ciency was reached, and when the work became concentrated in the short section of Culebra Cut as the other sections neared completion:

**CULEBRA CUT.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Cubic Yards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904</td>
<td>243,472</td>
</tr>
<tr>
<td>1905</td>
<td>1,167,628</td>
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<tr>
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<td>2,702,991</td>
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<td>1907</td>
<td>9,177,150</td>
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<tr>
<td>1908</td>
<td>13,912,453</td>
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<td>1909</td>
<td>14,557,034</td>
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<tr>
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<td>15,398,599</td>
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<td>1911</td>
<td>16,596,891</td>
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<tr>
<td>1912</td>
<td>15,028,413</td>
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<tr>
<td>1913 (to Sept. 10)</td>
<td>8,348,190</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>97,132,801</strong></td>
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**ENTIRE CANAL.**

<table>
<thead>
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<th>Year</th>
<th>Cubic Yards</th>
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<td>1,799,227</td>
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<tr>
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<tr>
<td>1909</td>
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<tr>
<td>1910</td>
<td>31,603,899</td>
</tr>
<tr>
<td>1911</td>
<td>30,269,349</td>
</tr>
<tr>
<td>1913 (to Sept. 1)</td>
<td>20,937,718</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>209,218,030</strong></td>
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</table>

Two makes of steam shovels were used in the excavation work, the Bueyras and Marion, of 45, 66, 70, 90 and 105 tons, equipped with dippers ranging in capacity from 1\(\frac{1}{2}\) cubic yards to 5 cubic yards. In Culebra Cut, shovels with

These models of Pedro Miguel Lock give a good idea of how ships will enter and pass through the locks.
A comprehensive view of one of the great locks of the Canal under construction, where the largest concrete monoliths in the world have been built. One is almost bewildered by the tremendous machinery of the work—the enormous Berm and Chamber cranes with their almost uncanny air of intelligence towering over the scene with their interlaced-ironwork arms extended above the cement walls which they are constructing.
5-yard dippers were used almost entirely, and a shovel thus equipped averaged about 1,800 cubic yards per 8-hour day. A cubic yard of earth and rock weighs about 3,600 pounds, and represents about a two-horse cart load. The work done by the steam shovels would dig a canal 55 feet wide and 10 feet deep from Maine to Oregon.

In transporting material to the dumping grounds three classes of cars were used—Lidgerwood flat cars with one high side with a capacity of 19 cubic yards, and Oliver and Western side dump cars, large and small, having a capacity of 17 and 10 cubic yards, respectively. To haul trains composed of 20 flat cars, 27 large dump cars, or 35 small dump cars, American locomotives were used. These trains would make an average of 1 1/2 trips daily to the dumps, an average distance one way of 11 miles. The average time consumed in unloading a train of flat cars at the dumps was from seven to 15 minutes. This was accomplished by the use of what was known as an unloading plow. The large dump cars were operated by compressed air from the locomotive, while the small dump cars were operated by hand, and the time consumed in unloading was from 6 to 55 minutes.

The constant arrival of spoil trains on the dumping grounds made necessary a quick method of changing the construction tracks. This necessity led to the invention by W. G. Bierd, formerly superintendent of the Panama Railroad, of a track shifting machine. This machine consists of a boom, extending from a flat car out over the track in advance of the car, to which a block and tackle is attached by which the track is lifted from its bed. Another boom extending from the car at an angle with the main boom pulls the track to one side or the other. In this way track may be thrown nine feet from its original position in one operation.

In addition to the unloading plow and the track shifter for the rapid handling of spoil, there was also used a machine to spread the material on the dump
and keep them in a uniformly level condition. This spreader consists of a car on which has been placed a machine with steel wings, and it works exactly like an electric snow plow on the city streets in the United States, with the exception that the wings are operated with compressed air obtained from the locomotive which hauls the car over the dump. With a perfect organization, modern equipment, a well planned system of transportation, and the rapid disposal of the spoils on the dumps, the maximum possible output of the steam shovels was obtained and maintained, and many world records were made on the Isthmus in excavation work.

ACROSS THE Isthmus IN A HYDROBIPLANE

Several attempts have been made during the past few years to cross the Isthmus in a heavier than air flying machine, but none were successful until April 27, 1913, when Robert G. Fowler, the aviator, accompanied by R. A. Duhem, photographer left the Pacific entrance to the Canal at 10 a.m., and arrived at Cristobal Point on the Atlantic side at 10:57 a.m. The route of the canal was followed closely, the aviator making a circle at Culebra, in order to obtain views of all parts of Culebra Cut. The highest altitude attained during the flight was 1,800 feet; the lowest height at which the machine flew was 400 feet. The President has since signed an Executive Order prohibiting further flights over the Canal, or to take photographs from a flying machine, without written authority of the Chief Executive of the Canal Zone.


