt water, sewerage acids, etc. For a time only imported cements were used in the under-water construction on the Key West extensions of the Florida East Coast Railroad. When Alpha cement was tested thoroughly it was found to meet every test, and thereafter was used in the under-water construction of the extension.

The Martin's Creek quarry of the Alpha Company is perhaps the best known of any of the Portland cement plants on the continent. Here are a thousand acres of the finest quality of cement rock, the face of the quarry being from 100 to 170 feet high, and the limestone possessing just the proper percentage of lime needed for a perfect Portland cement. In the blasting methods followed at the Martin's Creek quarry, holes are drilled in sets of ten to fourteen down the entire quarry face and snake holes driven in to meet the vertical borings. In the blasts as much as ten and one-half tons of dynamite are used to bring down the rock.

In addition to having been selected as one of the brands for use on the canal, Alpha Portland cement has been liberally used by the United States government in important operations, such as the fortifications at Egmont and Mullett's Keys, Forts Hancock, Wadsworth, Slocum, Monroe, Strong, Mott, Totten, and Schuyler, as well as in the Navy Yards at Portsmouth, Charleston, Brooklyn, Norfolk, League Island, and Boston. It has been also used extensively by the government for piers, sea walls, dry docks, light houses, etc. The company has recently enlarged its capacity so that now it has a producing capacity of 9,000,000 barrels a year, and storage facilities for 2,000,000 barrels.

One of the most remarkable records during canal construction was that of the Atlas Portland Cement Company. The government used 5,000,000 barrels of the company's cement in the Panama Canal without the rejection of a single barrel.



1. Austin concrete mixers at work on the canal. (Miraflores Locks.)
2. The mixers at work on the gate sills. Upper locks, Miraflores.
(Supplied by F. C. Austin, Municipal Building and Contracting Company, Chicago.)

Following this record the company then practically supplied all the cement needed to supply the canal work, following its first consignment of 5,000,000 barrels with additional shipments which soon ran over the half million barrel mark, and continuing until the canal was finished. In keeping with the policy of "safety first," cement was needed at Panama which by the most rigid and extensive tests could prove its superiority. These requirements were met by the Atlas Company, and the enormous consumption of cement for the work and the possibility of loss through idle equipment and a shifted payroll in case of slow deliveries made necessary the selection of a cement manufactured where production not only met but could exceed any demands made. The Atlas Portland Cement Company, having a daily productive capacity of 50,000 barrels, or 18,000,000 barrels per year, therefore was able to cope with any demands for Panama without interfering with other shipments. The company's productive capacity was and is by far the largest in the world. The first 5,000,000 barrels furnished by the Atlas Company was used in constructing the canal locks, and Gatun dam and spillway. Because of the importance of this phase of the construction the cement was given most rigid and exacting tests in the government's laboratories, and not a single barrel was rejected for any reason. This is an incomparable record of industrial efficiency in production and one which can scarcely be paralleled by any concern in the world. It can, therefore, be readily understood why the United States government when it found it would require a large additional supply of cement to complete the work decided to enter into a new contract with the Atlas Portland Cement Company to supply the cement required to complete the canal. If one could realize the magnitude of 5,000,000 barrels of cement or 5,000,000 packages of any kind, some appreciation could be reached of the feat of the Atlas Company in having this vast number of deliveries passed unchallenged by the guardians of the canal. The achievements in Panama will go down in history as monuments to those who labored there, but not the least among the achievements was the steady and uninterrupted delivery of great quantities of supplies of the highest efficiency by American industrial concerns.

Mixing the Concrete

A total, in round figures, of 5,000,000 cubic yards of concrete was required in the structures for the Panama Canal. The costs of this concrete are available only for main structures, but a fair average is perhaps $6 per cubic yard. In dollars and cents, therefore, the concrete work of the Panama Canal represents $30,000,000. Such an expenditure warranted extreme care in choosing all machinery for making concrete. Besides this reason there was the equally important reason that these concrete structures were for all time and were to be a monument, before the eyes of the world, of American engineering proficiency in concrete construction. Every motive of selfish interest as well as of professional honor and pride prompted exceptional precautions to insure concrete construction above criticism. One of these precautions, and logically the first that would occur to trained engineers, was superior mixing.

There were available to the canal engineers a number of different concrete mixers. Claims of superiority were made for all. No impartial comparative test records existed. In order to decide certainly which mixer was superior, it was determined to test in the field in preliminary work all those mixers which had gained prominence in engineering construction. The field tests were made, and from the experience thus obtained the decision was made to adopt the Austin improved cube mixer. Altogether over a hundred of these mixers were bought; they ranged in size from two cubic yards to one-third cubic yard; they mixed concrete for every canal structure from building blocks of less than

a cubic foot to the great Gatun Locks of 1,945,457 cubic yards in one mass.

The success of the Austin improved cube mixer in the preliminary competition at Panama was not fortuitous. This mixer had a history which was unique among the records of machines of its kind. The very first form of machine to be extensively used for mixing concrete was a cubical box, journaled at diagonally opposite corners, and having a door in one side through which the charge of cement, sand, stone and water was filled and the batch of mixed concrete was emptied. These machines were mechanically crude, but they produced a remarkably perfect concrete. Old concrete makers will recall the arrangement—a wooden box shod with iron and hung and bolted by the contractor's carpenter and blacksmith, but turning out a concrete so thoroughly and uniformly mixed that no hand-mixed product could compare with it. The cube mixer first demonstrated the great economy of machine mixing over hand mixing, and, it is essential to remember, it did so not because it presented any nicety of mechanical construction or because it gave an enormous output, but because it made a better concrete.

But to discharge the mixer the cube had to be stopped with the side containing the door on the bottom, and to charge it again it had to be turned until the side containing the door came on top.

In other words, some time was lost in unclamping the door to discharge the batch and in clamping it in place again to enclose the new charge. Altogether, the arrangement was unmechanical, but it had the saving grace of doing good work, even if it did it slowly. Through this quality it supplanted hand mixing. The army engineers, who until a few years ago were executing most of the concrete work being done, adopted the cube mixer. They did not require rapid mixing, but they did require unusually perfect mixing, and the old style cube gave them this. For twenty years no other mixer was used; practically no other mixer was known. Then the railways, the city engineers, the big public service corporations, and the general building public began to see the great advantage of concrete construction.

The possibilities of concrete reinforced with steel gave impetus to the movement. All this meant that more concrete had to be made, and made faster, and a multitude of inventors set about to devise a mixer that would beat the old style cube in rapidity of mixing.

Twenty years of experience had demonstrated that the perfect method of mixing concrete by machine was to hold the entire batch of materials together and incorporate them with one another by the criss-cross puddling action given by the revolving slides of a cubical box hung at diagonally opposite corners. The inventors who started out to improve the old style cube did not fail to perceive these facts. They adopted the batch principle at once, but the problem of retaining the criss-cross puddling action troubled them. They did not see how a cubical box could be mechanically arranged so that it would receive the charge and dump its batch quickly and without stopping. They took the easy road of substitution. Circular drums were substituted for the cubical mixing box, and as a smooth circular drum would simply slide from under the wet mass of concrete, sand, and stone, they riveted shelves or fins to the inside of the drums. To meet the criticism certain to occur that the crosswise movement of the materials, which was a cardinal feature of the cube, had been lost in their substitute, they fashioned their fins or shelves with a cant or slope, designed to toss the material back and forth longitudinally. Thus came about the rotating drum mixer with inside disintegrators. It was cheap and it turned out concrete rapidly, but the concrete was not cube-mixed quality.

