Corrugated copper gaskets supplied by the Akron Metallic Gasket Company, of Akron, Ohio, were used in large numbers for making joints on steam lines carrying from 100 to 200 pounds pressure, on tugs and dredges in the service of the Atlantic division, and also in the power plant at the dry dock shops on the canal. In making these gaskets precaution was taken to see that faces of flanges were smooth, as those of the irregular surfaces do not give as satisfactory results. In a report to the company, officials of the canal stated that no blowing-out of joints made up in this manner had occurred and that the results obtained were satisfactory. The officials further reported that the tug *Reliance*, belonging to the commission, had a joint made up in this way between the main steam line and the throttle previous to her trip around the Horn to Balboa, and that the joint remained tight throughout the trip.

On account of the extreme dampness of the atmosphere the canal engineers were confronted with problems in the operation of the machine shops at Gorgona and Empire which are not encountered in temperate climates. The steam shovels and locomotives had to be kept going; repairs were made to the shovels on the spot; castings were made for all kinds of purposes; and it was necessary that the shop operations should be continuous and efficient, in spite of weather conditions. Here, as elsewhere in the canal work, minute attention to detail and the application of American methods brought success.

An example of this is found in the comparatively minor item of belting. In the maze of big machinery at Gorgona and Empire, and in face of the stupendous concrete works at Gatun, Miraflores, and Pedro Miguel, the casual visitor would pay little attention to the matter of belting. "And yet," said one of the canal engineers, in discussing the difficulties that had been encountered, "if it were not for the belts what would the machinery amount to? These belts were the very sinews of our shops. They simply had to do their work without regard to heat or dampness, oil, or dryness. A breakdown in these shops on account of poor belts would have meant a stoppage of the shovels and locomotives, a lack of repair parts and castings, and a shut-down of canal work itself.

"We found that ordinary belting would not do on the Isthmus. It stretches with the moisture, and then, when it dries out a bit, it opens at the laps and has to be cut constantly in order to keep it at the proper length to pull the machines. Two- or three-ply belting was very apt to part company and prove worthless as a driver of machinery in this climate.

"We tried several kinds of belting, and finally an American concern, as usual, helped us out by furnishing an article that would stand the test of these severe conditions. The Duxbak belt made by the Charles A. Schieren Company, of New York, we found satisfactory, and over 18,000 feet of Duxbak was installed in these shops and along the canal. It was worked under the most trying conditions and really it is with a great satisfaction that I speak a word for it. We would have been up against a serious proposition if we had not been able to find somewhere in the United States a belt that would do our work. It is a little thing, compared with steam shovels and ocean-going dredges, but if you look into the building of the Panama Canal you will be impressed by the fact that it was attention to the 'little things' that made the big thing possible."

Automatic couplers and parts, and miscellaneous castings for the equipment for new railway cars for work on the canal, and for maintenance and repair of rolling stock already in use were furnished to the Canal Commission by the National Malleable Castings Company, of Cleveland, Ohio, a very large concern which has works in six cities. This company's shipments began in 1906 and continued until the completion of the canal. From October, 1906, to August, 1912, the company furnished 6,000 couplers.

The majority of these couplers were of

the style known as the "Tower" coupler (named after the inventor, Mr. A. C. Tower), of the master car builders' vertical hook type. The couplers were manufactured principally at the company's steel castings works at Sharon, Pa. They were constructed mainly of cast steel, under patents owned by the company.

Couplers of this make have been in use for many years on the railroads of the United States and in Canada and Mexico, during which time their adaptation to the requirements of the service, their simplicity and perfection of design, ease of operation, and durability have been established by experience and by the severe tests to which they were continually subjected.

Recognizing the inadequacy of the old spike to secure the rail to the tie in modern railroading, the government laid all its roadbed in the Canal Zone with screw spikes and tie plates. There are several points of view from which such a practice should be studied. The means of holding the tie to the rail should have the following advantages, which are found in the screw spike tie plate:

It should be strong enough to prevent rail spreading under most severe traffic conditions; it should have a factor of permanence which obviates too frequent necessity for inspection and maintenance; it should minimize abrasion of the tie by the rail; it should protect the tie against the elements as much as possible; and it should be capable of removal and reapplication with a minimum of depreciation.

The original practice of fastening the rail to the tie by the use of a spike driven into the tie, the head of which is in contact with the rail flange, has been found open to several objections.

There are in service two forces acting on the head of the spike—a lateral thrust and a vertical pull. The first is caused by the weight of the traffic being applied against the inside of the head of the rail in such a way as to force the rail against the throat of the spike, this continual action eventually distorting the spike by breaking down the fiber of the tie behind the head of the spike.

The second, or vertical, action on the spike is the result of so-called "wave action" in the rail, and tends to raise the spike from one-eighth inch to one-fourth inch from its original position, until there is very little resistance to the rail spreading.

In addition to these two disadvantages, it is very difficult to drive a spike into a tie properly, and the most common practice necessitates striking the back of the head of the spike after it is driven until a perfect bearing on the rail flange is secured, leaving an opening of about one-sixteenth inch behind the head of the spike. This allows for an initial movement of the spike head, and also for the entrance of the water, which acts on the crushed fibers of the tie, and the tie soon disintegrates at this point. Then, with the friction caused by pulling out the spike on account of wave action, a mechanical wearing takes place between the base of the rail and the top of the tie. Dust from the ballast hastens this wear and greatly shortens the life of the tie.

The practice on the Panama Railroad avoids as much as possible the difficulties mentioned. The tie plate used has a shoulder, against which the outside of the rail flange bears, and bosses which support the heads of the spike on the outside prevent distortion of the spike, which would take place where the spike head is supported on one side only. These tie plates are supplied with screw spikes, for which holes have been bored in the tie.

The holding power of the screw spike in wood has been determined by several tests to be about three times as great as that of an ordinary spike, and when to this advantage is added the boring of the tie in a vertical direction, so that the screw spike is applied under most favorable conditions, and then the support given to the neck of the screw spike by the tie plate, and to the head of the screw spike by the boss on the outside of the spike, a very much more satisfactory condition obtains.

TYPES OF AMERICAN BUSINESS MEN WHO CO-OPERATED ALONG VARIOUS LINES IN AMERICA'S GREAT WORK AT PANAMA

1. William B. Harris, New York.
2. Howard Elliott, Pres., N. Y., N. H. & H. R. R. Co.
3. J. H. Weaver, J. H. Weaver & Co., Phila., Pa.
4. William L. D'Olier, Pres., D'Olier Engineering Co., Phila., Pa.
5. Herman L. Hohlfeld, Pres., Hohlfeld Mfg. Co., Phila., Pa.
6. J. H. Einstein, Pres., Tower Mfg. & Novelty Co., New York.

This is recognized on a great many American railways to the extent of using tie plates and screw spikes on approaches to bridges, on trestles, and around switches, frogs, and crossings. Their use in these places proves that this method of applying rails to ties will stand heavier traffic conditions with greater factor of safety than any other now known. The commission adopted this form of fastening for all of the roadbed in the Canal Zone for the reason that where a railbed is laid, and the maintenance cost is figured with the initial cost, screw spikes and tie plates make economical installation.

The cost of inspection and maintenance has a growing significance in railroad operation, and the greater holding power of screw spikes used with tie plates minimizes the amount of inspection and maintenance necessary to keep railbed in proper condition.

Reference has been made to the abrasion of the tie by the rail, which takes place under ordinary conditions as soon as the spike loosens slightly. When tie plates and screw spikes are used, the pressure of the rail is distributed over a much greater surface of the tie, and the tie plate is fastened permanently to the tie, so that, were any movement possible with this form of installation, it would take place between the rail and the tie plate, neither of which would be injured, and the tie would not suffer as it does now. However, this form of tie destruction is eliminated by the use of tie plates with screw spikes, as no movement takes place between the rail and the tie.

The protection of the tie against the elements where the rail bears is another important advantage gained by the use of tie plates. After the rail loosens slightly from the tie, water seeps in, is forced down into the tie, and soon induces decay. Particularly is this true after the tie has been abraded until there is an open fiber, into which the water is easily attracted. In a broader sense, the use of spikes which need to be redriven at frequent intervals results in "the spike killing the tie," because, whenever the spike is redriven, a new portion of the tie fiber is crushed, and before long such a large part of the tie is decayed that no more firm wood remains into which to drive the spikes. The greater holding power of screw spikes and tie plates removes this necessity for redriving the spikes at frequent intervals.

It is sometimes advantageous to take up a section of track and relay it in a new position. Tests have shown that where common spikes are pulled and redriven, their holding power is decreased to about one-third. Where screw spikes are removed and redriven in the same hole, their efficiency is not affected.

Briefly, then, tie plates and screw spikes are economical on account of the safety factor which they present under most severe traffic conditions; on account of the permanence of installation, and freedom from "upkeep" expense; on account of the longer life of the tie secured by their use; and on account of lending themselves to reapplication.

The screw spike tie plates used in the Canal Zone are known as "Economy No. 9 R. W.," and were manufactured by the Spencer Otis Company, Chicago.

The Pennsylvania Steel Company, of Steelton, Pa., was brought into connection with canal construction through the shipment of steel castings for the racks for the electric locomotives which tow vessels through the locks. These castings were made in 9,261 sections, weighing approximately 717 pounds each, and were shipped to the Canal Zone between January, 1911, and January, 1913.

For their particular work, it was required that these castings be exceedingly accurate. The company had no difficulty in turning them out to the complete satisfaction of the canal authorities.

The S. G. Taylor Chain Company, Chicago, Ill., which supplied steam shovel hoisting chains for the canal, is an old established concern, organized in 1873. While it manufactures a general line of welded chains, it has always paid particu-

lar attention to steam shovel and dredge chain, having supplied it for this very exacting service in all parts of the United States and in several foreign countries. The Taylor-Mesaba chain, the particular brand adopted for work on the canal, is a hand forged chain made from a special brand of triple refined iron, rolled expressly for this purpose. The bulk of chain used was one and one-half inch diameter material, and one hoisting chain of this size for a ninety-five ton shovel weighed about one and three-fourths tons. The Canal Commission specifications required that sample breaking tests of this material should run not less than 134,000 lbs. The tests actually made ran up in some cases as high as 165,000 lbs.

Bolts, nuts, rivets, screws, upset rods, and forgings were supplied for the canal work in large quantities by the Pittsburgh Screw and Bolt Company, of Pittsburgh, both by direct order and through other contractors. This company has for many years supplied the war and navy departments with this class of material.

Another Pittsburgh concern which shipped large quantities of iron and steel forgings and material for the Panama Railroad tracks was the Pittsburgh Forge and Iron Company. In a long list of shipments from this company, extending over several years, track bolts, frogs, and stay-bolt iron, machine bolts, drift bolts, fish plates, knuckle pins, and other equipment were included.

