plunger, piston or bucket (Fig. 6) though none of these names defines it. A pole four to five feet in length and having a diameter of 1 to 2¾ inches is fitted with a cross handle like the handle of a gimlet. The other end of the pole is cut to a smaller diameter for a distance of 1½ inches from the end, leaving a shoulder. This part of smaller diameter is passed through a hole of equal diameter in the center of a disk of green or thoroughly soaked rawhide. The diameter of this rawhide disk is from six to eight inches, depending upon the diameter of the bore of the tube. To the outer edge of this disk and equally spaced are fastened six rawhide straps about six inches in length and three-fourths of an inch in width. These straps are nailed or tied to the pole at such a distance above the shoulder as to allow the soft disk to form a pocket or sack, the outer diameter of which, when expanded by the pressure of the water, will be sufficient to permit a more or less tight fit in the working barrel of the pump tube. The flexibility of the plunger allows it to fit all the irregularities of the interior of the palm stalk crudely fashioned as it usually is. Riveted sheet-iron pipes of four, six, or eight inches in diameter may be readily converted into hand pumps by the use of such valves and plungers. The rivet heads inside of the pipes seem to have no effect upon the working efficiency of pumps thus constructed, so great is the adaptability of the flexible rawhide plungers.

The pumps in their working positions stand at angles from 35 to 50 degrees from the horizontal and raise water from six to eight feet in vertical height. One lift is usually sufficient for pits sunk in the sand bars of the rivers. Where one lift is not sufficient, one side of the pit is cut down and a shelf is formed. The water is raised by one series of pumps from the bottom to the shelf and by another series from the shelf to the surface. As depth is gained and the flow of water increases the pumping keeps pace by increasing the number of pumps. In extreme instances as many as 20 pumps have been used to keep a 12x14-foot pit free of water. As the work of each pump operator is equal to that of every other, and as the pay is equal, the boss of the pit insists on synchronous movement. If all keep time with the pacemaker no one is loafing.

PARTS OF RIVER CUT OFF BY DAMS.

The most ambitious of all the native engineering projects for reaching the gold in the river bottoms is known by the name of the *tapado*. The *tapado* might be defined as a wing dam that bends back to the bank inclosing and cutting off a part of the river bed. The dam is constructed by driving stakes close together in a double line and filling the space between the lines with clay, well tamped in. The lines of stakes are separated by a space of about four feet. The stakes are fastened together by binding all to horizontal poles placed near the top. These horizontal poles are then bound to cross poles placed about every four or five feet. Vines, *bejuocos*, from the jungle are used for the binding.

Previous to filling in with clay, palm leaves are placed inside and against the stakes. When the *tapado* has been completed, the water is pumped from behind the dike and mining proceeds. At points near riffles or cascades, the *tapado* dam may be run out from the bank above, and terminate at a lower level, going down the riffle. If the fall is greater than the depth of the water outside of the upper end of the *tapado*, the lower end is left open and no pumping is required, as the space inside drains itself.

At most of the large mines on the Porce River, where the playas are being worked by means of hydraulic elevators, the operators take advantage of a protracted dry season to put large *tapados* into the river, thus making accessible considerable additions to their workable territory. Since the borders of the playas adjacent to the river are almost without exception the richest parts, the areas thus added are highly remunerative.

LEASING SYSTEM POPULAR.

The river workers generally consume so much time in building their *tapados* that little is left of the dry season for the work of getting at the bedrock. Partly for this reason and partly from the fact that the natives find it the usual thing to do, the *corte* system consists in leasing small *cortes*, or areas within the mine or *tapado*, for a percentage of the product. This percentage depends upon the expected total yield and upon the live lines of the competition for the opportunity to work a *corte*. If the mine or *tapado* has the reputation of being rich and competition is active, the owner may demand and get as high as 50 to 60 per cent. of the gold produced. On the other hand, he may not be able to secure leasers unless he concedes to them 80 per cent. of the product.

WAGES DEPEND ON AMOUNT OF GOLD RECOVERED.

The river workers are always required to pay 20 per cent of their gross washings to the owners of the mines. The river miners have unlimited opportunities for concealing the amounts of gold they actually wash out, and their incessant shifting from one mine to another makes it a hopeless task for the owners to keep track of them. It is safe to say that a portion much smaller than 20 per cent gets into the pockets of the owners.