The next substitution was the "continuous" mixer. In this machine the substitution of paddles was not only carried a step further, but a substitute for the

batch principle was introduced. The reason was, again, cheapness and greater rapidity of output. Quality of mixture was still further discounted.

The remaining chapter in this story of substitution was the devising of the "gravity" mixer; a trough studded with pegs and ears was set on a stand and the cement, sand and stone chuted down it. Cheapness and capacity were advanced another step, and quality of mixture was practically relegated to the non-essentials.

Then there came a new man into the mixer manufacturing field, F. C. Austin, who took up the problem of bettering the old style cube mixer. His first step was to eliminate the idea of substitution and to set firmly in its place the idea of improvement. It was seen that there could be no substitute for the distinctively peculiar mixing action of the cubical box journaled at diagonally opposite corners, if concrete equal in quality to that produced by the old style cube was to be turned out. It was further accepted as an article of faith that quality of mixture must not be sacrificed to speed and cheapness of mixing. The task was to improve the old style cube mixer, to make of it a compact, portable, self-contained machine that could be charged and discharged without stopping and loss of mixer time. It would have been easier to design a substitute, but a careful study of the possibilities of substitution convinced this engineer that no departure from the cube principle could be made without deterioration in the quality of the product. This was a contingency which, as stated above, had been eliminated from the things to be even considered—the object was to improve the old style cube in every function it possessed, not merely to better its speed. The reader is not interested to know all the steps of this labor, but the result—the finished Austin Improved Cube Mixer—is the machine that mixed the concrete for the Panama Canal.

Briefly stated, the shaft which passed through diagonally opposite corners of the old style cube mixer was removed and replaced with hollow trunnions riding on rollers. These hollow trunnions were made large enough to serve as openings for charging and discharging the mixer. To rotate the cube, a strong circumferential rack was fastened around it on a drum at right angles to and midway between the trunnions. This rack, geared with a pinion shaft, was operated by the engine shaft in such a way that all gearing was removed as far as possible from the material which flies about in charging and discharging. To discharge the mixer, a simple automatic power dumping device was introduced, by means of which the discharge can be made by the man who operates the engine, an extra man not being required to tilt the dumping device. To permit the use of a larger cube in the same space, the sharp corners and edges were rounded. Finally the whole mechanism with its motive power was mounted compactly on a frame which could be put on wheels and moved from place to place.

The records of the Austin Improved Cube Mixer at Panama justify the selection by Mr. Austin of the cube mixer body and for all his labor in developing it into a perfect mixing mechanism. These Panama records are too voluminous to present, but a few selections indicate the character of all and demonstrate the claims made.

During the year ending June 30, 1912, Austin Improved Cube Mixers, ranging in size from one-half cubic yard to two cubic yards, mixed a total of 1,209,506 cubic yards of concrete. The actual working time of these mixers was 24,946 hours, or 3,118 eight-hour shifts. Therefore, each mixer mixed per hour worked, an average, for all sizes, of 48½ cubic yards, or one cubic yard every 75 seconds. This output record is the average of all mixers, large and small. Individual batteries of mixers made better records. For example: Two mixers working on Gatun Locks mixed 80,544 cubic yards in 1,175 hours worked, or 68.54 cubic yards per mixer per hour worked. Output life records have not been

computed, except in one case of a battery of two mixers which were withdrawn from canal construction and put on fortification work. These two mixers had, up to the time they were withdrawn from canal construction, mixed 410,000 cubic yards, or 205,000 cubic yards each. How much greater output life these two mixers have cannot be stated—they are still mixing concrete.

Represented in the American machinery used in concrete work at the canal were the concrete mixers furnished by the T. L. Smith Company, of Milwaukee, Wis., which furnished the canal commission with eight of its standard equipments between 1907 and 1909. All of the machines were portable outfits, of approximately half-yard capacity, and consisted of the mixer on truck, with engine and boiler, the entire apparatus in actual work discharging the mixed concrete into position without shoveling or wheeling.

The mixers furnished by the T. L. Smith Company gave thorough satisfaction at the canal. They had already won an enviable record in construction work in this country on the Florida East Coast Railway, the Galveston sea wall, the Roosevelt dam, and the great dams built at Keokuk and Helena, as well as in extensive concrete jobs completed by the government in Porto Rico, Hawaii, and the Philippines.

The Corrugated Bar Company, of Buffalo, N. Y., entered into canal work in October, 1908, and continued shipments up to June, 1912, its contracts in full calling for 2,150 tons of steel bars, used as reinforcement in concrete work at the Isthmus. These included operations in connection with the construction of retaining walls, locks, docks, and other similar building operations at the canal.

In addition to its headquarters at Buffalo, this company has district offices in St. Louis, New York City, Boston, Chicago, and St. Paul. It was the first to introduce the idea of a mechanical bond for reinforcement in concrete work, and it started in business in 1891 as one of the earliest of the expanded metal companies. Its engineers were responsible for the first scientific formula for the designing of reinforced concrete beams, so that it can rightly claim the place of being the pioneer in its particular line of activity in this country.

During the first ten years of its history, the Corrugated Bar Company confined its operations mainly to the line of fireproof construction, in which it acted as an engineering and contracting firm. Later it specialized in making designs and selling reinforcing material. During the entire period of its existence, it has never had a failure in its particular field of operation. This justifies to the fullest extent its slogan, adopted a few years ago, of "twenty-one years without a failure," for no building collapse ever followed where it furnished the design.

As regards the work of this company at the canal, its successes in competitive bidding were due solely to the superiority of its product. As steel and concrete have practically the same coefficient of expansion, tropical conditions on the Isthmus introduced no new difficulties that had specially to be met. But if they had, the corrugations on the steel bars furnished by the company made them independent of the question of adhesion. The corrugations on the bars are sufficient in number to make the bond positive and entirely independent of any adhesion with the concrete. These ribs are also designed in such a way as to entirely avoid, at all stresses short of the proof load, any splitting tendency on the concrete, this representing the patented novelty of this type of reinforcement.

Corrugated bars used at the canal were rolled from billet stock, and can readily be supplied either in medium or high carbon steel. Large stocks are carried at numerous points throughout the country for immediate shipment. More of this bar has been sold in recent years for concrete construction than of all other types combined, and it is generally regarded by engineers as

representing the last word in scientific design for concrete reinforcement.

Extensive examinations recently made of important concrete structures abroad, reinforced with plain bars, have indicated that the results were by no means as satisfactory as similar structures in the United States and elsewhere, reinforced with corrugated bars, and preparations are now under way in France and other foreign countries for the local manufacture of this material.

In the construction of the rock crushing plants for the concrete used in building the locks, a great quantity of accessory machinery was installed.

Hill friction clutches were specified and purchased in order to provide for the desired flexibility, as these clutches permit starting the motors under no load, and also provide for the instant release of the load in case of accident requiring repairs to any part of the equipment.

The Hill friction clutches have been manufactured since 1884. There have been many improvements made in the design and action since the original Hill clutch, but the essential principle of operation remains the same.