One of the American concerns which more than met the rigid specifications laid down by the Isthmian Canal Commission was the Ross-Meehan Foundry Company, of Chattanooga, Tenn., which supplied large quantities of malleable castings for cars. It also supplied similar castings for dump cars under a sub-contract, and also under sub-contract supplied conduit cover plates and brackets, insulator clamps, and other malleable castings. The conduit cover plates were used on the conduit for the electric towing locomotives.

The record of tests taken showed physical qualities considerably in excess of the rigid commission specifications, and all the work turned out was highly satisfactory, great care having been exercised as to the quality of the crude material. The castings were manufactured in the company's reverberating furnaces and annealing ovens.

Automatically operated valves of latest design for the protection of boilers and their steam lines were supplied in large quantities by the Golden-Anderson Valve Specialty Company, of Pittsburgh, Pa. Double-cushioned, triple-acting, non-return valves designed to automatically protect boilers in case of a bursting tube and to act as a safety stop to prevent steam entering a cold boiler, were among the variety of valves furnished. These valves automatically shut off the steam from every boiler at the instant of a pipe rupture, and immediately cut out a boiler when a tube bursts. The valves can be closed by steam or electricity from any part of the plant, or they may be closed by hand, like an ordinary valve.

The modern plan of centralizing the power plant with its batteries of boilers generating high steam pressures, and particularly where they have a large number of branch lines, has suggested the provision of this automatic safeguard against emergencies. It applies to all power plants in a general way, whether one or many boilers are in service.

Another corporation which supplied valves of various kinds for the canal machinery was the Roe-Stephens Manufacturing Company, of Detroit, Mich.

The E. F. Keating Company, of New York, which carries the largest stock of pipe fittings, valves, and tools in the United States, was one of the concerns which supplied the canal with a variety of materials in its line. Their orders included machines for threading pipe, wrought iron pipe, malleable iron fittings, screwed and flanged fittings, plumbing supplies, and steel and iron parts of infinite variety.

The O. F. Jordan Co., of Chicago, Ill., specialists in railroad construction and

maintenance equipment, furnished the canal authorities with iron and steel material, in the form of spreaders, unloading plows, cast steel, and manganese crossings. A number of the full pneumatic-control Jordan spreaders, manufactured by this company, were used on the Panama Canal, and gave great satisfaction. The spreaders were used in leveling, spreading, and ditching material along the canal route, and their easy disposal of heavy rocks was one of the features of their work. The spreader has many uses. In cold climates it renders efficient service as a snow plow, and it is generally used in construction work where the moving, leveling, and spreading of material is necessary.

Wrought iron washers for binding bolts were supplied to the Canal Commission during the entire period of construction by Henry A. Hitner's Sons Company, of Philadelphia, Pa., dealers in iron, steel, and metals. The washers were manufactured from new plates, under power pressure and were all found flat and true to center.

Steel and copper hose for steam, air, water, and oil transmission was supplied for the canal by the Pennsylvania Flexible Metallic Tubing Company, of Philadelphia. This hose was for use under the highest pressures, and was particularly suitable for rough usage. As it was made entirely of bronze, with asbestos packings, it was unaffected by the temperature or general climatic conditions at the Isthmus.

The company's shipments to the canal continued until the completion of the work. In the period from the latter part of 1908 to the beginning of 1912, the shipments of tubing, steel sectional hose, brass conduit hose, and copper hose of various sizes totaled nearly six miles in length.

The Boston Belting Company, of Boston, Mass., began to furnish articles of its own manufacture to the Canal Commission in November, 1908, and continued with other contracts as late as April, 1912. Among the supplies sent were thirty-three dredging sleeves; "Imperial" stitched rubber belting; brass wire insertion sheet packing; and 5,000 feet of special cotton jacket fire hose, coupled with heavy expansion ring couplings, Chicago fire hose thread.

The numerous pumps and engines on the Isthmus required large quantities of rubber sheet packing for flanged joints, and flax packing for pumps. Large quantities of this material were furnished by the Home Rubber Company, of Trenton, N. J. The company also supplied a large quantity of rubber hose.

Another firm which supplied great quantities of rubber in the form of water, steam, air suction, and fire hose, and dredging sleeves and belting, was the Boston Woven Hose & Rubber Company, of Boston, Mass. In the period between 1908 and 1912 this company supplied the canal authorities with nearly ten miles of rubber material, and continued to supply additional material until the completion of the work.

The Manhattan Rubber Manufacturing Company, of Passaic, N. J., was another firm which supplied the canal with steam, air, water and fire hose. This firm is a large maker of mechanical rubber goods, and its articles supplied to the canal were the regular commercial qualities and sizes, common throughout the United States.

Still another concern which furnished a varied assortment of rubber equipment for the canal was the Voorhees Rubber Company, of Jersey City, N. J., manufacturers of high grade mechanical rubber goods, including hose, belting, packing, valves, tubing, and "Nubian" packing and gaskets.

The Republic Rubber Company, of Youngstown, Ohio, supplied water, steam, air and suction hose for the canal. This was used in the general construction work, the company's shipments beginning in 1905 and continuing until the completion of the canal. The hose turned out by this company was of special construction adaptable for tropical climates and was manufactured under the Canal Commission specifications.

implements, harness, wagons, wheels and other supplies even down to needles.

Surveying and Other Scientific Instruments and Materials

Before the actual work of construction began, appliances which have been brought to a high state of scientific precision by American inventive genius were busily engaged all along the canal route. These were the surveying instruments, which in the hands of the engineers, enabled them to map out in advance the exact details of the work that was to come. Aneroid barometers of American make early found employment in taking gradients along the Canal Zone, and other instruments of precision did their part in preliminary work.

In the prosecution of survey work at the Isthmus, the Buff & Buff Manufacturing Company, of Jamaica Plain, Boston, Mass., was early in the field, supplying the triangulation theodolites that were used in surveying, leveling, complete triangulating and all manner of measuring details. Their contracts extended over a period of five years and comprised numerous orders.

The instruments of the Buff & Buff Manufacturing Company were selected as the result of competitive tests, in which their product proved superior in design, workmanship, and accuracy, the engineers finding them particularly satisfactory because of their ability to withstand great heat and excessive moisture. The evolution of this finished instrument embraces a long series of modifications and improvements in mechanical detail, from the Stackpole transit of sixty years ago to the Buff & Buff transit of today. The old firm of Stackpole & Sons, of New York City, manufactured the instrument that, in its day, was used and demanded by the best engineers on all the large surveys then being made. George L. Buff was foreman of that concern, and it was his handiwork that gave the instruments their reputation.

The principal characteristics of the old Stackpole transit that differentiated it from the cumbersome English theodolite were the increase in power and freedom of motion of the telescope, the greater rigidity secured by mounting the telescope axis in double cone bearings, the introduction of a coarser horizontal graduation reading to single minutes that permitted greater speed in reading and at the same time decreased the liability of error, and important improvements in the construction of the centers and graduations.

In 1871 George L. Buff left the firm of Stackpole & Sons, and established a business in Boston, where he designed and constructed the first Buff & Berger transit, using the old Stackpole instrument as a basis and adding to it numerous improvements gleaned in research work. His personal skill, together with the use of special bronze mixtures for the different bearings and parts, brought to the Buff & Berger transits a reputation that grew steadily for twenty-seven years.

The partnership formed in 1871 was dissolved in 1898, when Mr. Buff and his three sons—all of them technical graduates —established the Buff & Buff Manufacturing Company. Again the transit was taken in hand, and nearly fifty distinct improvements were incorporated in the new design. It is this finished product, representing fifty-seven years of close application and hard work on the part of the senior member of the firm, that was used at the canal. Of the large number of instruments furnished, not one failed to give satisfaction.

Many of the large number and variety of instruments manufactured by C. L. Berger & Sons, of Boston, Mass., were in daily use on the Isthmus, during the survey and development work, notably levels and transits. This firm, well known in its particular field, was founded in 1871, having been reorganized under its present management and control in 1898. At its present location, at 37 Williams Street, it has established a specially designed plant for making engineering and surveying instruments of the highest accuracy. The principal output consists of transits and

levels, which are sent to all parts of the world wherever American engineers are engaged in active practice. Over 10,000 of these instruments have been used in the various lines of railway, canal, and tunnel construction, topographic surveys, and general base line and boundary line determinations.

The mechanical features of its transits and levels are especially adapted to work under all conditions of temperature and climate, which largely accounts for their popularity and the unqualified satisfaction which followed their employment on the canal. In addition to the regular type for civil engineers' use, others have been devised for special use, as in iron mines where a compass could not be employed, in dripping mines, for mountain work, and for triangulation. For mining work numerous accessories have been invented in order to enable engineers to solve the complicated problems encountered under the surface of the ground. The wet mine transit, for example, is designed to protect all working parts from corroding gases, as well as from dripping water that often contains acid or alkaline properties. Other contrivances are especially adapted to deep shaft work, while its light mountain transit has in view conditions of reconnoissance work in which lightness of weight combined with high telescopic power is of great importance. These, together with many other specially designed features are found in the instruments of this company, and have been introduced not as novelties, but for practical use to enable engineers to accomplish the maximum amount of work in the shortest time, and with the greatest ease and highest degree of accuracy.

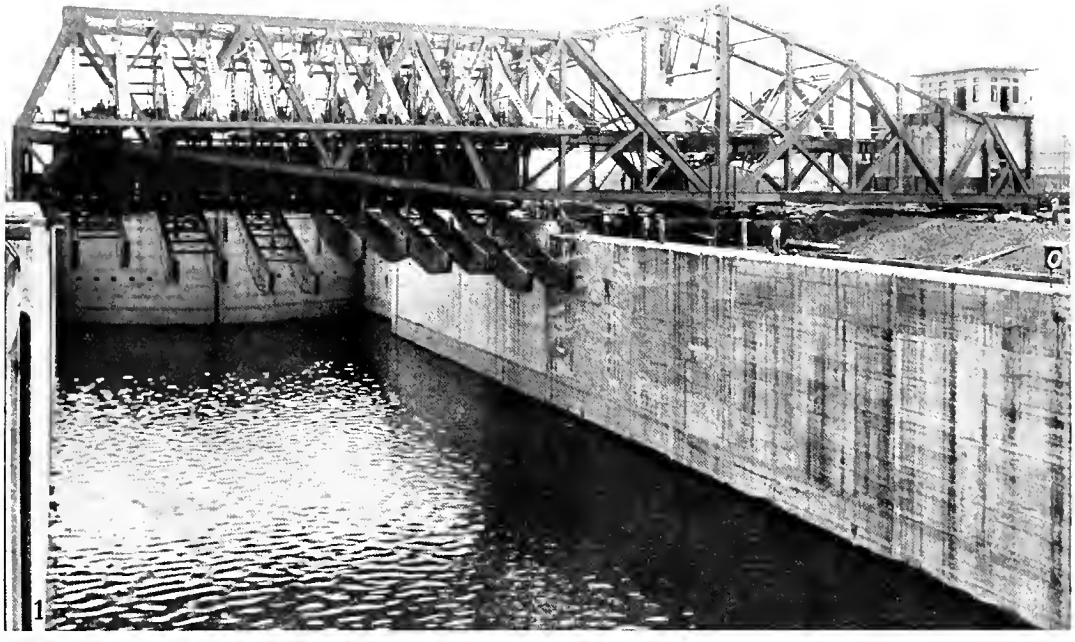
Besides supplying apparatus through other agencies, the Hohmann & Maurer Manufacturing Company, with headquarters in Rochester, N. Y., and branch offices in Boston, New York, Chicago, and London, made numerous shipments of its scientific and engineering instruments direct to the Canal Commission at the Isthmus.