The owners of the *tapados* keep out the water, receive, weigh and sell the gold. The lessees frequently sublet their privileges. The peons sometimes receive their food and lodging only and are promised a proportional division of one half of the gold that falls to the share of the lessee or sublessee after he has paid his percentage. Sometimes the peons prefer to board themselves, particularly if they have families. Since they invariably live from hand to mouth, they must have some pay. In that event their employer contracts to pay them one half of the ruling wage and promises a proportional division of one quarter of his share of the gold to complete their pay.

At other times the peon receives something less than

the ruling wage and is promised by his employer a *pinta* as a final settlement. This is the product of a *batea* full of gravel taken from the bedrock. On the Porce River, 95 per cent of all the gold is on bedrock or within a foot of it, so this method is sometimes highly satisfactory. The peon is always ready to take a gamble in a small way.

GRAVEL CARRIED FROM THE PITS.

The operating force for each *corte* usually consists of one shoveler, rarely more, *batea* passers, hand-barrow carriers and washers, who wash the gravel and attend to the sluices. The lessee or sublessee generally acts as *capitan* or boss. Each pair of hand-barrow carriers will carry the loaded barrows a distance of only 25 to 40 feet, depending upon the steepness of the runways. As many as four to seven pairs of carriers are employed for each *corte*, where the runs are from 200 to 300 feet in length. The transportation of the gravel for such distances is not infrequent at the playa mines, in which the gravel is from 40 to 50 feet in depth.

As stated elsewhere, the wages of the peons are higher during the dry seasons, so that the cost for each peon (wages and food) will not be far from 70 cents per day. During the wet seasons plenty of good peons may be employed at a total cost of 50 cents per day each. The hand-barrows as loaded hold from 1 to 1¼ cubic feet. From 3 to 5 cubic yards of gravel are removed from each *corte* per day at a cost of from 80 cents to \$2 per cubic yard. It takes good ground to stand such costs and to produce a profit. The *corte* system has been defined as the one designed to distribute the product of the mine to the greatest number of Colombians.

BEDROCK NEVER THOROUGHLY CLEANED.

Within the last eighteen months the native miners have learned a lesson from the Americans, who are putting in hydraulic elevators for the purpose of working the deeper water-filled gravels of the playas. The depth of the gravels range from 12 to 55 feet. Up to the present, these more progressive miners seem to have been so inadequately supplied with capital that their elevator equipments are too small to do more than serve as pumps and keep the pits fairly clear of water. These water elevators are so far superior to the old-time overshot water wheels used for driving four to six pumps, that the latter are now being but little employed. These ponderous slow-moving contraptions were never more than partially successful and enabled the miners to reach only the highest portions of the bedrock. The same ground formerly mined by natives with the aid of these water-wheel-driven pumps, has since been washed by Americans, using hydraulic elevators with most satisfactory returns. The mining done by the Americans developed the fact that the natives of former times had succeeded only in cleaning up the ridges of the bedrock, whereas the best of the gold was found in the depressions. Thus a rich harvest was left for those who arrived late upon the scene.

Economy Due to Superheated Steam in Marine Practice*

Increased Thermal Efficiency Gained Without Additional Cost for Repairs

By Walter M. McFarland

THE theoretical advantages of the use of superheated steam were evident at an early date, as indeed would be inevitable when the principle of the Carnot heat cycle was understood. In the early days, when materials were not nearly so good as at present, and steam pressures were accordingly much lower, the benefit of getting the economy due to a very much higher initial temperature with no increase of pressure was, of course, obvious. Accordingly, very many experiments were made and a number of plants were installed using superheated steam, often with special superheating boilers. On the whole, these early installations were not practical successes, on account of the rapid corrosion of the superheaters, although the heat economy was obtained. In those days workmanship was not so good as now, and the causes of corrosion were not only not properly understood but there was dense ignorance concerning them, so that the measures taken to prevent corrosion really increased it. Obviously, there was no commercial economy in a system where the cost of repairs far exceeded the saving due to increased economy.

In more recent years, since corrosion has been better understood and the means for preventing it are fairly well known, the attractiveness of the benefit to be derived from superheating has led to its reintroduction, and this article is intended to be a brief discussion, with some illustrative examples, of the economy which comes from the use of superheat.