Both standard type and Smith type Hill friction clutches were installed,—the latter being a later development of the former, and perfected after the date of the first order.

English system rope drives were used for transmitting the power. The friction clutches were all used in connection with rope sheaves, and the complete drives were furnished by the Hill Clutch Company, of Cleveland, Ohio.

Another firm which furnished equipment designed for the speedy handling of large quantities of material was the Stephens-Adamson Manufacturing Company, of Aurora, Ill. It furnished the conveying machinery used in the crushing plant at Porto Bello, which supplied the stone for the concrete work in the canal. The equipment included two "S-A" pivoted bucket carriers and two "S-A" steel pan carriers, each with a capacity of conveying about 500 tons of material per hour. The company has installed many plants for handling crushed stone, with capacities running from 100 to 1,000 tons per hour.

Concrete dumping buckets constructed of steel and iron for handling concrete on the canal were supplied by the G. L. Stuebner Iron Works of Long Island City, N. Y. These buckets were supplied under five separate contracts entered into between the canal authorities and this company, running over a period of several years. The contracts were repeated as the buckets were needed. They were correctly balanced, thoroughly well constructed in every detail, and worked perfectly.

Hercules steel bumping posts, placed in cement foundations at the ends of the towing tracks for the use of the electric towing engines, were furnished to the canal by the Railway Traction and Supply Company of Chicago. These bumper posts were made of boiler plate steel, each weighing about 1,000 pounds.

They were adopted on the canal because they were stronger than any other post, more easily installed, and had greater strength and lasting qualities. They are impervious to tropical insects or climatic influences, with no wood to decay or burn, and take up comparatively little track room.

There were six heavy car springs in the head of each post, making the use of the bumper very easy on the equipment, the engines catching the bumper as though coupling to another car.

Equipment for the Lock and Dam Gates

As described elsewhere, the construction and general equipment of the gates for the Panama Canal locks developed problems in mechanical engineering, including operations in the foundry and machine shop, of such stupendous proportions as scarcely to be overshadowed by the civil engineering work on the Isthmus.

The material and construction work on the gates required for the flights of locks

of the canal system were largely furnished and performed by the Wheeling Mold and Foundry Company, of Wheeling, W. Va. The total contracts of this company amounted to 19,000 tons, comprised in iron and steel castings for the locks and gates (these furnished by the company), and in 334 machines for operating the gates and valves (furnished by direct contracts with the Isthmian Canal Commission); in conductor rails for supplying current to the electric locomotives that tow vessels through the canal locks on a cogged way; some 40,000 pounds of manganese bronze; rolled nickel-steel pins, bearing-plates, and the like; and a pumping system covering 350,000 pounds of piping, valves, etc.

In the general contract for all the gates proper, the Wheeling Mold and Foundry Company supplied not only the yoke and the pintle bearings, and the quoin end and miter and reaction castings, but also the nickel steel bearing plates for both ends of the gates. It also furnished the heel casting which carries the entire weight of the gates on the pintle bearing, this being the most important casting used in connection with the gates. It has been estimated that if all the gates leaves in the canal were to be piled on top of one another they would make a tower more than a mile and a quarter high.

The mechanism for operating the gates is one of the most interesting features of the mechanical engineering work at the Panama Canal. The motion imparted to the leaf is by means of a machine so constructed that it is capable of exerting its greatest force at the moment when the resistance is greatest, and it is to be emphasized that the rate of increase of the force from minimum to maximum is, in fact, greater than the rate of increase of the resistance. The contract for the ninety-two complete machines thus required was taken directly by the Wheeling Mold and Foundry Company.

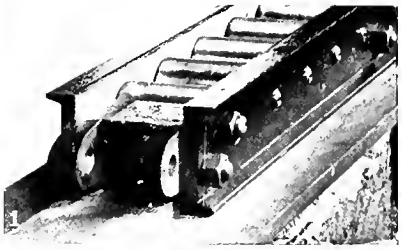
In addition to furnishing material for the gates, the Wheeling Mold and Foundry Company also furnished for the McClintic-Marshall Construction Company the castings for the two gates for the Balboa dry docks, these being practically duplicates of the lock gates, and also furnished, through the commission, two moving machines to operate the gates.

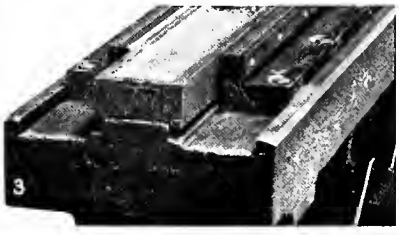
With regard to the rising-stem valves and the machines for their operation, the valves themselves were obtained under a separate contract. However, the contract for the machines and the lifting connections of the mechanism was awarded to the Wheeling Mold and Foundry Company, for the entire 116 machines, which are for the valves that control the main culverts of the locks. The total weight of the moving parts is 22,500 pounds in air, while the rising-stem valve machines' complete weight is about 7,200 pounds. The guide frames for the machines had to be built into the solid masonry, and were therefore ordered considerably in advance of the machines proper. The material for the frames, also furnished by this company, amounted in weight to about 9,000,000 pounds.

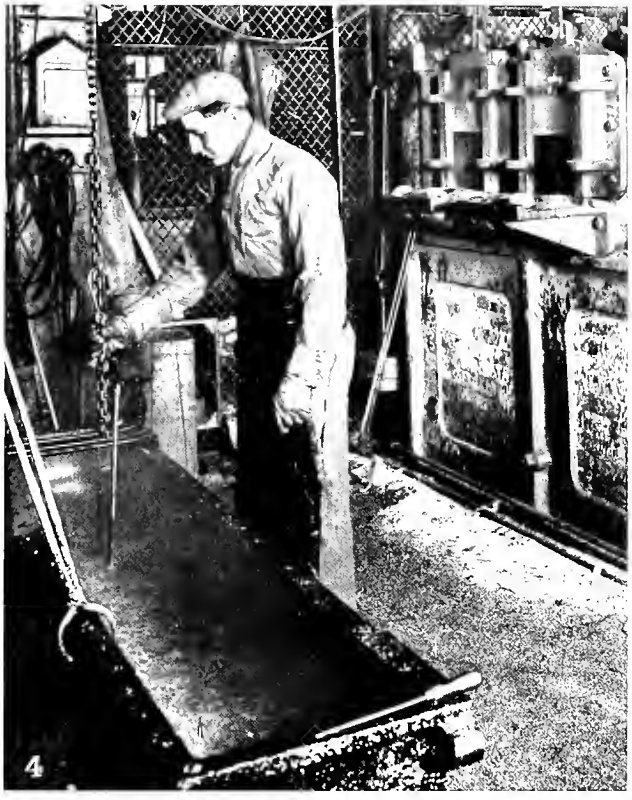
The cylindrical valves used for operating the gates for each lock chamber are located at the points where the lateral waterways for filling the locks connect with the main culvert. They are six and one-half feet in diameter, and have a lift of three and one-half feet. Each is connected to its driving mechanism by a machine built by the Wheeling Mold and Foundry Company, there being 130 of these machines in all, weighing altogether about 550,000 pounds.

The foregoing account only briefly reviews the operations of this company in its relations with the construction work at the canal, but it is calculated to indicate its capabilities for handling unusual work as well as work of great magnitude. The work with the Isthmian Canal Commission represents four important contracts, all secured in open competition.