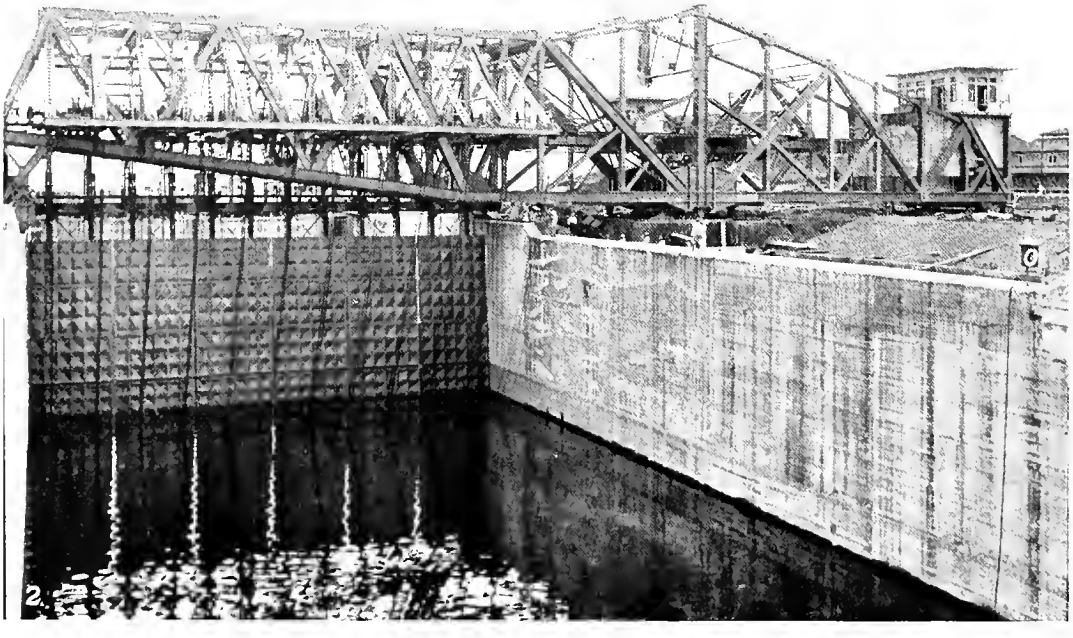
These instruments consisted of various sorts of thermometers,—gas, superheated steam, feed water, flue gas, and refrigeration thermometers, and a number of aneroid barometers, the direct shipments being made on contracts entered into in 1911. Most of the thermometers were for the power plant at Miraflores, while the barometers were sent to the Isthmian Canal Commission's dock at Colon. The Hohman & Maurer Manufacturing Company also supplied indirectly a number of special vacuum gauges, which were used in connection with the equipment of the steam plants furnished by other companies that had contracted for outfits as a whole.

The instruments of this company have a world-wide reputation for careful construction and perfect accuracy. As temperature measurement and control in modern refrigeration as well as in steam plants are vital factors in their economical and successful operation, the selection of Hohmann & Maurer thermometers and gauges by the canal officials furnished its own guaranty of their superior excellence. The same may be said of the Short & Mason aneroid barometers furnished by this firm and made by the Short & Mason division, which found service in ascertaining variations in gradients and levels along the course of the canal, as well as in determining the elevations of the hills and mountains of the surrounding country.

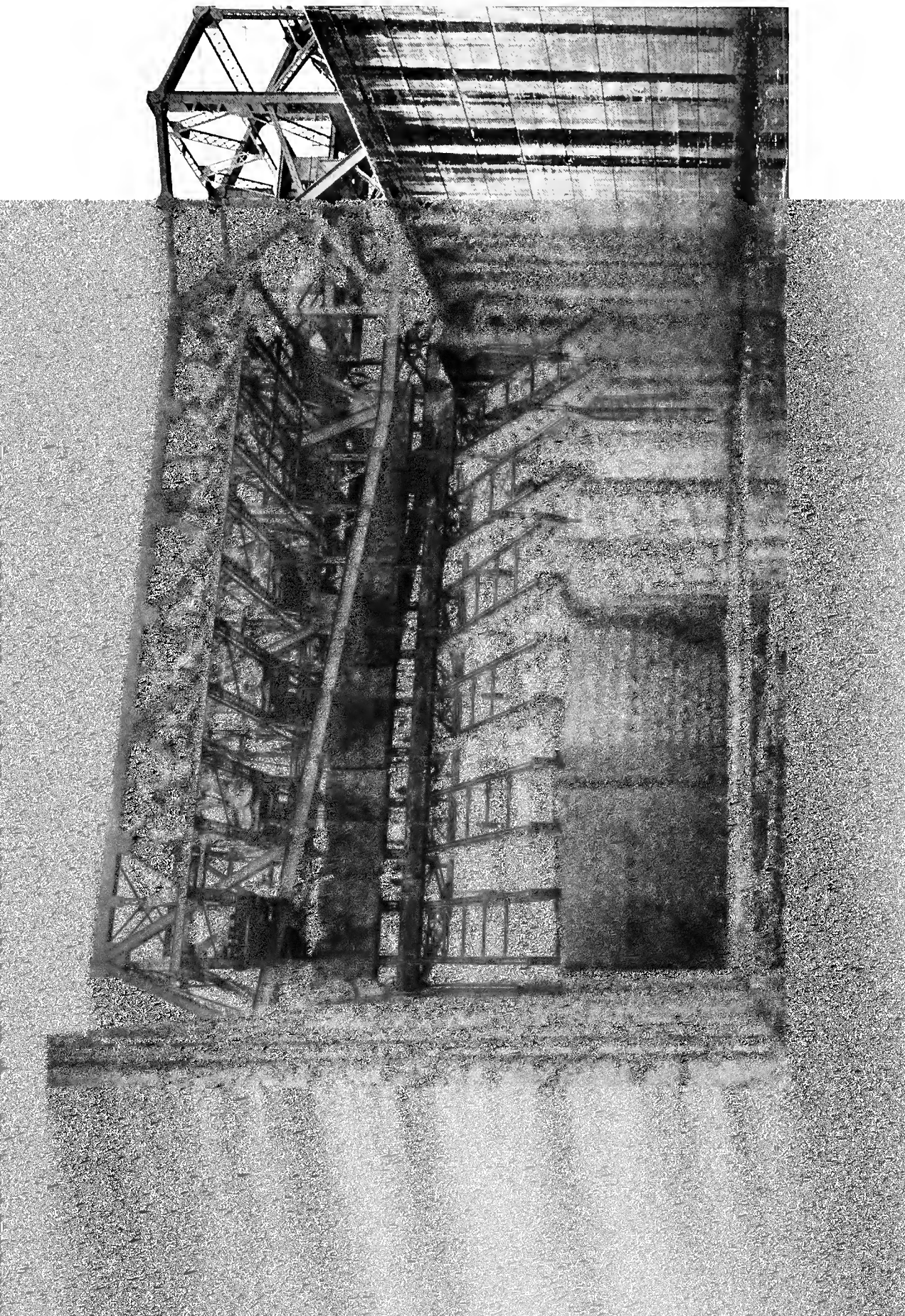
The Hohmann & Maurer Manufacturing Company is a division of the Taylor Instrument Companies. Mr. J. M. Taylor is president, and Mr. H. J. Winn treasurer of the controlling concern.

Among the successful bidders for furnishing materials used in the office and draughting departments at the canal, as well as in the survey work, were F. Weber & Company, of Philadelphia, Pa., manufacturers and importers of artists' materials and draughtsmen's and engineers' supplies. Their shipments included miscellaneous articles, all of their own manufacture, such as non-deteriorating waterproof India inks, water colors, the "F. W. & Company's and Riefler Tubular Round System" drawing instru-





1. Emergency dam at Gatun. Normally this dam is pivoted on the side wall, parallel with the lock instead of across it. When accidents occur it will be swung across the lock, the steel wicket girders let down, as in the upper picture, and great sheets of steel let down on them, as in the lower picture, thus completely closing the lock.



ments, blue and brown print papers, and other office supplies, and engineers' and mining surveying instruments. These supplies were extensively used at the Isthmus, and gave thorough satisfaction both in clerical and in field operations.

Another prominent firm which supplied mathematical, engineering, and surveying instruments for the canal experts was Heller & Brightly, of Philadelphia, Pa., makers of instruments of this kind. In addition to other instruments, a number of the firm's transits and levels were furnished to the canal authorities. The president of the company is Charles W. Heller, a native of Philadelphia.

Nearly all of the blue prints prepared for the canal were made on paper supplied by Williams, Brown & Earle, Inc., of Philadelphia, one of the leading, as well as one of the oldest, of the manufacturers of engineering and scientific instruments in the United States. This firm also supplied the two washing and drying machines and the two blue-printing machines that were sent to the Isthmus. These machines, equipped with electric lamps, motors, and dryers, were so constructed as to wash and dry the prints in a single operation at the rate of four to six linear feet a minute. At its full capacity the machinery provides for the production of completed blue prints fifty-four inches wide and of unlimited length. During the year 1912, Williams, Brown & Earle furnished about 50,000 yards, or nearly thirty miles, of blue print paper for the use of the engineers on the canal, in making blue prints for construction work.

The firm manufactures its own machines for photographically coating its paper, either by the blue print or other photographic processes. The paper is coated with special care and then packed in metal tubes, to prevent decomposition and change in the photographic surface liable to occur in the tropics. Other scientific apparatus was furnished by this firm for use in various lines of scientific investigation, as well as for the purpose of furnishing entertainment and amusement to those residing along the canal during its construction.