In land installations, where poppet valves can be

used, so that the question of valve friction does not come up, superheat may be used to almost any degree that is desired, and there are a great many examples of such engines on the continent of Europe which are working with a remarkable degree of economy, in some cases very closely approaching 1 pound of coal per horse-power hour.

With the steam turbine, where there are no rubbing surfaces, the benefit to be derived from superheat was at once apparent, and, generally speaking, it may be said that all the large power houses and central stations which use steam turbines also use superheat. In these cases there is not only the thermal economy due to superheat, but it has been found that the dry steam has much less erosive action on the blades of the turbines than steam which is moist. An excellent article by Capt. C. A. Carr, U. S. N., published in the *Journal of the American Society of Naval Engineers* for February, 1911, gives a great deal of information with respect to these land plants, and will repay very careful study. Speaking generally, it is considered that with steam turbines of modern design and carrying from 175 to 200 pounds of steam pressure, there is a saving in steam consumption of about 1 per cent for each 10 degrees of superheat.

About ten years ago, Capt. Augustus B. Wolvin, then the manager of a number of steamboat lines on the Great Lakes, and who has been one of the pioneers in the adoption of improvements in marine machinery tending to economy, installed Babcock & Wilcox boilers and superheaters in one of the vessels under his control, and followed this by similar installations on several other ves-

sels. One of these, the "James C. Wallace," was subjected to a test by a board of naval engineer officers, and showed a saving in coal of about 9 per cent, with an average superheat at the engine of about 85 degrees. The Bureau of Steam Engineering took up this subject, and in 1904 ordered Babcock & Wilcox boilers and superheaters to replace the old cylindrical boilers on the "Indiana." This was followed by installations of similar boilers and superheaters on the "Massachusetts" and the "New York" (now "Saratoga") in the way of replacements, and on the "Michigan," "South Carolina," "Prometheus," "Vestal," "Delaware," "North Dakota," "Texas" and "New York" (new), new vessels. In 1905 boilers and superheaters from the same makers were ordered for the steamship "Creole," with respect to whose performance some interesting data will be given later on. The Pennsylvania Railroad, in its marine service, has always shown a desire to get the safest and most efficient machinery, and in 1909 ordered from this concern boilers and superheaters for three of their large tugs, the "Johnstown," "Wilmington" and "Harrisburg," which have given great satisfaction and economy in service. The steam yacht "Idalia" also has a boiler and superheater supplied by this same firm.

It will thus be seen that superheat is in use on a large number of vessels, and undoubtedly a great deal of experience has been accumulated, but, unfortunately, not very much has been published.

Table I gives the performance of the steamship "Creole," which is fitted with Babcock & Wilcox boilers and superheaters, as compared with the performance of

* Reproduced from *International Marine Engineering*.

her two sister ships, the "Momus" and "Antilles," which have ordinary cylindrical boilers without superheat. As shown by the table, the hulls are practically identical. The "Creole" has twin screw engines of about 7,000 horse-power, while the "Momus" and "Antilles" have single screw engines of about 7,500 horse-power. All three ships carry about the same steam pressure—about 210 pounds. The "Creole" was originally fitted with Curtis turbines, but the speed was too low (15½ knots) to permit economical use and they were removed. It is to be noted that so far as there is any advantage in engine economy it should be with the "Momus" and "Antilles," which have each a single engine of about the same power as the aggregate of the two engines on the "Creole," thereby reducing the losses due to cylinder condensation. The engines are all triple expansion and of excellent design. The "Creole's" first trip with her new engines was made in the spring of 1910. Two comparisons are given, one of five round trips of the "Creole" in the summer of 1910, as compared with five round trips of each of the others, obtained by taking their best performances in the three summers of 1908, 1909 and 1910. The second comparison is between two round trips of all three vessels made in the month of October, 1910. They run over the same route from New York to New Orleans, and, as the hulls are identical and the engines designed and built by the same firm, the only material difference is in the boilers and superheat. The table shows that the "Creole" operates with about 17 per cent less fuel per round trip than her sister ships. The average superheat carried is about 60 degrees, from which a saving of about 6 per cent would be expected. It is to be noted however, that there is a distinct gain in economy due to the use of the Babcock & Wilcox boiler, as contrasted with the cylindrical or Scotch boiler.