The personnel of the Wheeling Mold and Foundry Company is composed of C. E. Blue, president of the company since its







1. Roller trains for lock gates. 2. Sealing device for rising stem gate valves. 3. Assembling the sealing device.
4. Bathing the rollers in oil. 5. Forging the rollers.

(Lock and Dam Mechanisms made by the Westinghouse Machine Company, East Pittsburgh, Pa.)

organization, in 1897; L. V. Blue, vice-president; F. du Pont Thompson, chief engineer; H. S. Bradley, secretary; H. Quarrier, treasurer; W. V. Hoge, Jr., business manager, and E. C. Rauschenberg, superintendent.

The Steacy-Schmidt Manufacturing Company of York, Pa., furnished all the machinery to operate the spillway gates at Gatun and Miraflores lake, with the exception of the electric motors. These spillway gate machines are designed to raise or lower the spillway gates for controlling the water levels of Gatun and Miraflores lakes. There are twenty-two gates, fourteen at Gatun and eight at Miraflores. Each machine consists essentially of two counterweights of approximately 47,000 pounds each, one at each end of the gate.

The screws are of a special composition forged bronze, 4⅛ inches diameter and practically 28 feet long over all with 24 feet of thread, of 1 inch pitch. The chains are made of 2-inch diameter stock of a total length of approximately 67 feet each. Each link is 5 inches wide and 7⅛ inches long. There are 44 screws and 44 chains for the 22 machines.

The counterweights practically balance the weight of the gate, so that the machines have to overcome only the resistance to the movement of the gates due to water pressure. The counterweights are guided and travel in pits beneath the floor of the machinery tunnel.

The machinery tunnel extends the full length of the spillway within the dam and contains all the operating machinery. The screws for lifting the gates pass through this tunnel, extending downward to the counterweights and upward to the hoisting chains through openings provided for the purpose.

The machinery located in the tunnel consists of the worm nuts, worm wheel castings, motor, motor driving shafts and limit switches. Portable hand operating devices are provided in case the electric motors are disabled or out of commission, which are clamped to the driving shafts when in use and are operated by two cranks.

The two-inch hoisting chains are connected to the upper ends of the lifting screws, passing up through pipes at the top of the gate piers, run over sheaves and down to the gates, where they are fastened approximately in the plane of the center of gravity of the gates.

The sheaves on the bracket move with the gate until the gate is above water, where the movable sheaves are engaged by a casting projecting from the pier, thus causing the roller train to rise more rapidly. When the gates reach the end of lift the roller train is well clear of the water, thus protecting it from floating débris. Just before the roller train starts to move more rapidly than normal the gate is moved bodily up stream a short distance by two rollers near the ends, so that the pressure is removed from the roller trains, enabling them to move freely.

The limit switch geared to the driving shaft prevents over-travel at the two ends of travel of the screw by cutting off current from the motor in the direction of travel. The limit switch allows the motor to be reversed at the ends of travel or at any intermediate point.

The main level of the canal being much higher than the sea level, the vessels using the canal are raised by water collected in the upper lake, mainly during the rainy season. Should the locks become damaged through any means and this water escape, the entire canal would be rendered useless until the next rainy season. This contingency was foreseen by the Canal Commission engineers, who carefully worked out a system of emergency dams in the form of pivotal bridges carrying hinged girders and sliding water gates, together with the machinery for their operation. These emergency dams are pivoted at one side of the canal and will normally lie parallel with the waterway, but are so arranged that in the event of a breakage to a lock gate permitting the escape of water, they

may be quickly swung across the waterway and the emergency gates dropped to prevent the further escape of the water. In the event of damage to a lock by a vessel which afterward should founder between the gates, the emergency dams will be of value in permitting the prompt raising of the ship and its removal from the path of traffic. The wicket girder and gate-hoisting machines for the emergency dams at the Gatun, Pedro Miguel, and Miraflores locks were supplied and installed by the Otis Elevator Company, of New York City.

The Westinghouse Machine Company, whose offices and works are at East Pittsburgh, Pa., furnished the sealing devices to render watertight the rising stem gate valves and the spillway gates. They also furnished the roller trains upon which the valves or gates move in their comparatively frictionless passage.

Most of this machinery thus provided is under water, and being out of sight and difficult of access for repairs, the materials employed are the very best for the purpose, and the workmanship and execution are of the highest order.

The rising stem gate valves, and the spillway gates travel on roller trains. There are sixty-three rollers in each train for the rising stem valves, and forty-seven such rollers in each of the trains for the spillway gates. The rollers themselves are made of open hearth steel of a grade known as "tool steel," which is especially low in sulphur and phosphorus and contains about 0.70 per cent. carbon.

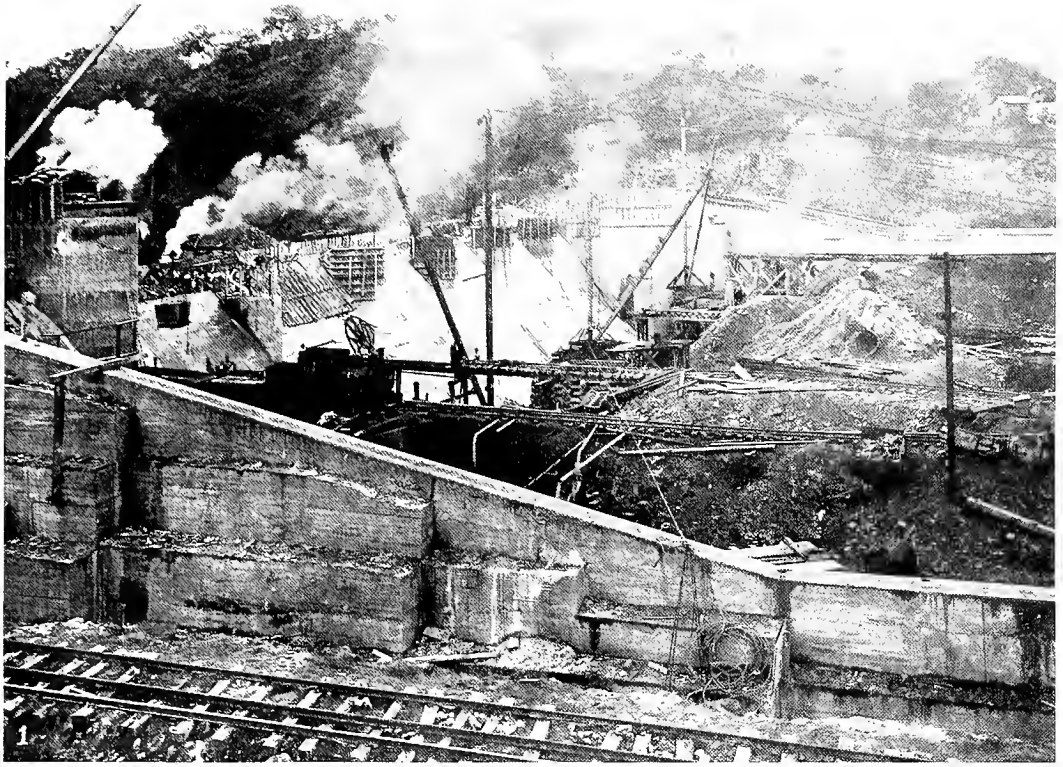
In the execution of this contract 18,794 rollers were required. These rollers are four inches in diameter and six inches in length of working face, and have a trunnion on each end, which trunnions engage in suitable holes, in channel bars, thus maintaining constant and perfect alignment.