The firm of Ernst Leitz, of New York, N. Y., supplied microscopes and laboratory materials for use in medical diagnosis and the examination of the water supply that was carried on in connection with the sanitation work at the canal, for the protection of health and maintenance of suitable living conditions for the immense army of workers. The Leitz microscopes are manufactured at the firm's factory in Wetzlar, Germany. Their instruments were first introduced in 1848, and have obtained extensive use in critical research work in the laboratories of governmental and educational institutions all over the world.

Oiling the Machinery

The vast quantities of lubricating oils used in canal construction give an inkling of the tremendous mechanical powers at work on the Isthmus.

Contracts with the Canal Commission for furnishing lubricating oils and other related materials were first made in May, 1910, by the Texas Company, with general offices in Houston, Texas, and New York, and were followed by numerous renewals. The total of these contracts up to June, 1913, reached the high figure of 824,000 gallons of the various kinds of lubricating oils, and 448,000 pounds of the greases manufactured by the company, with lesser shipments of kerosene and gasoline in addition. Shipments of these materials followed immediately after the original award, and have been in progress monthly ever since.

The samples furnished by the Texas Company were submitted to critical laboratory and practical tests, and successfully withstood them all. The adaptability of "Texaco" lubricants was proved by their action under the severest construction conditions, in which lubricating problems were encountered of a nature that are exceedingly difficult to overcome. Some idea of these difficulties may be obtained from the statement that the canal dipper

dredges often were worked under thirty feet of water, and had to be kept properly lubricated while so submerged. The railroad equipment, also, was often compelled to be kept moving with mud and water up to the wheels, axle boxes, and other parts of the machinery usually protected from dampness and grit. Not only did the oils of the Texas Company meet these deterrent obstacles, but they also earned the approval of the canal officials under conditions that required the greatest economy, as well as continuous service for thousands of hours without cessation or breakdown. The report of the commission for 1911 showed that in all the power plants where this lubricant was used, not a stoppage was made on account of a heated bearing or any other lubricating trouble during the whole year. The oils were also used generally on locomotives, cars, dredges, steam shovels, and, in fact, all the machinery employed on the Isthmus. The company manufactures its lubricants from various crudes, each best adapted to the special grade of oil or grease desired. This work has called for a special study of oil refining in order to meet the required commercial conditions, and has also resulted in the designing of much special equipment to achieve the ends in view. The established facilities of the company in the way of ocean terminals and storage sites met all requirements for quick transportation of its products to Panama.

One of the oldest firms which had a part in the construction of the canal was the Crew-Levick Company, of Philadelphia, Pa. This firm recently celebrated its fiftieth anniversary, and is one of the oldest refiners of petroleum in the United States. The company was well known to the United States Government as well as the governments of the European and Asiatic countries before the beginning of canal construction, and after the commencement of the work was a constant supplier of large quantities of cylinder engine and dynamo oils to the Isthmian Canal Commission. In addition to its wide foreign business the company has always enjoyed a very large domestic business, making a specialty of high-grade products meeting all the demands of the manufacturing industries, and distributing them through their many branch offices to all parts of the United States. In recent years the company has made a specialty of motor oils, and this department has developed rapidly. All of the plants of the company are located in Pennsylvania, and in addition to its United States agencies it has agencies all over the world in all the principal business centers, its largest export trade being from the ports of Philadelphia, New York, and Baltimore. The company was one of the earliest in the United States to realize the great possibilities of trade expansion in foreign fields. Its first foreign branch was established in Liverpool nearly forty years ago, when Mr. Levick ascertained that a great market awaited the company's products in Europe. Since that time Mr. Levick has made almost yearly trips abroad, and the export business of the company, growing steadily in volume, has for many years been a beacon to other American lines of industry in pointing out channels to foreign trade.

W. N. Best, of New York, engineer in caloric, supplied the commission with oil burners, oil furnaces, and fire brick for relining. The oil burners were used for steams boilers of all types and sizes in power plants, dredges, etc. The furnaces were used for bolt making, rivet heating, forging, welding, plate heating, and other purposes. The burners supplied by Mr. Best were specially adapted for using the California fuel oil. About 200 burners were supplied, with twenty-one furnaces.

Early in 1912 certain achievements in increasing the life use of metals, by the Whitmore Manufacturing Company, lubricating engineers of Cleveland, Ohio, came to the attention of the Isthmian Canal Commission, and thereupon the commission requested from the Whitmore Company full details regarding their special work in lubricating, together with statistics

of past performances, and samples of their material for testing purposes.

Upon request representatives of the Canal Commission furnished the Whitmore laboratories minute data regarding the requirements of lubrication in the canal works. In brief the data furnished gave the following requirements:

Lubrication was required for the center pivot bearings and the roller bearings of the emergency dams. The nature of the service was very unusual, and offered a very difficult problem. The center pivot bearings are constructed with three discs, forty-three inches in diameter, the upper and lower discs being of forged vanadium steel, with concave bearing surfaces, hardened to test eighty-five to ninety on the sclerescope, and the center disc of forged manganese bronze, having an elastic limit of 90,000 pounds, surfaces convex, with five grooves radiating from a two-inch hole through the center to within one-fourth inch of the circumference, by means of which the lubricant is conveyed to the bearing surfaces during the period of movement only. The lubricant is forced through twenty feet of one-inch pipe to the two-inch hole in the center by means of a screw compressor on the floor of the dam.

A total weight of 6,700,000 pounds rests on each bearing, being a unit of pressure of 4,620 pounds to the square inch. As the emergency dams are operated only once in thirty days for testing, there are rest periods of twenty-nine days during which the pivot bearings must support the entire 6,700,000 pounds weight. A lubricant, therefore, must be employed which will have the capacity of holding the bearing surfaces definitely apart during those twenty-nine day rest periods of super-excessive pressure, because if not definitely apart at the initial moment of the movement, the bearing will stick and cut, and the dams lose their value for emergency purposes.

The problem in connection with the roller bearings was that of protection of the polished steel under the excessive corrosive conditions prevailing on the Isthmus.

With complete data regarding the conditions of the service in their possession, the Whitmore laboratories set to work on the problem, and developed a product especially to meet the requirements. Tests of the Whitmore product were conducted by representatives of the Isthmian Canal Commission under reproduced conditions. These tests showed phenomenal results. Whitmore's anti-friction composition, made especially for this purpose, not only withstood the required pressure of 4,620 pounds, but was subjected to units of pressure as high as 13,300 pounds to the square inch, with the bearing parts definitely apart, and the lubricant still capable of indefinite further expansion; and providing a factor of safety in the starting coefficient of over 700 per cent. compared with the best foreign greases submitted for tests.

Expert commission men, who stocked the chain of government stores of the Panama Canal Commission, recognized in advance that they had a mighty rust problem to contend with, just as the sanitation department had to face the mosquito and yellow fever problem.

Tropical rains in torrents and moist salt air spelled rust, corrosion, and verdigris on everything metallic in the Canal Zone, unless carefully protected. That protection was afforded by oil, the product of the Three-In-One Oil Company, of New York. It was used on guns, revolvers, sewing machines, typewriters, ice-cream freezers, bolts, locks, clocks,—everything made of metal, in-doors or out.

"Three-in-One," the conqueror of rust and corrosion, was put in every store from the Atlantic to the Pacific. The members of the commission used rust-preventing "Three-in-One" oil for their razors, reels, golf clubs, and other personal property, as did the humblest worker in the zone. And the record that this trouble-dispeller made along the canal was notable.

No one appreciated "Three-in-One" more than the soldiers and marines. It kept their arms and accoutrements in perfect condition, thereby saving money for

Uncle Sam, as well as saving the soldiers' and marines' time, temper, and energy. It helped every one, every day, to stand up to their severe tasks under climatic handicaps. "Three-in-One" not only fought off rust and corrosion but it also oiled every kind of light mechanism or device, and kept veneered and varnished furniture and woodwork.

William W. Nugent & Company, of Chicago, supplied oiling devices for the machinery on the canal. Several shipments were made of Nugent's patented oil system for steam and gas engines and refrigerating machines. Among these were the Nugent patented anti-stand crank pin center oiler, the Nugent anti-packed telescopic positive feed crosshead and top guide oiling device, Nugent oil pumps, oil tanks, and oil filters, and automatic water separators. The superiority of these machines was in guarding against the waste of oil.

With the largest plant in the world devoted to the manufacture of lubricating devices, the Detroit Lubricating Company, of Detroit, Mich., furnished great quantities of hand oil pumps for machines operating on the canal. These were in the form of glass and brass body push pumps, and other forms of lubricating devices. These push pumps were manufactured without springs, and thus were less liable to weakening because of heat and wear.

The Keystone Lubricator Co., of Philadelphia, Pa., furnished large quantities of lubricants to the canal.

Fuel Supplies

The prosecution of any engineering work of the magnitude of the Panama Canal would be impossible without a continuous and uninterrupted supply of fuel, required by the modern steam-driven machinery that played such an important part in the canal's construction. The absence of any coal of commercial value nearer than the United States presented to the canal officials the problem of obtaining and transporting to the Isthmus huge quantities of coal of suitable quality.

To avoid all possibility of delay or complete stoppage of work, an unfailing source of supply from responsible shippers was imperative, and coal capable of being stored under severe climatic conditions without deterioration, and not liable to spontaneous combustion under the tropical sun, was required. In this phase of the canal work, Castner, Curran & Bullitt, Inc., of New York, had a large part.

The conditions comprised in the specifications for coal of necessity limited the choice of fuel to the best to be found in America. This fuel proved to be the Pocahontas and some of the New River coal of West Virginia.

The following letter from Mr. E. A. Drake, vice-president of the Panama Railroad, who had full authority in purchasing all coal for use on the Isthmus, sets forth the coal situation:

New York, Sept. 27, 1912.

Mr. Lemuel Burrows, Jr., Vice-President
and General Manager,
Castner, Curran & Bullitt, Inc.,
1 Broadway, New York City.

Dear Sir: Complying with the request contained in your letter of the 21st inst., I take pleasure in saying that this company's relations with your company, in maintaining our coal supply at the Isthmus, for many years have been intimate and most satisfactory.

From 1895 to 1901 you furnished practically all of our Isthmus coal requirements, which during that period increased from 10,000 to 40,000 tons; and, subsequently, by 1906, to 180,000 tons annually.

We felt justified in dealing almost exclusively with your firm during those years, because you were the chief purveyors of first quality "Pocahontas" coal, classed in naval circles as highest in efficiency, which rating was verified by results we obtained on the Isthmus.

When our necessities increased so that there was justice and propriety in the claim by other firms, who had entered the Pocahontas and New River fields, that they were entitled to participate in the business of supplying our wants, sharp competition in price and quality was inaugurated.

Our fuel necessities increased for 1907 to 375,000 tons, and that quantity was, in effect, divided between your firm and the Berwind-White Coal Company; later our purchase increased to 500,000 tons per annum, and other large firms secured a share of the business.