Crossing the Locks at Gatun on a bucket operated by the cableways.
THE LAND DIVIDED — THE WORLD UNITED

"On they struggled, ever onward,
Blasting stone, and earth and men;
Filling rivers with razed mountains;
Filling graves with parts of men.
Blood and bone are mixed with concrete,
Sweat of brow and grime of toil
Mark the rough-neck as he swelters,
Weary 'mid the grease and oil.
Weary flesh, nor fever's terrors
Halt them as they onward go.
Forward! Forward! Ever Forward!
Is the only cry they know."

—John Hall.

SEVENTY MILLION POUNDS OF DYNAMITE

The greater part of the material excavated by the Americans in Culebra Cut before the dredges were introduced consisted of hard rock, and it was necessary to drill and blast it before it could be handled by the steam shovels. About 50,000,000 pounds, out of a total of about 70,000,000 pounds for the entire Canal was used. When it is considered that nearly three cubic yards of

The scene of a premature explosion of nearly 22,000 pounds of dynamite at Bas Obispo, December 12, 1908. About 50 men were injured and 26 were killed, among them being three Americans. Blasting operations are conducted with great care, and the heavy shots are usually fired off after the men have quit work for the day, although several of these premature explosions have occurred.
Laborers loading well-drill holes with dynamite near Contractor's Hill. A small charge is first exploded, enlarging the hole at the bottom. Then the main charge, usually consisting of from 75 to 200 pounds is placed, and exploded by means of an electric light wire.

A group of tripod drills at work. Churn drills are used also. All drills are operated by compressed air supplied through mains, and an average of 75 miles of drill holes is sunk each month.
material are blasted for each pound of explosive used, the important part dynamite has played in canal construction can be readily seen. Blasting powder was not used to a great extent due to excessive moisture and water in the holes.

In order to keep the steam shovels going at capacity, it was necessary to blast large areas at a time and as much as 26 tons of dynamite was used at one time. In the use of such large quantities of high explosive there have naturally been many serious accidents although extreme care was taken in the handling. The most serious accident occurred in the Cut at Bas Obispo on December 12, 1908, when there was a premature explosion of nearly 22,000 pounds placed in 52 of the 53 holes it was intended to explode. The powder gang was working on the last hole when the entire charge for some unknown reason went off. The result was appalling. Twenty-six men were killed, among them being three Americans, and some 50 injured, many of them seriously. There had been a premature explosion of 26 tons a few months previous, May 22, 1908, in the Chagres section of the Canal, which is supposed to have been caused by lightning. There were few casualties, however, although there were many narrow escapes as several hundred men were in the immediate vicinity. The thing most dreaded by the steam shovel men, with the possible exception of a sudden slide of rock, was the chance of the shovel digging into a charge of dynamite which had failed to explode. An accident of this nature occurred in the Cut on October 8, 1908, with the result that five of the shovel crew were killed and several injured. A few days later another premature explosion of over 24,000 pounds in 154 holes caused the death of eight men. This latter accident was also attributed to the action of lightning upon the wires which, although connected with the holes, were not carrying any electric current at the time.

To prevent such accidents as much as possible, many lectures and discussions were held from time to time among the employees engaged in the handling, storage, etc., of explosives. Representatives of the Nemours-DuPont Powder Company, which supplied a large part of the blasting material, explained the making of dynamite, the right method of handling, and its action under certain known conditions. As a result of these
discussions, it was decided to use a high amperage current from an electric light plant in exploding charges of more than a dozen holes, instead of by the use of storage batteries. Under the latter method, with the holes wired in series, instead of in parallel, there was no certainty that all the holes had exploded after the current was turned on. In addition to the use of a strong current, the holes were placed closer together, in order that the detonation from a nearby hole would explode those which would otherwise have failed to go off. Stringent rules and regulations for the handling, storage and use of dynamite were also introduced and enforced to minimize the danger. But no rules or regulations could prevent all accidents without cooperation of the men engaged on the work. This impossibility was forcibly demonstrated in the case of a Spanish laborer who, becoming impatient at the slowness of a negro helper, started to knock the cover off of a box of blasting caps with a machete. It is hardly necessary to say that he did not complete the work assigned to him.