In an article by the late Admiral George W. Melville U. S. N., published in the *Engineering Magazine* for January, 1912, are given reports of very accurate tests of Scotch boilers and of Babcock & Wilcox boilers, made by boards of navy officers and committees of independent engineers, so that the reliability of the data is beyond

TABLE I.—ECONOMY DUE TO SUPERHEATED STEAM—MERCHANT VESSELS.

Name of vessel	Creole	Momus and Antilles
Date of tests	1910	1908-9-10
Length, feet	407	410
Beam, feet	53	53
Draft, feet	26.7	25.6
Tonnage, gross	6,754	6,878
Tonnage, net	4,302	4,326
Cylinders, diameter and stroke	(2) 27½, 40½, 70, 42	(1) 34, 57, 104, 63
I. H. P.	7,000	7,500
Boiler pressure, pounds	210	210
Kind of boilers	Babcock & Wilcox, with superheaters	Scotch, no superheater
Ratio of superheating to evaporating surface, percent	1 to 15.5	
*Av. coal per trip for five round trips, tons	1,149	1,374
Percentage of saving by use of B. & W. boiler and superheater	116.38	
Av. coal per trip for two round trips, each vessel, in October, 1910	1,206	1,461
Percentage of saving by use of B. & W. boiler and superheater	117.45	

* The "Creole's" trips were in summer of 1910; those of the other ships are their most economical trips in summers of 1908, '09 and '10.

† The improved economy is due partly to greater efficiency of boiler of "Creole" and partly to superheat. See text for analysis and discussion.

as being within a few per cent of the actual consumption. This shows a gain of about 16 per cent over previous navy practice; of this gain one half may be assigned to the use of superheated steam, and the other due to reduction of clearance and better cylinder proportions."

In October, 1909, a test was made of the machinery of the yacht "Idalia" with superheated steam by Dr. D. S. Jacobus, and witnessed and reported by Lieut. John Halligan, Jr., U. S. N. The owner of the "Idalia" is an accomplished engineer, which insures the maintenance of the machinery in first-class condition at all times. She has a four-cylinder triple-expansion engine, the cylinder diameters being 11.5 inches, 19 inches, (2) 22.7 inches by 18 inches stroke. All the cylinders are unjacketed and have piston valves. There is one Babcock & Wilcox boiler, with 65 square feet of grate surface and 2,500 square feet of evaporating surface and 340 square feet of superheating surface. These tests are notable from the fact that the weight of the steam used was carefully determined by weighing the steam condensed in tanks on

been raised whether there is a corresponding saving in fuel. That is, will not the fact that a pound of superheated steam contains more thermal units than a pound of saturated steam require in the long run a greater expenditure of fuel per pound of steam, so that, although fewer pounds of steam are used per horse-power, it takes a greater amount of coal for a given number of pounds of water evaporated? Speaking generally, it may be asserted that with superheaters properly designed and located, and within the limit of superheat ordinarily used in marine practice—50 to 100 degrees—such tests as have been made, and such general experience as has been gained, tend to show that there is in the long run practically no increase in the fuel per pound of steam, or, in other words, there would be almost exactly the same percentage of reduction in the amount of fuel used as in the amount of steam per horse-power. It is not difficult to understand why this should be the case in a properly designed arrangement of superheaters. In all the cases cited, and these are the only ones for which data are available, the superheaters are used with Babcock & Wilcox boilers. As is well known, a system of baffling is used in these boilers which causes the hot gases to cross the tubes three times on their way from the furnace to the up-take. The superheaters are placed at the passage from the first to the second pass, after the gases have crossed the tubes once before they cross the second time, so that the temperature is very much higher than in the case of the older types of superheaters, where they were placed in the up-take like a feed-water heater. The experiments which have been made on these boilers under various rates of combustion show that the temperatures where the superheater is located, when burning from 30 to 35 pounds of coal per square feet of grate, would be about 1,000 deg. Fahr., while the temperature of saturated steam of about 200 pounds is about 388 deg. Fahr. There is thus a good difference in temperature, so that a considerable degree of superheat is obtained with a moderate amount of superheating surface. There are still the second and third passes of the boiler to be acted upon by the hot gases, and the only effect is to reduce slightly the temperature of the gases in the up-take. Hence the efficiency of boiler and superheater is at least as great as that of the boiler alone.