During the years from 1895 to 1911, in which your firm supplied all, or the larger part, of our requirements, the character of your coal was such that it

uniformly met our B. T. U. specifications, and in use satisfactorily passed the various tests of its handling in railroad and canal construction work on the Isthmus, and in bunkering our own vessels, United States war vessels, and those of our co-carriers at that point.

It was subjected to very many trials, being stored in enormous quantities, under severe climatic conditions, without perceptible deterioration.

Uninterrupted progress of canal work often depended upon your zeal and coöperation, under your contract, in aiding us to keep up our Isthmus coal supply, at times under extreme difficulties of production at the mines and dispatch from loading point. I refer, with peculiar satisfaction, to this phase of our relations, as a dearth of fuel on the Isthmus at any time would have been regarded as a national disaster.

You are aware it is against the policy of this company to furnish testimonials, but I consider writing such a letter as you request an act of simple justice, in recognition of the integrity, helpfulness, and cordiality of your relations with this company over an extended period.

Yours truly,
E. A. DRAKE,
Vice-President.

From April 1st, 1911, the fuel needs of the Isthmian Canal Commission and the Panama Railroad were largely supplied under contract with the original Pocahontas coal produced by the Pocahontas Consolidated Collieries Company, Incorporated, and from a few other coal mining operators in the Pocahontas and New River fields of Virginia and West Virginia.

Contracts for the supply of more than half a million tons annually for the work on the canal were awarded to the Pocahontas Fuel Company, of New York City, the selling agent of the original Pocahontas producers. The first contract was for one year from April 1st, 1911, and such was the satisfaction given that on the first of April, 1912, a second contract was awarded for the entire estimated period for the completion of the canal, namely, to October 1st, 1914.

The producers of this coal congratulate themselves that their fuel as a power producer was a strong factor in the remarkable record of construction at Panama.

Pocahontas coal is produced in southwestern Virginia and southeastern West Virginia within a distinctly limited area, where, however, there are more than a billion tons of this coal still available for mining. Mining was first commenced at the famous Pocahontas Baby Mine, which is still operated, in 1882, and since that time the opening of new collieries has proceeded steadily until almost the entire Pocahontas field is being mined. The Pocahontas Consolidated Collieries Company alone has nineteen mines in full operation, the output of which is nearly thirty per cent. of all Pocahontas coal marketed. The officers of this company are Isaac T. Mann, president; Charles S. Thorne, first vice-president; Jenkin Jones, second vice-president; James Ellwood Jones, general manager; and George W. Woodruff, secretary and general counsel.

The Panama Railroad, buying for itself and the Isthmian Canal Commission, in 1911 awarded its entire contract of 550,000 tons a year to the Pocahontas Fuel Company, impelled thereto by two reasons,—that it might get the greatest power efficiency from its engines and machinery, and because the Pocahontas Fuel Company, having control of a greater and more certain output than any other Pocahontas and New River selling agency, would be able to supply the quantity and quality of coal contracted for promptly on the arrival of the colliers.

In this connection it is interesting to note that the unequalled quality and output, combined with the ability of the company to give prompt despatch to vessels reporting at bunkers for cargoes of coal, has made it possible for the Pocahontas Fuel Company to invade the markets of Europe, South America, and the west coast of Africa.

Original Pocahontas coal is known as a "smokeless" coal for the reason that it has so little volatile matter in it, and also because this volatile matter readily burns in the furnace or firebox, and thus produces heat instead of escaping into the air as gas and smoke. It has been in use in the navy for many years and is sent in large quantities to the Pacific coast for naval purposes.

Among those coöperating in the construction of the canal through the shipment of supplies were J. H. Weaver & Company, mine owners and coal dealers, with general offices in Philadelphia and New York. From the beginning of operations this company sent large quantities of bituminous coal to the Isthmus. As they confined themselves exclusively to the sale of their own coal, they give personal supervision to the mining and shipping of their orders, and consequently filled all orders with the Canal Commission satisfactorily and with dispatch. The mines of the company are located on three great coal-carrying railroads—the New York Central, the Pennsylvania, and the Baltimore and Ohio—with shipping piers at New York, Philadelphia, and Baltimore. A large proportion of their coal output is especially adapted to steamship, manufacturing, and power house use, and for general steam generating purposes, although they have other mines that furnish coal suitable for locomotives. Their success at the canal has already served them well by greatly increasing their foreign exports of their own high grade, low ash coals.

The Canal and Petroleum Products

The full effect of the completion of the Canal upon the petroleum commerce of the world is yet a question of surmise, and will not be definitely settled until the European war is ended, and commerce has resumed its normal trend. The adjustments that will follow the war may in themselves lead to great changes in international trade in petroleum, particularly depending on what the status of the Dardanelles will be at the conclusion of the war.

A study of the map of the world and its petroleum producing and consuming countries is suggestive of many interesting possibilities. The canal brings the markets of the east and west coasts of the United States in readier contact, subjecting commerce in petroleum to the fluctuating production and values of the eastern and western oil fields. The mid-continent oil fields may find an outlet through the Gulf of Mexico and the canal to the western countries of South America and a number of important Oriental markets. Mexico may find a similar outlet for its petroleum, while Peru may ultimately seek European markets via the Canal. If the end of the European war leaves the Dardanelles open to Russia, petroleum and petroleum products from the great Russian and Roumanian fields may use the canal as a connecting waterway to Oriental markets, while on the other hand, the petroleum interests of the Dutch Indies may utilize the canal in seeking the great consuming markets of Europe. In this country, the Standard Oil Company, with its extensive fleet and ramifying foreign commerce will use the canal extensively in its trade, and will be keenly interested in the canal's effect upon the trade of foreign oil producing countries.

To the canal work itself, American petroleum contributed no less than five important manufactured products, distinctly different, but all essential to the work of constructing the canal. Of these gasoline and kerosene held the lead, while petroleum lubricants, greases, and candles were used in great quantities.

As an indication of the importance of petroleum in the canal work, the Standard Oil Company in the six year period from 1908 to 1914, delivered to the canal authorities 2,400,000 gallons of kerosene and 700,000 gallons of gasoline. This amount of gasoline would enable an average automobile to make nearly 200 trips around the world.

It is expected that the Canal Zone itself will become one of the world's great entrepôts for fuel oil to meet the requirements of merchant and naval ships, with constantly increasing facilities for the storage of all petroleum products required to feed the commerce of the canal and the growing markets accessible thereto.

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1. One of the 57 A-G-A buoys used exclusively in lighting the canal.
2. Canal lighting and buoying rear tower, Pacific entrance, looking Northeast.
(American Gasaccumulator Company, Philadelphia, Pa.)

Lighting the Canal

In its great work the Canal Commission called to its aid the discoveries of modern science, not alone in the work of actual construction, but to safeguard life and property, and expedite the transferring of vessels from one ocean to the other. Nothing was left to chance, and so far as human intelligence and foresight could provide, all possibilities of accidents were eliminated. The commission, too, kept in sight the importance of so completing the work that the cost of future maintenance would be reduced to the lowest possible figure.

One of the great discoveries of modern science is that of acetylene, which as an illuminating agent surpasses all other gases used for lighting purposes. The lighting power of acetylene is five times that of the richest oil-gas, which formerly was extensively used for lighting aids to navigation.

Acetylene was well known for its superior and brilliant light, but it was not until the French chemists, Claude and Hess, in the nineties, made their discovery of the dissolving capacity of acetone that it became possible to store large quantities of acetylene under pressure in an entirely safe manner.

The dissolved acetylene has been utilized by the commission in lighting the canal, for the purpose of safeguarding navigation, so that the route is as safe at night as in daylight.

The American Gasaccumulator Company of Philadelphia, at a total cost of $189,933, installed along the line of the canal fifty-seven acetylene light buoys, eighteen front and rear range lights, and a small number of beacons, all of which are the AGA system.

From the Atlantic to the Pacific, or throughout the canal, a double row of these buoys mark the channel, which is further defined by the range lights and beacons, each having its own characteristic.

The buoy consists of a cylindrical floating steel body of eight feet diameter, surmounted by a steel frame which supports a lantern with lens and flash-light apparatus at a height of about fifteen feet above the water level. The draught of the buoy is about twelve feet and it is moored on its station by a heavy chain and sinker.

The source of light is an acetylene flame of about forty Hefner candlepower, which through the lens will develop a lighting power of about 400 Hefner candles, giving a range of light of about eleven and one-half nautical miles in clear weather.

The acetylene for each buoy is stored under 150 pounds pressure in four tanks, known as accumulators, each accumulator being inserted in a pocket of the buoy body from which it may be easily withdrawn when empty and replaced by a fully charged accumulator without taking the buoy out of the water.

The most prominent features of the AGA system are the flasher, the sunvalve, and the accumulators. The AGA flasher gives any desired characteristic, thereby eliminating the possibility of mistaking one light for another, and also distinguishing it from fixed lights on shore. The flasher is acted upon by the pressure of the gas, and delivers automatically after a prefixed interval a quantity of gas to the burner, where the gas is lit by a small pilot flame.

The flasher can be set to give as many as 55,000 separate distinct flashes from one cubic foot of acetylene. The saving of gas effected by this apparatus depends upon the light period compared with the total period; *i.e.*, the light plus the dark period, which is generally known as the "luminous time." For instance, with a luminous time of one-tenth, *i.e.*, .3 seconds light plus 2.7 seconds dark, the saving of gas will amount to ninety per cent. Thus this light consumes only ten per cent. of what a steady light would require.

An apparatus known as the sunvalve has been employed on range and beacon lights, in order to obtain further economy over that gained by the flasher. Its construction is based on the well-known law that a dark surface will absorb more light

than a bright one, transferring the luminous energy into increased molecular action. The sunvalve is therefore composed of one copper cylinder coated with lampblack, and three rods which are made light-reflecting by being gold-plated. When full daylight appears, the black cylinder absorbs light and expands, thereby closing a valve controlling the flow of gas to the installation. This valve remains closed until, for one reason or another (sunset, fog, heavy clouds, etc.) there is no more light to be absorbed, when the black cylinder contracts, and the valve, acted upon by a spring, opens again, allowing the gas to pass, and causing the light to flash.

The saving effected by this apparatus is about forty per cent. of the gas consumption of the burner, and the saving obtained by employing the flasher with a luminous time of one-tenth, together with a sunvalve, is about ninety-four per cent., compared with steady light.

The gas used by the AGA system is stored in seamless steel tanks, which are completely filled with the AGA porous mass, entirely eliminating from the gas its explosive qualities. An accumulator thus prepared has the power to absorb a quantity of acetylene in dissolved form equal to 100 times its own volume at a pressure of ten atmospheres. This large amount of gas is available at all times.