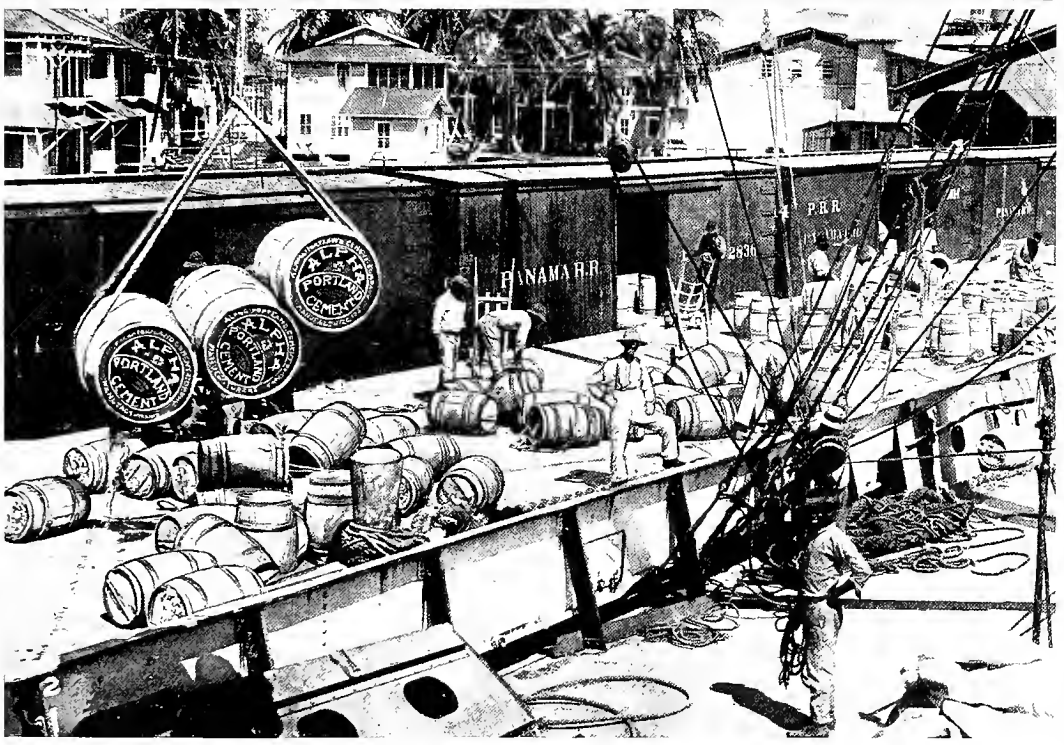
The rollers were first cast in ingot form and rolled down in blooming mill to four and one-half-inch square billets. They were then reheated and hammered in swage dies to four and one-half inches round, after which they were cut into suitable lengths and turned to size slightly larger than the finished dimensions. The rollers were then heat treated and oil tempered to improve their wearing qualities and to harden the working faces, after which they were ground on centers to precise size.

The channel bars which keep the roller train in alignment are rolled steel sections especially made for the Canal Commission, planed on the inner faces and drilled to hardened steel templates so as to be perfectly interchangeable, and fitted together with steel distance pieces and steel bolts, the latter being protected by a process of zinc coating known as sherardizing.

The rollers were forged into round bars in the forge department of the Westinghouse Machine Company. After forging, the round bars were carefully annealed in a special annealing furnace, in order to make it possible to machine these high carbon rollers at the desired speed. After annealing, they were cut into appropriate lengths, turned to proper size, with allowance for subsequent grinding, and were hardened by being heated to proper temperature by electric pyrometer, and quenched in oil. In the heating descent from the cold region to the hottest part of the furnace, gradual and even heating was insured.

In order to protect the trunnions, or small projecting ends, from being over hardened, special tongs were employed to pick the rollers out of the fire. These tongs prevented the cooling oil from coming in contact with the trunnions until the body of the roller had been partially cooled by immersion in the oil. The operator seized the heated roller with the protecting tongs, dipped the roller in the oil bath, and moved the heated roller back and forth through the oil for a stipulated number of seconds; this time being determined by careful experiment. At the expiration of this perfectly definite period, he removed the tongs and allowed the partially cooled roller to drop to the bottom of the tank of oil.





1. Laying Alpha Cement at Miraflores Spillway Dam.
2. Part of a single order of 20,000 barrels of Alpha Portland Cement.
(Cement from the Alpha Portland Cement Company, Easton, Pa.)

of a high grade were necessary for the work, and that the safety of vessels and cargoes might be greatly endangered should any part of the steel used give way on account of the corrosive action of the water or climate, the importance of finding the best protector for all the steel work will be readily seen.

The forty-six lock gates present an internal surface of more than 3,200,000 square feet, all strongly subjected to the deleterious influence of the climate and water. The same is true of the dock gates at Balboa, the automatic gas buoys, and anchorage boxes. To replace one of the lock gates would require a large expenditure of money, and cause a loss of much time, and might materially interfere with canal navigation for many days. Under all these considerations it became necessary to secure the best preservative from corrosion that could be had.

The lower half of each gate is an air chamber, into which water will rarely enter, while the upper half is a water chamber, which is filled and emptied many times each during the progress of locking, thus offering the most destructive corrosive conditions which could possibly obtain. As the most effective and permanent protection against these corrosive conditions the canal engineers, after an exhaustive investigation, adopted "Bitumastic" solution and enamel, made by The American Bitumastic Enamels Company, of Philadelphia, Pa.

In the words of one of the leading engineers connected with the construction of the canal, the main reason for the selection of this special material was its excellent record in the vessels of the United States navy and on foreign vessels of war, as well as vessels engaged in the merchant marine. So successful has been this material in meeting the requirements of the difficult conditions on navy vessels, and other ships, and so great was the faith of the canal engineers in its efficiency, that after the work of construction was started they specified "Bitumastic" on five other contracts connected with the construction of the canal.

The company began preparations to fill its first contract August 12, 1911, and since that time the "Bitumastic" was used on forty-six lock gates, the Balboa dock gates, fifty-seven automatic gas buoys, ninety-two anchorage boxes, and on material used in the hydroelectric plant.

Thus American manufacturing ingenuity and excellence of materials contributed to the successful construction of the great steel structures at Panama, and insured their permanence under the most adverse conditions. The same care displayed in construction is exercised in the upkeep of the costly canal equipment, and American manufacturers are always ready to meet any demands.

Steel and Iron Castings, Machinery, and General Tools

Everything about the canal work spelled immensity. Machinery and supplies did not reach the Isthmus in small units. If rubber hose was wanted, the material totaled miles in length. If metallic equipment or fittings were needed, the amount ran into millions of pounds. As the work progressed, the Isthmus accumulated the greatest collection of machinery, tools, steel and iron material, mechanical parts, and equipment which the world has ever seen assembled in one territory. A great number of American firms participated in supplying this varied and vast quantity of material.