The examples we have given of the navy vessels, of the "Creole" and her sister ships, and the "Wallace," with and without superheat, all show results as measured in coal, while the "Idalia" experiments give them in water. None of these experiments has the conditions absolutely ideal for determining with extreme accuracy the exact amount of gain due to superheating, because other items vary besides the extent of superheat. What practical men desire to know, however, is not results to the last decimal point, but to be reasonably sure that there is a decided gain due to superheating and this has, from the data given, been shown beyond question.

We have already mentioned one of the benefits which has been found in land service where superheated steam is used with turbines, and, obviously, thoroughly dry steam, as against very moist, would be a blessing in reciprocating engines, so that this, of course, is another benefit of superheating. On board ship, where there are so many auxiliary engines scattered over a large area, and many of them simple cylinders following full stroke, it can readily be seen that the use of superheated steam ought to be conducive to a great increase of economy. Unfortunately, if tests of this kind have ever been made by the Navy Department they have not been published.

It now remains to mention some of the drawbacks, or rather matters which have to be attended to, if the use of superheated steam is to be entirely satisfactory. In the central stations and power houses on shore, before the use of superheated steam, many of the valves and fittings in the pipe lines were of cast iron. It was found that superheat of 100 degrees, or higher, caused considerable trouble, due to distortion of the cast iron fittings and inability to keep the valves tight. The general practice now is to avoid the use of brass or cast iron, and the valve bodies and fittings which come in contact with superheated steam are to be of cast steel. Valve seats are made of bronze with a large percentage of nickel or of Monel metal, which is a natural bronze of somewhat similar composition. The navy is now using Monel metal valves and seats. With these precautions, experience has shown that superheated steam up to 100 degrees can be used with great satisfaction as far as practical service is concerned, with no increased cost of repairs and with decided increase in efficiency.

TABLE II.—ECONOMY DUE TO SUPERHEATED STEAM.

Name of Vessel	Kansas.	New Hampshire.	Michigan.	South Carolina.
Builders	New York Shipbuilding Co.	New York Shipbuilding Co.	New York Shipbuilding Co.	Wm. Cramp & Son S. & E. B. Co.
Date of trial	Dec. 14, 1906.	Dec. 20, 1907.	June 10, 1909.	August 25, 1909.
Displacement on trial, tons	16,000	16,145	16,064	16,064
Twin screw engines, diameter and stroke of cylinders, inches	32½, 53, (2) 61; 48	32½, 53, (2) 61; 48	32, 52, (2) 72; 43	32, 52, (2) 72; 48
Kind of boilers	Babcock & Wilcox	Babcock & Wilcox	Babcock & Wilcox	Babcock & Wilcox
Evaporating surface in use, square feet	52,752	47,112	42,432	42,432
Superheating surface in use, square feet	No superheaters.	No superheaters.	5,174	5,174
Ratio superheating to evaporating surface, per cent			12.2	12.2
Heating surface, total square feet	52,752	47,112	47,606	47,606
Grate surface, total square feet	1,097	1,100	1,046	1,046
Ratio evaporating to grate surface	* 48.0 to 1	42.81 to 1	40.6 to 1	40.6 to 1
Speed, average for trial (4 hours)	18.004	18.162	18.79	18.86
Revolutions, average per minute (4 hours)	121.32	118.75	119.46	121.28
Steam pressure at boilers, gage, pounds	278.2	246.00	297.70	285.00
Steam pressure at high-pressure steam chest, gage pounds	250.0	222.00	246.00	241.00
Steam pressure, first receiver, absolute, pounds	106.5	93.00	77.40	96.50
Steam pressure, second receiver, absolute, pounds	38.0	32.20	8.10	35.10
Vacuum in condensers, inches of mercury	28.0	26.60	27.00	26.2
Superheat at high-pressure chest, degrees Fahrenheit	None.	None.	86.70	47.5
I. H. P. of main engines only	19,302.00	16,772.00	16,019.45	17,651.00
I. H. P. of all auxiliaries in use	455.00	495.00	600.85	706.00
I. H. P. total	19,757.00	17,267.00	16,620.30	18,357.00
Coal per hour per I. H. P. of main engines	1.779	1.785	1.51	1.395
Coal per hour per I. H. P. of main engines and all auxiliaries	1.737	1.773	1.46	1.341
Coal per hour per square foot grate surface	31.21	27.31	23.28	23.47
Air pressure in fire rooms, inches of water	0.60	0.49	0.67	0.78

question. These tests showed that, at the rate of combustion obtaining in these vessels, the Babcock & Wilcox boiler shows an efficiency of about 74 per cent, as against from 62 to 67 per cent (average 64.5 per cent) for the Scotch boiler. Working out the saving due to this greater efficiency, it comes to 11.7 per cent, and this subtracted from 17.45 per cent, the total saving, leaves 5.75 per cent as the saving due to superheat, which agrees quite well with the rough general rule of 1 per cent saving for each 10 degrees of superheat.