The flasher, as well as the sunvalve, and the AGA porous mass were the inventions of the eminent Swedish scientist, Gustaf Dalen, for which he was awarded the Nobel Prize for Physics in 1912.

At frequent intervals during the period of the construction of the Panama Canal, the R. E. Dietz Company, of New York City, furnished the commission with lanterns. Those used most extensively on the Isthmus were the Dietz iron clad pattern. The main points of superiority in Dietz lanterns were their dependable burning qualities and excellent light. The special feature of the iron clad lantern which caused it to be selected by the Canal Commission was the heavy iron base, which not only protects the oil pot, but prevents the lantern from being easily blown over by high winds. No other lantern is fitted with this attachment.

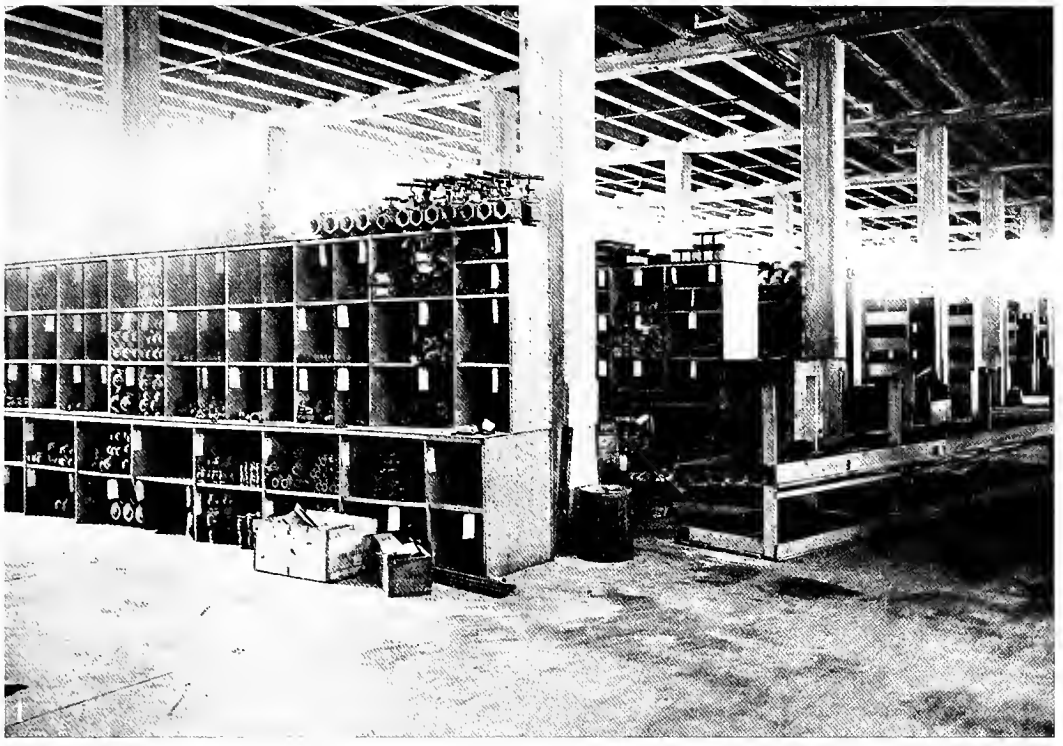
Considering that the cost of a single lantern is small, some idea of the number used on the Isthmus may be obtained from the statement that the Dietz Company furnished more than $13,000 worth of its lanterns to the commission.

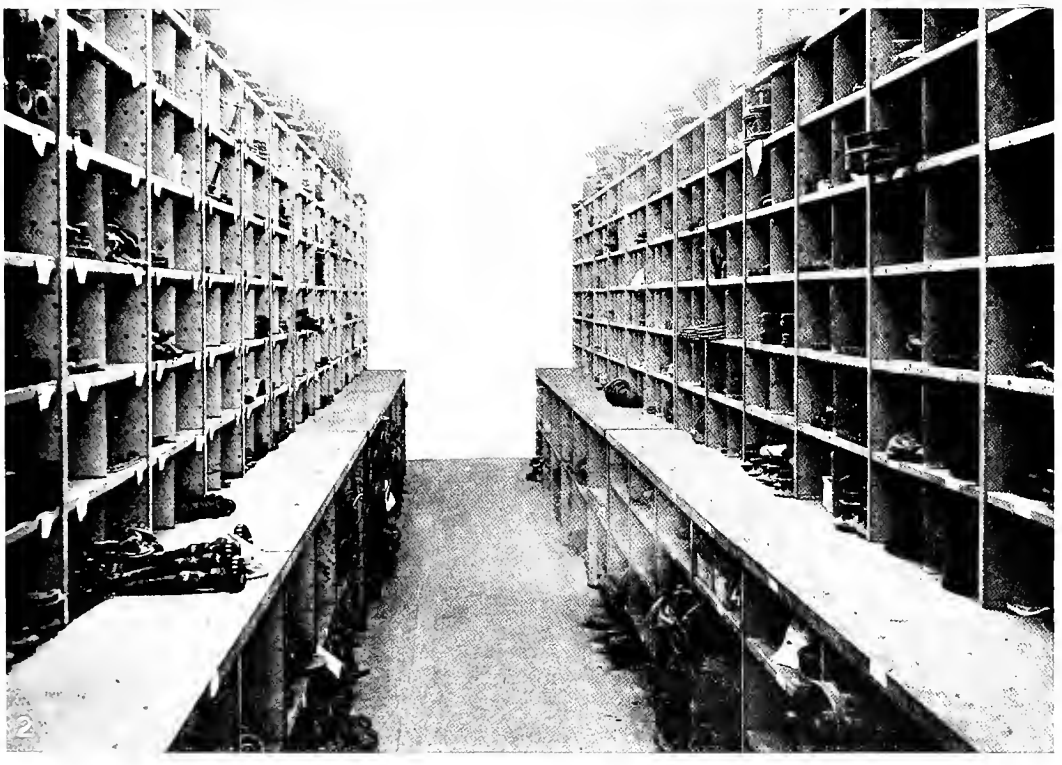
In connection with lights on the canal, the Macbeth-Evans Company, of New York and Pittsburgh, supplied large quantities of lantern globes, lenses, and railroad headlight chimneys. In this the Macbeth Pearl glass was specified. This firm supplies lenses to the light-house service, and the United States Navy, and headlight chimneys to the United States Army.

Special Devices at the Canal

That nothing should be left to chance which could be prevented by proper precaution, the commissioners, early in 1906, determined to have installed and put in operation a complete automatic electric fire alarm system for the protection of property in the Canal Zone. The automatic fire alarm and telegraph system manufactured by the Gamewell Fire Alarm Telegraph Company, of New York City, was decided upon, and a contract made with that company to install a complete system at Cristobal, Ancon, Empire, Gorgona, and Gatun, the contract price for the whole work being $20,264.35; but additions and extensions decided on later added $2,400 to the cost.

The Cristobal system was installed in 1906, and during the next year those in Ancon, Empire, Gorgona, and Culebra were placed in working condition. The Gatun system was not installed until 1909. The work of installation was done by the government engineers, under instructions from the Gamewell Company, that company supplying the apparatus and all material. The completed system practically covers the entire Canal Zone, with a large number of street signal stations, and a





1. Steel bins and shelving used throughout storehouses, government buildings, Canal Zone.
2. Aisle between two assemblies of steel bins and shelf installation at Balboa storehouses.
(Furnished by Berger Manufacturing Co., Canton, O.)

number of auxiliary substations placed in buildings at some distance from the street signaling boxes. By these auxiliary stations all of the government buildings in the Zone are in direct connection with the whole fire department system, thus avoiding delay and loss of time in going to the street signal stations when fire is discovered in a building.

The contract was awarded the Gamewell Company on the acknowledged superiority of its system in other important government properties, and in more than 1,200 municipalities in all parts of the world. Fire alarm stations, being placed on streets and exposed to all variations of temperature, in order to be reliable at all times must be constructed and adjusted with such exactness as to resist all atmospheric changes. The apparatus manufactured by the Gamewell Company was especially adapted to meet the conditions prevailing on the Isthmus.

The signaling boxes used on the Zone are of the positive-non-interfering-successive type, which represents the highest development in fire alarm telegraphy. Boxes of this type are designed to prevent any confusion arising from alarms being sounded from more than one signal station at about the same time. They are so constructed that should two or more boxes be operated at or about the same instant, one box will be automatically selected to transmit its complete signal, after which the other boxes that were operated simultaneously will each, in turn, take the line, one after the other, and transmit its complete signal. By the use of these boxes the fire department is never misled or confused by a mingling of signals.

The gongs used in the systems on the Zone are of the largest size and are combined with visual indicators, thus giving the department the signal by both eye and ear. So complete are the arrangements that all possibility of mistakes in signalling is practically eliminated. Connected with the systems are automatic registers. Permanent records of all signals received at fire department houses are of great importance. The registering machines used in the houses on the Zone register the location number of the box sending the signal, together with the date and the exact time of receiving the signal. The registers are made of composition bronze and steel.

In addition to the non-interfering-successive signal boxes and the visual indicators, which minimize the chances for mistakes in transmitting and receiving signals, a repeating device is used. These repeaters are so designed that all circuits are operative from any of the box circuits, and they are equipped with positive non-interfering devices which prevent any interference between circuits. The repeaters are so arranged that should a break occur in any circuit the instrument after transmitting the signal on all the alarm apparatus in the system, will automatically lock out the disabled circuit, leaving the rest of the system intact; and when repairs are made in the disabled circuit the repeater will automatically take it again into service.

The American watchman's time detector, or as it is now called, the Morse magneto watchman's clock, supplied an important link in the vigilant watch kept on the Canal Zone during the construction period, and now has a permanent place in the administrative equipment. The clock apparatus is designed to keep a record of the various night watchmen assigned to the buildings and property along the canal and was furnished by the American Watchman Time Detector Company of New York.

During the construction period the clock itself in each place was located in the superintendent's office, and wires were run from this clock to the several stations where it was desired that the watchman should go; and as he operated each station in turn, it registered his time on the clock in the office, so that a permanent record was made of his doings. This covered the records of as many watchmen as were employed in that zone of operation.

The station instrument is simply a magneto generator, similar to the ringer

which was formerly in common use on the telephone system. The watchman merely turns the crank in the box at the station and this independently operates the clock in the office, without the use of battery or other electrical current, so that each station is entirely independent of every other station.

While the original installation was partly temporary, there is a constant demand for the clocks on the permanent buildings, and many are in use. The device conforms to the present requirements of the National Board of Fire Underwriters throughout the United States, and is the same apparatus that is in use in the great industrial and other establishments in this country and Europe.