A large part of the manganese steel castings for use on the canal work was furnished under contract by the Edgar Allen American Manganese Steel Company, of Chicago, Ill., and New Castle, Del. The steel used in these castings was entirely of the "Stag" brand manganese steel. The castings furnished by this company were for use as repair parts for steam shovels, such as dipper teeth with renewable points, dipper lips, latches, latch keepers, dipper-shaft pinions, racks, dredge tumblers, link pins, bushings, screen sections and car wheels. This company also furnished three

complete dippers made entirely of the "Stag" brand of manganese steel. One contract alone called for more than sixty-four tons of tooth points. The first contract with this company was in 1908 and others rapidly followed. "Stag" brand manganese steel was found particularly adaptable to wearing parts of the excavating machinery, owing to its extreme toughness. Manganese steel is so tough that it cannot be machined except by grinding, yet it can be bent cold without breaking.

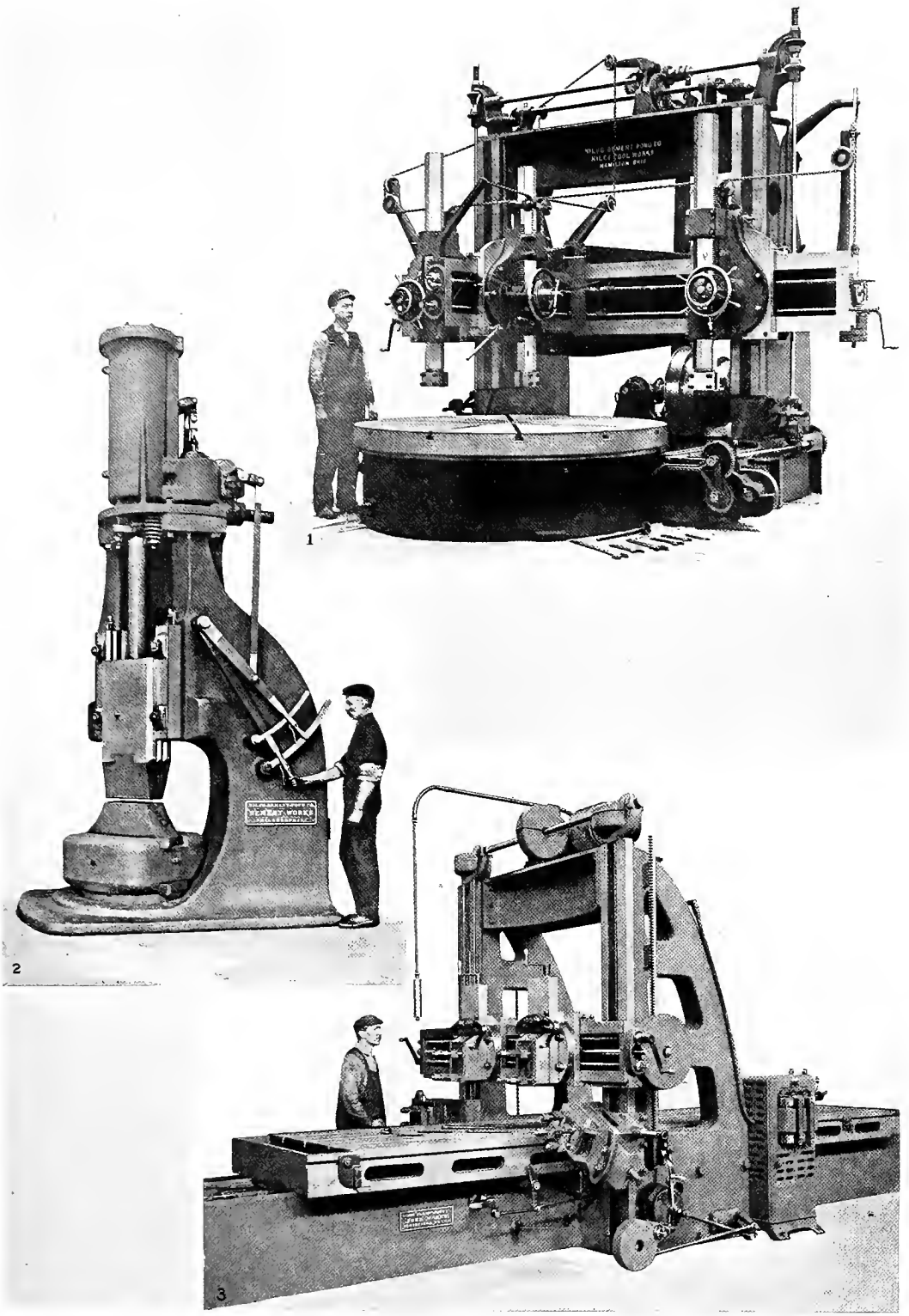
One of the government requirements in connection with material ordered is as follows: "Test specimens one-half inch by three-fourths inch cast under the same conditions and given exactly the same heat treatment, shall bend cold around a diameter of one inch to an angle of 180 degrees without cracking or exhibiting other signs of failure."

Another large firm which supplied steel castings for the canal work was the Detroit Steel Casting Company, of Detroit, Mich., which furnished large quantities of miscellaneous steel castings for dredges, machines, railroad equipment, and dump cars. In all it entered upon more than twenty-five contracts, running from 1909 to the completion of the work. This large number of contracts required no special preparation on the part of the company, as its plant was equipped to handle the orders easily with its standard equipment. All these contracts were secured in competition with other manufacturers. Its castings were turned out by the open hearth method.

The firm of Frank Samuel, of Philadelphia, Pa., consisting of Frank Samuel, S. M. Tomlinson, and S. A. Cochran, supplied a large tonnage of pig iron and alloys to the Canal Commission. Their facilities for international business fully equipped them for this feature of construction supplies, the material furnished by them going to the foundry at the Isthmus, where it was converted into the castings used in connection with the construction of the canal. This firm also made extensive purchases from the Canal Commission, large quantities of equipment, such as locomotives, engines, pumps, and other similar supplies no longer needed on the work having passed into their hands.

Among the contractors furnishing mechanical supplies, the H. A. Rogers Company, of New York City, was prominent from the very inception of the work. When the French company was attempting to construct the canal this company furnished large quantities of gauge glasses, pulleys, steam gauges, waste, shovels, picks, etc., and when the American government took hold of the enterprise it became an active and most successful bidder for the same line of supplies. During the course of construction it sold to the commission many thousands of dollars worth of materials, consisting mainly of gauge glasses, pulleys, steam gauges, cement, gauge glass washers, gaskets, pliers, cotters and planer knives. The Rogers Company, having been the sole United States agents for the Moncrieff gauge glasses—the glasses used altogether by the canal officials—has sold to the commission all such glasses used on the canal. The tremendous energy by which the work was pushed to completion made necessary large supplies of tools, and various parts of machinery, and when it is remembered that nearly everything bought in connection with the construction work was by the competitive bidding on specifications most carefully and rigorously prepared, it will be recognized that only the best was offered to and accepted by the commission. This rigorous supervision extended to the smallest tools purchased, and to be a successful bidder was to receive a certificate of quality of goods handled.

Early in the history of the construction of the canal the purchasing agents were solicitously engaged in search for a chain that could be used with their steam shovels for the longest continuous period without breaking. This was particularly desirable, for with a break in the chain the shovel stops, and all the work must stop with it, with consequent loss of time as well as expense for repairs.



1. Niles boring and turning mill.
2. Bement hammer.
3. Pond planer.

(High class canal machine shop equipment furnished by the Niles-Bement-Pond Company, New York.)