In dredging operations, submarine or underwater blasting is employed. Drill boats, like the one in the picture, sink the holes in connection with this work.

In making the necessary holes for the charges, tripod and well drills, obtaining their power from a compressed air main, were used. At one time there were as many as 377 of these drills at work in the Cut, and they were operated in batteries of from four to 12 drills. The usual depth of the hole drilled was about 27 feet, placed about 14 feet apart, and if all the drill holes necessary for the work were placed end to end, they would equal the length of the earth’s diameter from pole to pole with 1,300 miles added. After the holes had been drilled they were widened at the bottom, or “sprung,” by a small charge being exploded in them. After sufficient time had elapsed to allow the holes to cool, they were charged and wired. All blasting took place after the men had left the work for lunch or in the evening and at those times a naval engagement could be easily imagined by those living anywhere in the vicinity. At Porto Bello, where much powder was used in the quarrying of rock a series of blasts took place at one time when a British war vessel was passing close by.

[Image of drill boat and scene]
In the Pacific entrance dynamite was employed in subaqueous blasting, two drill barges being used to make the necessary holes. In addition to breaking up hard material for the dredges in this section, the use of dynamite under water kept many of those employed in the vicinity supplied with fresh fish for some time. Those whose employment necessitated their going out in boats considered themselves particularly fortunate. On one occasion, a private mess of Canal employes was kept supplied with fish as long as such a diet could be endured by its members.

SLIDES—eloquent argument against sea level project

The greatest difficulty in the excavation of Culebra Cut has been caused by slides which have from time to time precipitated great masses of earth and rock into the Canal prism burying steam shovels and dirt trains, tearing up dirt train tracks, and closing up the drainage ditch. There have been 22 slides and breaks at different times covering from one to 75 acres. These have added about 25,000,000 cubic yards, or about one-quarter of the estimated total of excavation necessary in the Cut. The largest and most troublesome of these is the Cucaracha slide on the east bank of the Cut at Culebra, which started in 1887 when the French were at work. When the Americans started operations in 1905, this slide again became active and, as the Cut deepened at this point, it continued to develop. Gold Hill presents a solid rock face 482 feet above the Canal bottom between Cucaracha slide and a slide immediately north. These two slides have broken so far back that the slope on their outer edges is away from the Canal. This has led to the introduction of hydraulic monitors which are engaged in sluicing the material from the top of the slides into the valley in the rear of Gold Hill, in order to reduce the pressure from above. Another serious slide occurred on the west bank of the Canal at Culebra covering an area of 75 acres, and necessitating the removal of about 10,000,000 cubic yards of material. This slide made necessary the removal of many buildings of the village of Culebra which were situated near the edge of the Cut.

There are two classes of slides. One, similar to Cucaracha, is caused by the slipping of clay and earth on a smooth sloping surface of a harder material. The other, commonly called a "break," similar to the one which involved the

Towing dynamite to the drill boat Teredo.
village at Culebra, is caused by the steepness of the slope and the great pressure of the superincumbent material upon the underlying layers of softer material.

Besides sluicing, steam shovels excavated a great amount of material from the tops to relieve the pressure, and the Cut was terraced to prevent a part of the material in the slides from going over into the Canal prism. Many schemes were proposed to prevent slides, one, the use of a cement gun to spray the sides of the Cut where the mass of stone became brittle and crumbled on exposure to the air, but, as Colonel Gaillard said in November, 1912: “The only successful method of treating the slides or breaks, once the material is in motion, is to dig it out and haul it away until the slide comes to rest upon reaching the angle of repose for the particular material then in motion.” No difficulty is anticipated with slides now that water has been let into the Cut as the back pressure of the water is expected to result in greater stability. What material remains in the slides in the prism will be handled by the dredges, which will continue their work until the “angle of repose” has been reached.

The slides have caused an immense amount of extra excavation and many delays in the work, but they have demonstrated the fact that a sea level Canal requiring a Cut 85 feet deeper than it now is would be nearly impossible to accomplish. It is believed that the slides would have prevented the carrying out of a sea level project, except at an enormous expense.
The sea going suction dredge Culebra, shown above, with its sister vessel, the Caribbean, constitute the most expensive units in the Commission's dredging fleet. These vessels move up and down the channel, sucking up the mud and loose material, conveying it into their own hoppers. When the hoppers are filled, the vessels go out to sea and empty. The suction dredges were used to advantage in the fill at Gatun Dam. Several of the old French dredges were repaired and used by the Americans.
Suction dredge No. 82, removing silt from the channel north of Gamboa dike. This was the first dredge put to work in the Gatun Lake section.