Table II gives the performance of four United States navy vessels, all of the same displacement and approximately the same power, and all fitted with Babcock & Wilcox boilers. The "Kansas" and the "New Hampshire" have no superheaters, while the "Michigan" and the "South Carolina" are fitted with superheaters. The performance of these four ships is very interesting, showing a saving, based on the average of the two ships, with superheaters as contrasted with the two without, of 18.52 per cent. In this connection it is interesting to note the remarks of Commander Henry C. Dinger, U. S. N., formerly editor of the *Journal of the American Society of Naval Engineers*, who wrote the account of the trial of the "South Carolina," and who says with respect to the better performance of the ships with superheaters:

"The engines of the "Michigan" and "South Carolina" represent a decided advance in economy of steam consumption of navy reciprocating engines. The design embodies the use of (1) superheated steam; (2) large

ratio of cylinders, namely, $\frac{H. P.}{L. P.} = \frac{1}{10}$, and (3) a consid-

erable reduction of cylinder clearance. Calculations from indicator cards indicate that the steam consumption at full power was about 12.6 pounds of water per indicated horse-power. This result may be considered

carefully standardized platform scales. The actual duration of the test in each case was about 2½ to 3 hours, but observations were made every 15 minutes. The well-known reputation of Dr. Jacobus as an experimenter insures the accuracy of the results, which are given in Table III. The duration of the experiments was obviously too short to make it worth while to attempt to measure the coal. It is to be noted that the feed, air and circulating pumps, all of which are independent, discharge their exhaust steam into the main condenser, so that the figures given for steam per horse-power include the steam used by these auxiliaries, as well as by the main engine, while the horse-power is of the main engine only. This is mentioned in order that the results, which might otherwise be considered rather high, may be thoroughly understood.

We have now given such experimental data as are available of measurements of coal and water to show the economy of superheating, and, as stated above, they bear out the rough rule that there is about 1 per cent in saving of fuel for each 10 degrees of superheat.

The practical effect of superheated steam is, of course, to give a greater thermal efficiency to the engine in which it is used and reduce the number of pounds of steam required per horse-power. The question has frequently

TABLE III.—ECONOMY OF SUPERHEATED STEAM. TESTS ON YACHT IDALIA. SUMMARY OF TESTS.

Date, 1909.	Conditions.	Pressures.			Vacuum.	Temperatures.		R. P. M.		Revolutions per Minute, Main Engine.	I. H. P., Main Engine.	Water per Hour, Total.	Water per I. H. P.	Per cent Saving of Steam.
		Throttle.	First Receiver.	Second Receiver.		Feed.	Hotwell.	Air Pump.	Circulating Pump.					
Oct. 11.....	Saturated.....	190	68.4	9.7	25.5	201	118.0	57	196	194.3	512.3	9,397	18.3	
Oct. 14.....	Superheat, 37°.....	196	66.0	9.2	25.9	208	109.5	56	198	11.5	495.2	8,430	17.0	7.10
Oct. 14.....	Superheat, 58°.....	201	64.3	8.7	25.9	205	115.0	53	196	195.1	521.1	8,234	15.8	13.66
Oct. 12.....	Superheat, 96°.....	198	61.9	7.8	25.4	202	114.5	54	198	19.5	498.3	7,902	15.8	13.66
Oct. 13.....	Superheat, 105°.....	203	63.0	8.4	25.2	200	111.0	45	197	193.1	502.2	7,790	15.5	15.30

Slide of Stratified Rock, West Bank of Canal. This Slide Involved About 900,000 Cubic Yards and Moved About 5 feet per Day on a Slope of One in Seven.

Bird's Eye View of Gatun Locks, Showing Ships Being Towed Through by Electric Locomotives.