After trials with various kinds of chains, that manufactured by the Columbus Chain Company, of Columbus, Ohio, was finally selected. It gave such satisfaction that the "Hercules Solid Weld" steam shovel chain manufactured by that company eventually became a standard in canal construction work. This chain is made of the highest grade of material, by a special formula, and has assisted in no small degree in bringing to pass the unequaled records achieved by the modern empire builder, the American steam shovel. Its record at the canal in the heaviest sort of service—that carried on in the stone quarries—has shown a continuous service for as long as eleven months without a single broken link.

From the beginning of construction work on the canal, the Buda Company, of Chicago, Ill., made extensive shipments under their contracts covering articles used in railroad building. All supplies furnished by them were of their own manufacture, and their plant was fully equipped and ready to furnish a class of material that is recognized as standard on ninety per cent. of the railroad mileage of the United States. Among the articles furnished, all bearing the firm's name, were hand cars, push cars, pressed steel wheels, track jacks, track bits, drills, switch stands, replacers, rail benders, gauges, levels, and automobile engines. More than a thousand cars and over three thousand switch stands went toward filling contracts that reached a total of $125,000 with this firm.

In the construction of the canal the successful completion of the work depended, to a great extent, on the continuous working of the construction machinery, such as steam engines, cars, steam shovels, concrete mixers, conveyors, etc. The heavy and continuous service required of the canal equipment caused break-downs of mechanical parts, thus causing delays and expense, and interfering with the continuance of the work. To avoid these delays the commission installed a large machine shop near the base of the work, where duplicate parts could be made or repairs quickly accomplished.

The machine shop covered a wide range of work. It was largely equipped by the Niles-Bement-Pond Company, of New York City. This company occupies a foremost place among machine tool manufacturers and crane builders. The largest and heaviest machines were required for repairing steam engine parts. The Niles-Bement-Pond Company furnished for this work several machines designed especially for such service. The heavy engine drivers were turned on the Niles driving wheel lathes; car wheels up to forty-two inches were turned on Pond car wheel lathes; Bement axle lathes turned and trued the axles; the wheels were pressed on the axle by Niles hydrostatic wheel presses of 200 and 300 ton capacity.

Boring, drilling, turning, and planing machines were furnished for the ordinary machine shop operations. To handle large and heavy repair parts and castings through the shop, the Niles-Bement-Pond Company installed several electric traveling cranes. These cranes would pick up, carry, and set down pieces weighing from one ton to sixty tons, with the precision of the human hand.

In equipping the machine shop, the American Tool Works Company, of Cincinnati, Ohio, was the successful bidder on a number of occasions, and consequently the company was well represented in the Canal Zone.

The American Tool Works Company is one of the largest and oldest builders of lathes, planers, shapers, and radial drills in this country, employing 600 men in their works in the exclusive production of the above-mentioned machines. The types of lathe built by the American Tool Works Company for use in the Canal Zone were built in various sizes from fourteen inches to forty-two inches swing. One of the principal characteristics of the "American" lathe is its patented drop bed, which gives additional swing over the nominal swing, and also permits the use of an unusually

deep carriage bridge. A complete quick change gear mechanism is supplied on all sizes of American lathes. It is of the cone and tumbler type, affording forty-eight changes for screw setting and feeding. In addition to this standard range any odd thread can be secured by simply adding a special gear to a quadrant provided for this purpose.

The multifarious details of the work of constructing the canal will probably never be understood and appreciated. For illustration, one firm, the Oliver Iron & Steel Company, of Pittsburgh, Pa., supplied to the commission about 13,000,000 pounds of such small articles of iron and steel as bolts, rivets, nuts, washers, picks, mattocks and claw bars. These articles were used in every branch of the construction work, and were supplied by the Oliver Company on contracts with the Canal Commission.

During the months of May, June, August, October, November, and December, 1912, the Pittsburgh Steel Company, of Pittsburgh, Pa., shipped to the Isthmus of Panama 349 tons of wire nails, and in May also ten tons, or fifty-five miles, of steel wire. All of this material was used in the construction work of the canal.

Basic open hearth material is used exclusively in all the steel and wire products manufactured by the Pittsburgh Steel Company, hence it was this superior material which went into the products supplied to the Canal Commission. Open hearth steel wire possesses a fine, even texture of strength and durability, and because its characteristics exist uniformly throughout the wire, from its skin to its core, it delivers the same high quality of service under all conditions of climate.

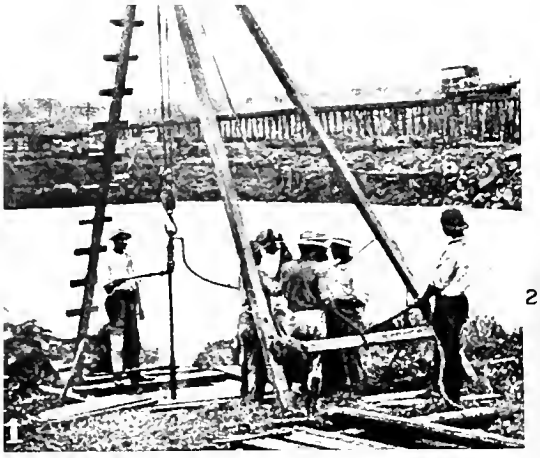
This company owns and operates the largest independent plants in the world manufacturing fencing, nails, and wire. The site embraces 160 acres of land along the Monongahela river front, with forty-nine and one-half acres under roof, and a water frontage of two and three-tenths miles. The company owns 60,000,000 tons of iron ore in mine, which it ships down as needed, unloads by its ore car dumper at the rate of thirty cars an hour, and stores by two massive traveling bridges. Its two blast furnaces, with a capacity of 1,400 tons daily, are the only electrically operated furnaces at the present time.

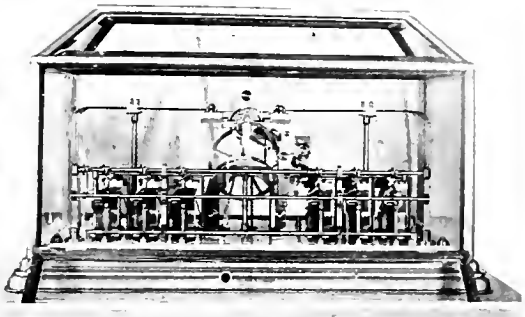
The finishing departments include two complete modern rod mills, one barbed wire mill, three galvanizing plants, and a factory for making electrically welded wire fencing. These departments are all at Monessen, Pa., but at Glassport, a few miles down the Monongahela River, the Pittsburgh Steel Company maintains complete mills for hot rolling all sizes of steel hoops used by the cooperage trade, steel bands, cotton ties, bars for concrete reinforcing, and rim stock for automobiles and motorcycles.