The fundamental requirements of permanence that characterized the equipment throughout the Canal Zone is strikingly apparent in the steel office and filing devices used in the offices of the Canal Commission. The long task meant a vast accumulation of documents of all kinds, and the filing system which made them instantly available for reference was worked out with the usual thoroughness of the canal work.

Much of this equipment, made chiefly of steel, was built by the Art Metal Construction Company, of Jamestown, N. Y., the largest maker of steel office furniture in the United States. Among the devices installed by it for the use of the commission were 160 four-drawer vertical letter file cabinets, with a capacity for more than 320,000 letters; a number of flat and roll top steel desks, map cases, document file cases, and a large number of built-to-order filing cabinets. It also supplied steel dining room tables, sideboards, chiffoniers, dressers, and other furniture, such as are supplied by this company to United States battleships.

Before contracts were ordered for this class of equipment, a careful investigation was made into the merits of steel furniture. The conclusion was reached that no other fixtures were so impervious to moisture, dust, microbes and vermin, and that none were so readily kept clean. Durability, convenience, attractiveness of appearance, and economy of space were also factors in the selection of this equipment.

The steel filing cases were found to possess special merits, the weather having no influence upon the perfect working of the drawers. At a very early date in the work on the canal the unsuitability of wooden office furniture became apparent. In tropical climates wooden furniture is subject to the ravages of moths, the insects eating away the wood on the inside, leaving only an outward shell. Wooden furniture was found to need constant replacing because of the destructive insects, and because of the tendency of the weather to warp the wood. The use of steel equipment was found economical, and the filing cabinets were especially valuable because they furnished protection against fire for the important canal records. The steel filing cabinets were of double-wall, fire-resisting construction.

In the construction of its steel office furniture, the Art Metal Construction Company used fine plates of open hearth steel specially rolled for their product, the plates being very smooth, without scale, and free from buckle. The workmanship throughout was of the highest character, the finishes being wear-proof and dust-proof, with several coats of the best enamel.

The acme of efficiency reached in the details of canal construction insured the appearance in the administration offices of automatic time stamps to keep time records of all kinds. These were furnished by the Automatic Time Stamp Company, of Boston, Mass., originators of the "art of printing time." This useful device, so familiar at home in offices where efficiency is the watchword, was used wherever a time record was indispensable, and as many time records of all kinds were checked up at the canal, the little device played its part in the canal work.

Where so many large steam shovels, dredges, dipper buckets, locomotives and other expensive pieces of machinery were engaged in such arduous work and running to full capacity there was considerable breakage of important machine parts, such

as locomotive frames, crank shafts, steam shovel arms, dredge pump casings, etc. Here the Goldschmidt Thermit Company of New York figured in an important capacity as having the only process permitting the welding of these heavy sections without removing them from their position. In the case of locomotive frames, these were welded without removing the frames from the engines and without keeping the locomotive out of service longer than 12 to 24 hours. In one instance, a two-throw crank shaft was broken through the crank web and about half way around the crank pin. This was welded without removing it from the machine, which was only out of commission 15 hours.

The Thermit used for this work is a mixture of finely divided aluminum and iron oxide. This mixture can be ignited by means of a special ignition powder supplied by the Goldschmidt Thermit Company, and a chemical reaction ensues. The aluminum burns, and in so doing, takes away the oxygen from the iron oxide, becoming aluminum oxide, while the iron is set free and is precipitated as liquid steel in a highly superheated condition. The temperature of this steel is approximately 5,000 degrees F. and the time of the reaction is only 35 to 40 seconds. In practice the welds are made by pouring this steel into a mold surrounding the ends of the sections to be welded together, and which have previously been brought to a red heat by means of a gasoline compressed air preheater. The superheated liquid steel melts the ends of the sections with which it comes in contact, and amalgamates with them to form a single homogeneous mass when cool. The process permits of welding the heavy sections at practically any point desired. The welding was executed entirely by the mechanical forces at the canal, the Goldschmidt Thermit Company supplying the necessary materials and appliances and furnishing the necessary instructions. From 1906 to the end of 1914, over 86,000 lbs. of Thermit were shipped to the canal.

The Thermit Process still continues its good work and is being used for repairing the dredges and other machinery required for operating the canal and keeping it in proper condition.

The Standard Underground Cable Company, of Pittsburgh, supplied for the electrification of the Panama Canal rubber insulated lead-covered cable, varnished cloth insulated lead-covered cable, magnet wire, fixture wire, weatherproof wire, and cable terminals for outdoor and indoor service.

All the terminals used in the canal electrification were made by the Standard Company or by licensees under this company's patents.

A cable terminal is a device placed over the end of a lead-covered cable to protect the insulation from moisture or from electrostatic discharges between conductors, or from conductors to ground. One of the distinctive features which characterize Standard open air cable terminals (known to the trade as D. O. A. Terminals), is the method of joining the conducting stem, which acts as a continuation of the underground cable conductor, to the terminal insulator. Since this stem projects through the insulator, the joint between the two is a vulnerable point for the entrance of moisture in the form of rain or fog. The joint is made by means of a hooded flange on the stem which fits over the top of the insulator, the joint being rendered water-proof by means of a rubber gasket fitted inside the flange, and upon which the stem is tightly screwed down when the terminal is assembled. This moisture-proof joint between the stem and cable terminal is a distinctive feature of all D. O. A. terminals. The terminals supplied for the Canal have special features to adapt them for certain conditions on the Isthmus, but as to their protective features they do not differ from stock terminals supplied to other purchasers.

In connection with the improvements on the Panama Railroad the Morden Frog and Crossing Works, of Chicago, sent numerous shipments of its railway ap-

pliances. This included split switches, rigid frogs, switch stands, guard rail braces, derails, compromise angle bars, etc. They were manufactured at the company's Chicago Heights factory, under the direction of skilled engineers and labor, and with the highest type of machinery, and were the best equipment of their kind at the lowest price. The company's shipments continued from the beginning of the improvements on the Panama Railroad until the completion of the canal, its appliances being used in the many tracks which were laid in connection with canal construction.

The construction of the dam at Gatun and the consequent flooding of hitherto dry territory resulted in the submergence of the original right of way of the Panama Railroad for a considerable part of its length and made it necessary to relocate the line at a higher level. The new line was built in the most thorough manner possible, with ties of the best quality to withstand the severe climatic conditions, using large tie plates, screw spikes, etc. The highest refinement was considered economy in this work.

As a large number of the ties used were of guiacum or lignum vitæ, and other very hard tropical woods, it was necessary to prepare the ties by adzing them to plane surfaces where the tie plates would rest, and to bore them for the spikes, as no spike of any pattern could be driven directly into these dense woods.

An ingenious automatic machine for performing these adzing and boring operations simultaneously was supplied by Greenlee Bros. & Co., of Chicago, and Rockford, Ill.

Greenlee Bros. & Company had also a number of interesting machines in the shops at Gorgona for framing the heavy timbers used in car construction, and in keeping in repair the steam shovels, dredges, etc., used in the excavation work. Among these were a large automatic timber groining machine and a heavy end tenoner for cutting tenons on the ends of timbers up to twenty inches square. On these machines the work is done from six to ten times as fast as it could be done by hand, and much more accurately. As time was the important factor in all work pertaining to the construction of the canal, these machines repaid their cost many times following their installation in 1908.

Various details of construction plans, as well as climatic conditions, called for the extensive use of wood screws in the work at the canal. The wood screws manufactured by the American Screw Company, of Providence, R. I., were furnished in large quantities, either direct from the point of manufacture or by outside firms handling their goods.

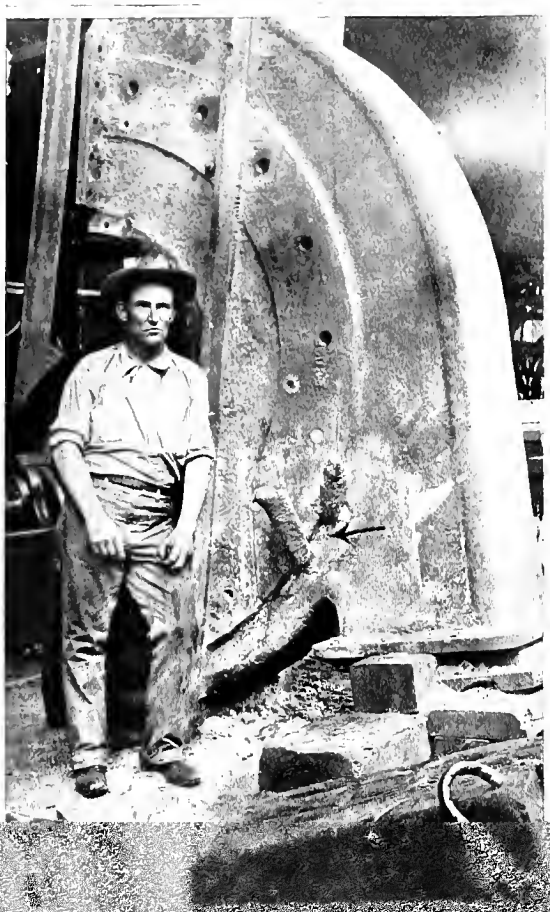
Samuel M. Nicholson, who is president of the American Screw Company, is also president and general manager of the Nicholson File Company, of Providence, which filled numerous orders and contracts for the supply of files to the Canal Commission from the beginning of construction on the Isthmus.

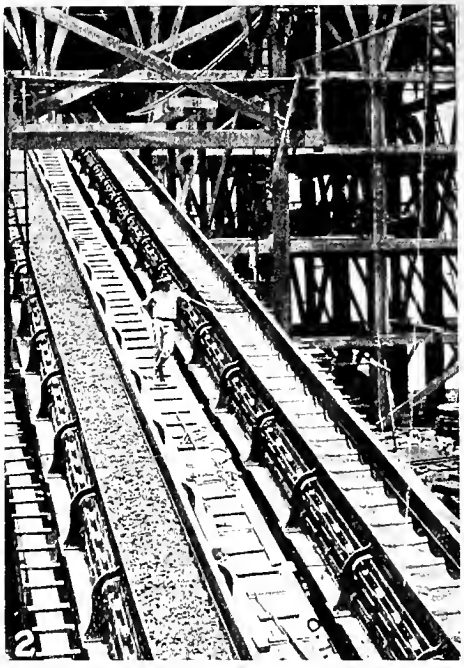
In the list of concerns furnishing the canal authorities with special efficiency devices was the Belding & Franklin Machine Company, of New York, which furnished for the commissary department a number of machines for peeling vegetables. These machines were selected for their economy and speed, and were found to be durable and efficient.