Culebra Cut, Empire, Looking North from West Bank at Cunette. The Two Shovels in the Foreground are Working on the Final Bottom of the Canal. Elevation, 40 feet.

Pedro Miguel Locks, South End of East Chamber, In Construction of Safety and Lower Gates. June 12.

Relocation of Panama Railroad. The Brazos Bottom, Looking North. June, 1912. Note the Heavy Filling on Each Side the Track, to Balance Earth Movement.

Completing the Panama Canal

A Brief Account of the Greatest Engineering Work of All Time

The present time is opportune for giving a résumé of the task which is now so near its close; and perhaps we cannot do this better than by outlining the course to be followed by the leading ships of the fleet which will pass through the canal on the great day of opening, January 1st, 1915.

The first evidence of American work at Panama will present itself, as we enter Colon Harbor, in the form of a massive breakwater, over two miles in length, which extends from Toro Point at the westerly side of Limon Bay. Rounding the breakwater, which by the way, has been built to protect shipping in the bay against the heavy northeasters, we shall enter a channel, 500 feet in width and 41 feet deep, which has been dredged from deep water to the shore line, a distance of about four and one half miles. Leaving Colon on the left, our ship will steam on a straight course through a comparatively low-lying land from the shore to the entrance of the Canal Locks at Gatun. This section of the canal will be also 500 feet in width and 41 feet deep, and here we pass through the slight divide, known as the Mindi Hills, on the further side of which is the valley of the Chagres River. At this point the valley narrows down to a width of about a mile and a half and to our right we note the long straight skyline of the crest of a vast artificial hill, 115 feet in height, which has been built laboriously from

one side of the valley to the other and is known as the Gatun Dam. At the center of this dam we see the Spillway, with the surplus waters of the lake flowing through its gates and passing down through the wide Spillway channel to discharge into the old bed of the Chagres River. Immediately in front of us is the 4,000-foot stretch of the Gatun Locks, each 1,000 feet long, 110 feet wide in the clear, and having a lift of 23 1/3 feet. We enter the right-hand lock, and the gates having closed behind us, we are lifted 23 1/3 feet, the process being repeated until finally the upper gates are swung open and we enter the broad waters of Gatun Lake. Our progress through the locks was not made under our own steam; instead, four electric-towing locomotives, running on the side and center walls were made fast to our ship, two at the bow and two on either quarter, and all movements, until we reached the lake level, where made under their exact control, at a speed of about two miles per hour.

Gatun Lake has been formed by the dam before mentioned and when it stands at its normal level of 85 feet, the lake has a surface area of about 170 square miles. As soon as the towing locomotives have cast off, we proceed under our own steam, and soon are moving at full speed through a channel dredged in the bottom of the lake, which is 1,000 feet in width for the first sixteen miles of our course. Then the channel narrows to 800 feet for

about two and one half miles, 700 feet for the next mile, and 500 feet for the following three miles, which brings us to the great cut through the Culebra divide. Here the channel narrows to its smallest width of 300 feet, which it holds for a distance of nine miles through the Culebra Cut, or until the two-flight lock at Pedro-Miguel is reached. Here we drop from elevation 85 to 55, and after steaming for about a mile and a half through a small artificial lake, impounded by a dam at Miraflores, we reach the locks of the same name which drop, in a single reach the locks of the same name which drop us, in a single flight, down to sea level on the Pacific side. About eight miles of steaming through the sea-level channel brings us to deep water on the Pacific side.

Only those who may have been so fortunate as to traverse the canal before it was water-filled, will have an adequate conception of the magnitude of the task. A pictorial representation of the quantities of excavated material and concrete was given on page 391 of the SCIENTIFIC AMERICAN Canal Number of November 9th, to which attention is directed. From this we learn that the excavated material would build a line of 63 pyramids of the size of the Great Pyramid which, if they were placed in line, would extend for a distance of nine miles. The work of excavation would dig a canal 55 feet wide, 10 feet deep, entirely across the United States.

An Aid to Navigation. Front Tower of Range 5-6, Atlantic Section. Height, 74 feet. July 14th, 1912.

Gatun Upper Locks, West Chamber, Looking North South End, Showing Construction of Three Sets of Gates. June 12, 1912.

Gatun Locks, General View, Looking Southwest, Showing North End of Locks with Temporary Cofferdam in place. June, 1912.