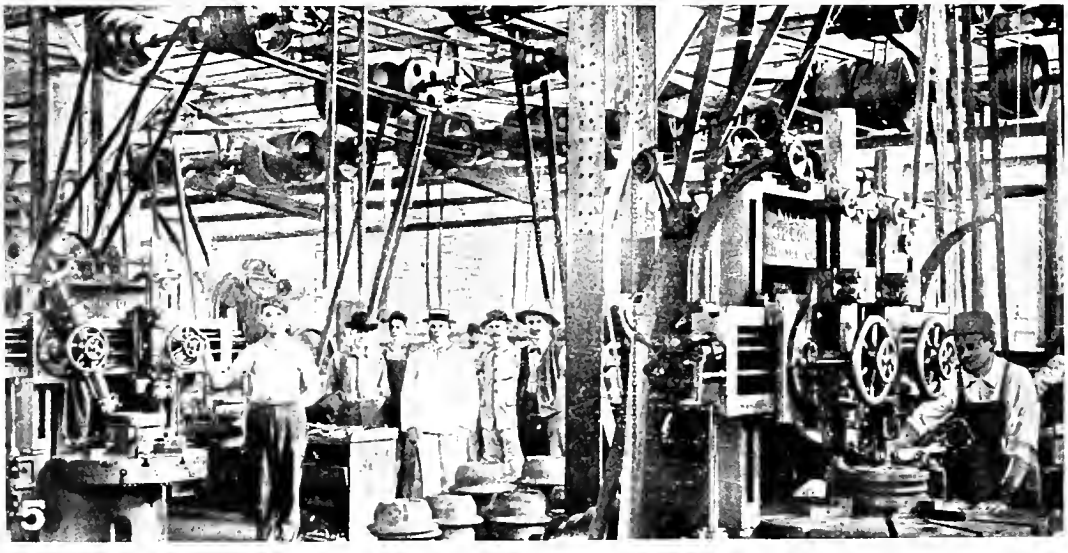
The annual capacity of the plants is 500,000 gross tons a year. Among other wire products from the finishing mills is a daily output of 350 miles of electrically welded wire fencing, 200 tons of barbed wire, and 8,000 kegs of wire nails.

Chain iron, special bar iron, iron roofing sheets, Carter special and Carter stay bolt iron were supplied the canal workers by the Carter Iron Company, of Pittsburgh, Pa., one of the largest concerns in this line. The company has furnaces at Ivanhoe, Va., and rolling mills at Paden City, West Virginia.

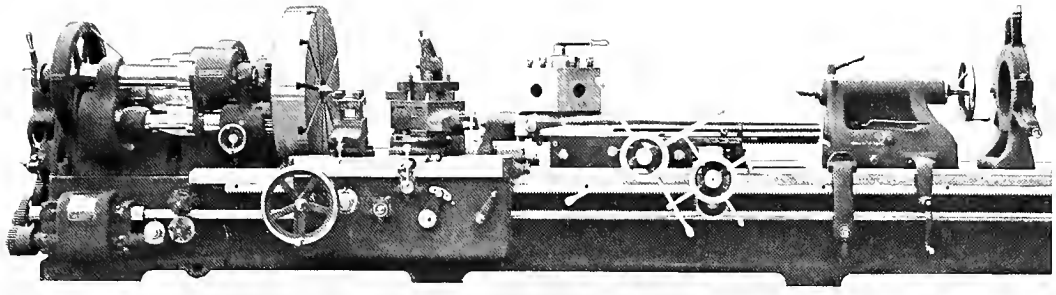
A firm located at the seat of government in Washington, and which furnished a great variety of iron and steel appliances for the canal, was the J. B. Kendall Company. This firm supplied thousands of tons of steel bars for concrete reinforcement, several thousand tons of steel bars, plates, channels and beams, railroad spikes, wire nails, and rivets, mostly manufactured by the Jones and Laughlin Steel Company, of Pittsburgh, Pa. The Kendall Company also furnished a large number of twist drills for use in canal construction, the drills being those manufactured by the Cleveland Twist Drill Company, of Cleveland, O.







1. Artificial limb furnished by A. A. Marks, New York, to a canal workman.
2. Automatic repeater. (Gamewell Fire Alarm Telegraph Co., New York.)
3. Standard fire alarm box. Gamewell system, used in Canal Zone.
4. Duxbak waterproof leather belting, woodworkers' shop, Gorgona.
5. Schieren leather belting, in Gorgona machine shops.



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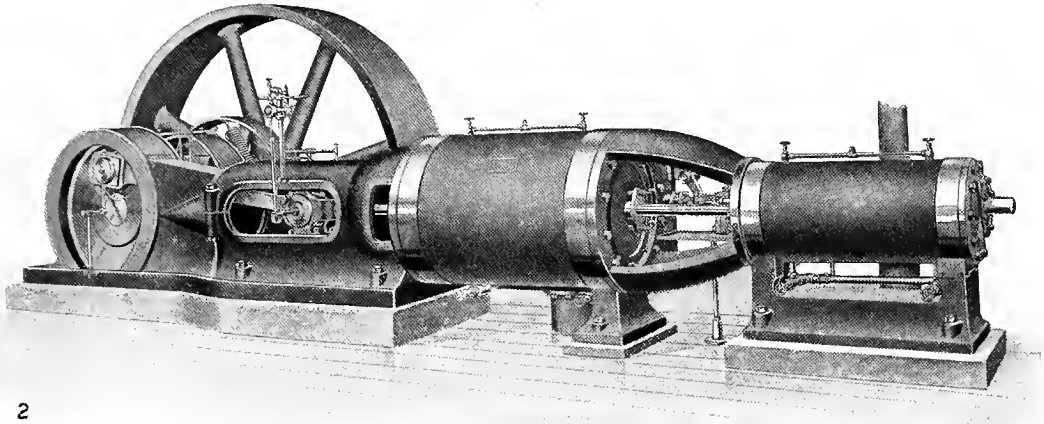

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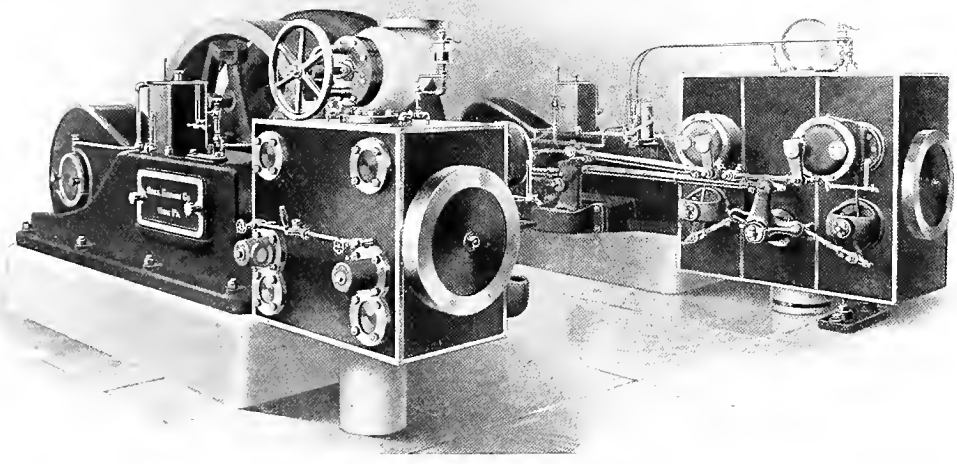

3

TYPES OF HIGH CLASS AMERICAN TOOL MACHINERY AT THE CANAL

1. Late design high-duty lathe. Furnished the canal machine shops by the American Tool Works, Cincinnati, O.
2. High grade automatic steam engine furnished by the Buckeye Engine Company, Salem, Ohio.
3. High speed engine furnished by the Ball Engine Company, Erie, Pa.