A dipper dredge at work in the Canal. The material is dumped into the barge along side the dredge, and when full the barge is towed out to sea and emptied.

The Corozal, the newest and most modern ladder dredge in the Canal service. It is equipped with five yard buckets and can dig to 45 feet below mean sea level.
Part of Miraflores lock site and the Canal channel to the south of it were excavated hydraulically. This view shows one of the hydraulic pumps forcing the water through pipes, fitted with monitors, with a pressure of 130 pounds per square inch at the nozzle, which washes the material into pits or sumps.

After the material has been loosened and washed into the sumps, centrifugal dredging pumps, shown here, force the material to the desired destination. Many acres have been reclaimed near Corozal by utilizing this excavated material.
The upper picture shows a view of the Canal looking north from Paraíso bridge toward Gold Hill, showing work progressing in the Canal, August, 1908. The center picture is a view looking south from the same point, 1908, Ancon Hill in the distance. In the lower picture taken the same year, the Canal is shown near Empire. The suspension bridge near Empire may be seen in the distance.
Paraiso in the French days. This was the site of one of the locks in the 10-lock Canal scheme when the French were at work. On April 23, 1904, the United States made the memorable purchase at $40,000,000, and on May 4, 1904, the property was turned over to the Americans.

Paraiso in the days of American occupancy, showing Ancon Hill in the distance. The cranes which are also visible, show the beginning of the work at Pedro Miguel Lock. The French had none of the big tools, up-to-date machinery, steam shovels, cranes, etc., but with the equipment which they had they took out 78,000,000 cubic yards of spoil, of which 39,000,000 cubic yards was useful to the Americans.
The Cut at Bas Obispo looking south June 30, 1910. The greater part of the excavating in this section had to be done through solid rock, and thousands of pounds of dynamite were used. It was in this section that the premature explosion occurred in 1908.

Steam shovel 218 buried under fall of rock, west side of Canal, near Las Cascadas. This shovel was working on the bottom of the canal when destroyed, May 31, 1912. Several steam shovels have been destroyed in this manner and a number of men injured and killed.
A close view of the suspension bridge across the Canal near Empire. This bridge is used for vehicles and foot passengers, but will be taken down when the Canal is completed. There will be no bridge across the Canal, except the pontoon bridge near Paraiso, which will be swung over against the east side of the Canal when not in use.

Ninety-five ton steam shovel at work in Culebra Cut. One hundred steam shovels have been used in the Canal work. Culebra Cut is a term officially applied to that part of the Canal between Bas Obispo on the north and Pedro Miguel on the south, a distance of about nine miles. The width of the Cut is 300 feet at the bottom.
A typical street scene in the native village at Chorera, Panama. On account of the mild climate, which prevails the entire year, the only protection needed is from the sun and torrential rains. The thatched roofs give ample protection to the natives who inhabit them.
A great many difficulties have been encountered and overcome in building the Canal. The greatest difficulty in the excavating, was due to slides and breaks, which closed the drainage ditches, upset the steam shovels, and covered the tracks. The water that was not carried off by the diversion channels, entered the Cut, necessitating pumping.
The side of the Cut at Gold Hill, where the deepest cutting was done. When this photograph was taken the steam shovels had 30 feet further to go at this point.
Culebra Cut near Culebra village, as it appeared October 1, 1912. You will note in the picture the manner of terracing the sides of the Cut. This was done as a preventive measure against the slides.
In the rainy season, two streams of considerable size originally crossed the route of the Canal in the Calebra Cut section, one of which was the Camacho River, now called the Camacho diversion. To prevent these streams from flooding the Cut, new channels were dug, paralleling the banks of the Canal, through which their flows were diverted. In this case it was necessary to dig a tunnel, which is shown above, to conduct the water through the hill.

Culebra Cut looking south from Gold and Contractor's Hills taken at a time when the Cut was practically free of material brought in by Cucaracha slide.
Loaded work train crossing the high trestle over the Canal at Paraíso. This bridge, known as No. 57 ½, is to be taken down as soon as the pontoon bridge a little above this point is constructed, as it obstructs navigation of the Canal.

Section of Culebra Cut in the vicinity of Las Cascadas after completion. Various small slides have occurred all along the banks in this part of the Canal.