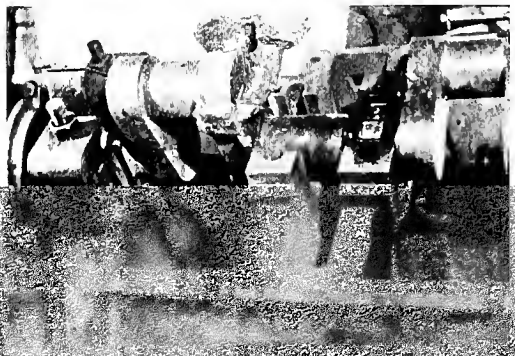
Administrative Supplies

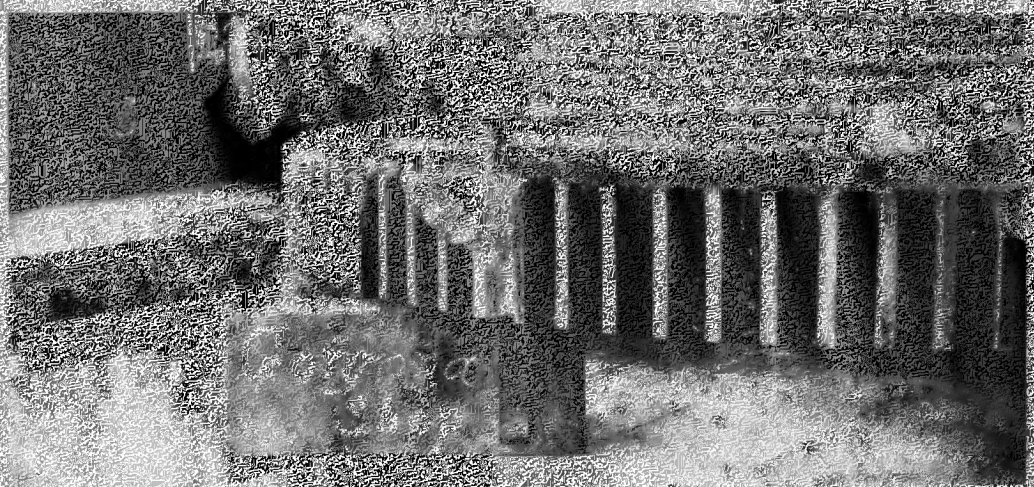
No single work ever undertaken by man called into play so many machines of different kinds, and for different purposes, as the building of the Panama Canal. The natural first thought of the layman would be to ask as to what possible part of the great work a typesetting or typecasting machine could apply.

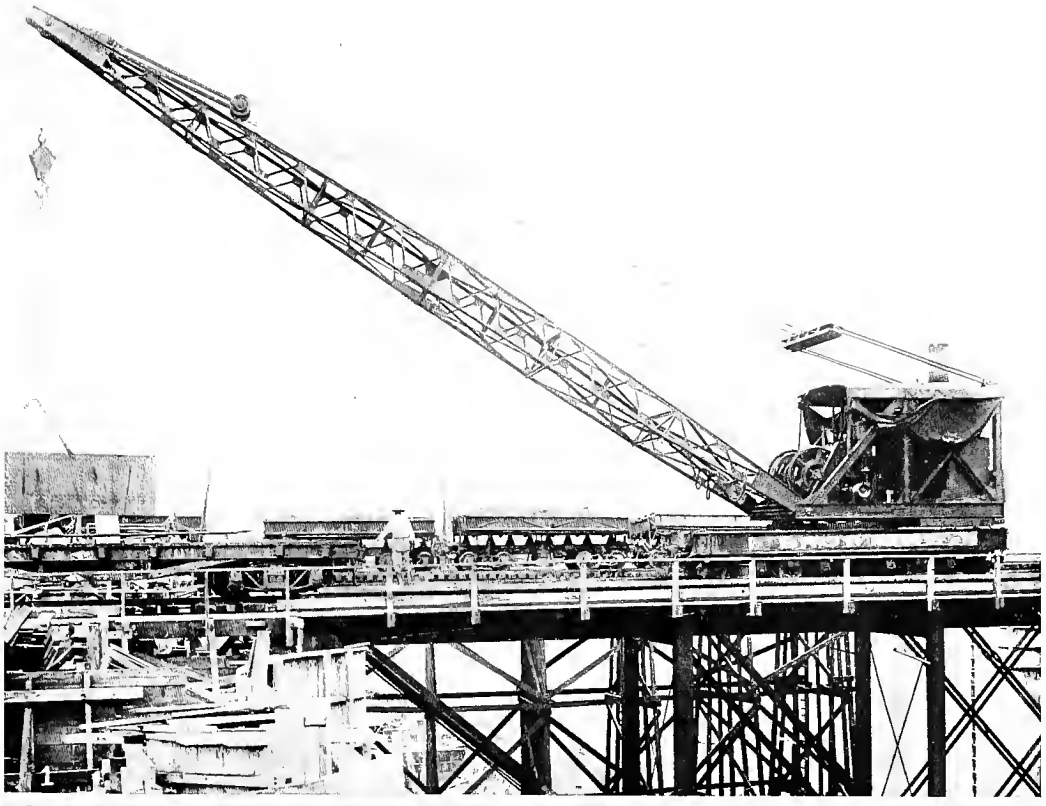
The commissioners early determined that the public should be thoroughly and correctly informed of the progress of the work. They believed, as the canal was to be the property of the people, the people should be given an opportunity to know just how the work was being done, and

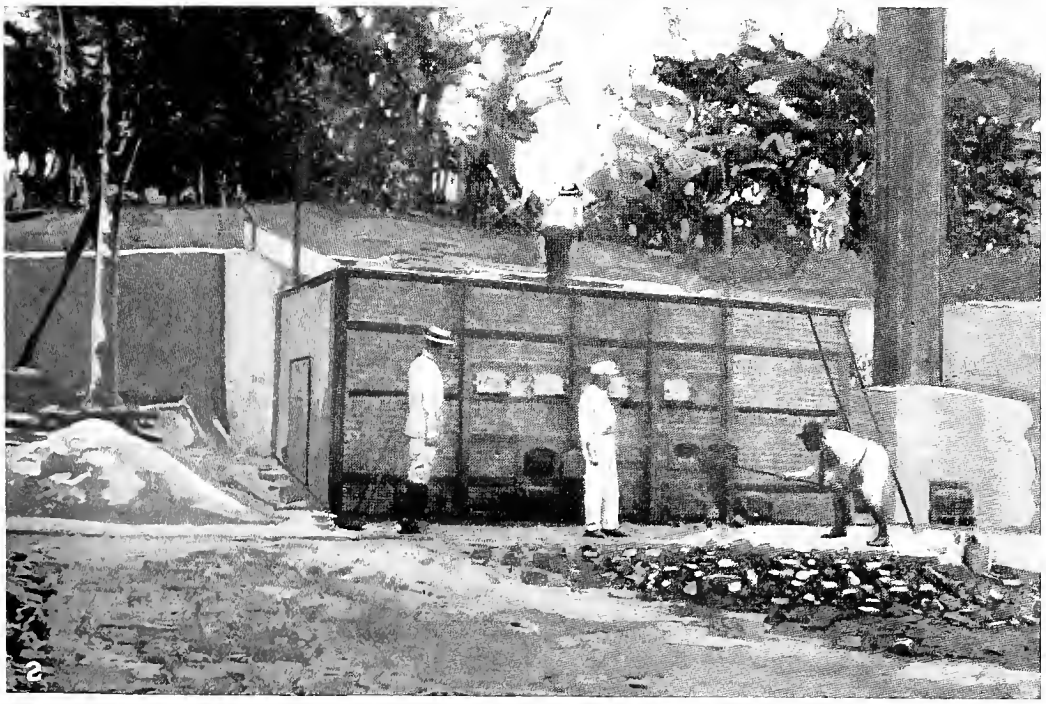












1. Locomotive crane at work on the canal.
   (Supplied by the Browning Engineering Company, Cleveland, Ohio.)
2. Ten-ton refuse destructor at Culebra, Canal Zone.
   (The Morse-Boulger Destructor Co., New York.)

know it from official sources, so a record of every event was kept and made public.

In this rapid age the old method of setting type by hand is almost a tradition. It was too slow a method to keep abreast of the times, and new inventions were called into play, among them being machines to compose type and cast type. The only machine of this kind is the one known as the Monotype. It is a modern creation, and has rapidly developed from its original form and capacity until it is now in fact a paragon of usefulness.

Nine years ago the capacity of the machine was limited to the casting and composing of type in four sizes only, the sizes most in use in newspaper work. The range has been extended until today it casts type of thirty sizes, and as a composing machine its range has increased until it reaches to what is known in printing offices as eighteen-point. At the same time the measure or width of the line has been extended from seven to fourteen inches.

It is difficult to give in a brief space a description of a Monotype which the layman can readily understand, but some points can be made clear to his mind, giving him an idea of the great advance made in printing by the introduction of machines for casting type.

The Monotype machine, or rather the Monotype system, is in two parts—the keyboard and the caster. This separation of the keyboard, or operating mechanism, and the caster, or casting mechanism, has resulted in a very high degree of composing-room efficiency, because the operator working on copy is undisturbed and has no more to think of than a stenographer operating a typewriter; and, similarly, the casting machine, which is wholly automatic, takes no account of the style or punctuation, and doesn't have to wait for copy. On account of this division of the work of a composing machine the Monotype is known among printers as a machine of continuous production, because one part of the Monotype mechanism is always busy.

The keyboard mechanism perforates a ribbon of paper, which, in turn, controls the movement of the caster. This perforated ribbon looks very much like the music rolls of a pianola. The perforations are made by punches controlled by the finger keys, arranged in identically the same letter-arrangement as that of the standard typewriter. There are two hundred and forty-seven keys. They correspond to all the characters used in the several faces of type intended to perform the work in hand, with thirty additional keys which control the justifying mechanism; that is, the device which accurately equalizes the space between the words, so that all the lines within one measure may be of the same length.

When the paper ribbon is fed into the casting machine, currents of compressed air pass through the perforations. These set the mold blade to the right size for the character to be cast, and cause the matrix to be properly positioned. Metal is pumped from a metal pot below, and when cast the type is placed in its proper position in the line, and when a line is finished it is automatically removed.

A great national undertaking, such as the construction of the Panama Canal, necessarily requires an amount of printing that could not be readily handled without a composing machine and a typecaster. The Monotype was selected by the commission because it was believed to be the best adapted to meet the exacting requirements of the work it would be called upon to perform.

The capacity of this machine may be best understood by the statement that the Encyclopædia Britannica, the largest job of type composition ever placed in the United States, consisting of some thirty thousand pages, was cast and composed by the Monotype, as was the Standard dictionary, a work requiring a great variety of special characters.

In connection with the office work of the administrative staff at Panama, the T. S. Buck Manufacturing Company, of New York, entered into contracts for supplying changeable rubber type outfits and holders.