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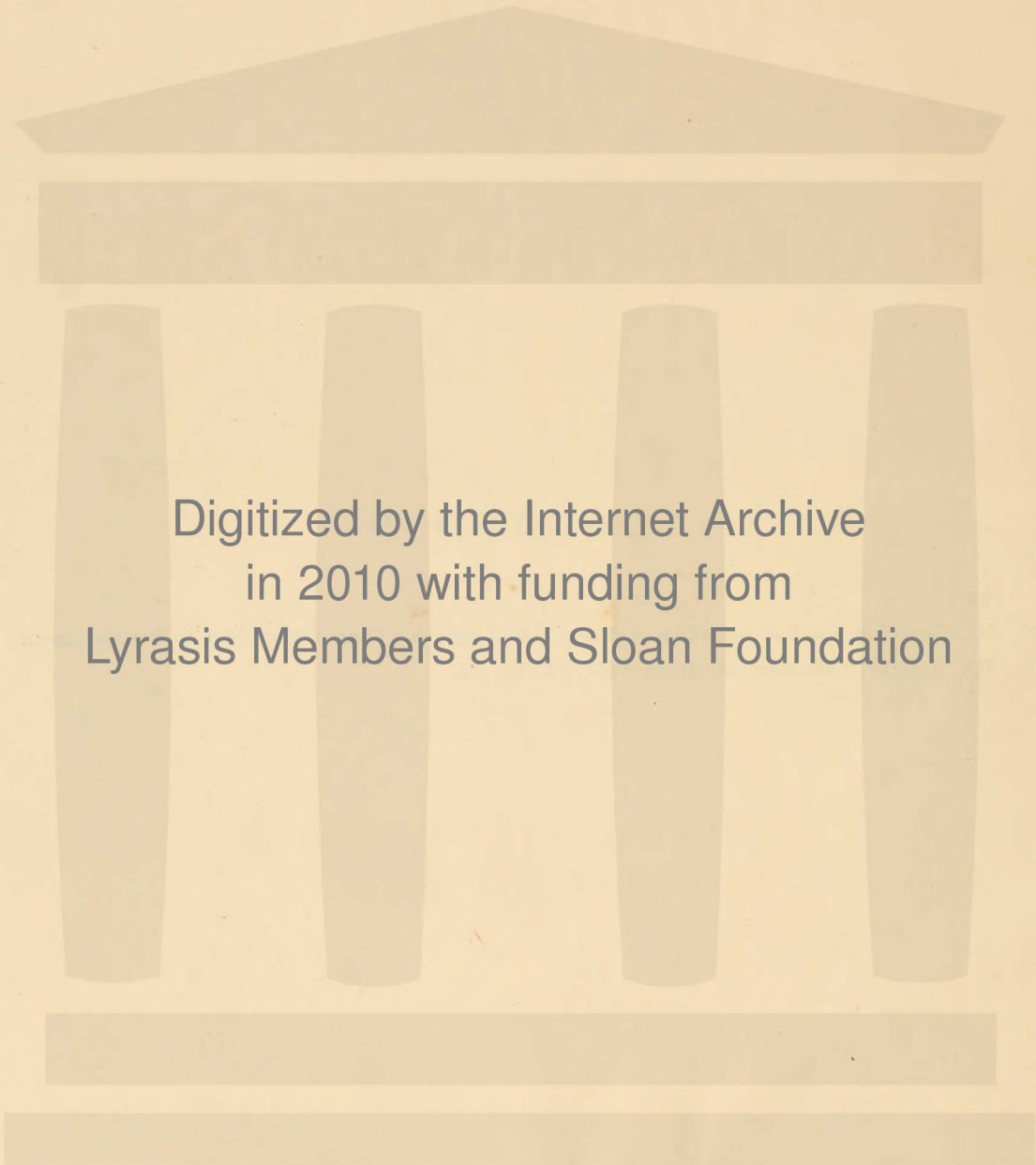
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MESSAGE

FROM THE

PRESIDENT OF THE UNITED STATES,

TRANSMITTING THE

REPORT OF THE BOARD OF CONSULTING ENGINEERS AND OF THE ISTHMIAN CANAL COMMISSION ON THE PANAMA CANAL,

TOGETHER WITH

A LETTER WRITTEN BY CHIEF ENGINEER STEVENS.

FEBRUARY 19, 1906.—Read; referred to the Committee on Interoceanic Canals and ordered to be printed.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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MESSAGE

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FEBRUARY 19, 1906.—Read; referred to the Committee on Interoceanic Canals and ordered to be printed.

To the Senate and House of Representatives:

I submit herewith the letter of the Secretary of War transmitting the report of the Board of Consulting Engineers on the Panama Canal and the report of the Isthmian Canal Commission thereon, together with a letter written to the chairman of the Isthmian Canal Commission by Chief Engineer Stevens. Both the Board of Consulting Engineers and the Canal Commission divide in their report. The majority of the Board of Consulting Engineers, eight in number, including the five foreign engineers, favor a sea-level canal, and one member of the Canal Commission, Admiral Endicott, takes the same view. Five of the eight American members of the Board of Consulting Engineers and five members of the Isthmian Canal Commission favor the lock canal, and so does Chief Engineer Stevens. The Secretary of War recommends a lock canal pursuant to the recommendation of the minority of the Board of Consulting Engineers and of the majority of the Canal Commission. After careful study of the papers submitted and full and exhaustive consideration of the whole subject I concur in this recommendation.

It will be noticed that the American engineers on the Consulting Board and on the Commission by a more than two to one majority favor the lock canal, whereas the foreign engineers are a unit against it. I think this is partly to be explained by the fact that the great traffic canal of the Old World is the Suez Canal, a sea-level canal, whereas the great traffic canal of the New World is the Sault Ste. Marie Canal, a lock canal. Although the latter, the Soo, is closed to navigation during the winter months, it carries annually three times the traffic of the Suez Canal. In my judgment the very able argument of the majority of the Board of Consulting Engineers is vitiated by their failure to pay proper heed to the lessons taught by the construction and operation of the Soo Canal. It must be borne in mind, as the Commission points out,

that there is no question of building what has been picturesquely termed "the Straits of Panama;" that is, a waterway through which the largest vessels could go with safety at uninterrupted high speed. Both the sea-level canal and the proposed lock canal would be too narrow and shallow to be called with any truthfulness a strait, or to have any of the properties of a wide, deep water strip. Both of them would be canals, pure and simple. Each type has certain disadvantages and certain advantages. But, in my judgment, the disadvantages are fewer and the advantages very much greater in the case of a lock canal substantially as proposed in the papers forwarded herewith; and I call especial attention to the fact that the chief engineer, who will be mainly responsible for the success of this mighty engineering feat, and who has therefore a peculiar personal interest in judging aright, is emphatically and earnestly in favor of the lock-canal project and against the sea-level project.

A careful study of the reports seems to establish a strong probability that the following are the facts: The sea-level canal would be slightly less exposed to damage in the event of war, the running expenses, apart from the heavy cost of interest on the amount employed to build it, would be less, and for small ships the time of transit would probably be less. On the other hand, the lock canal at a level of 80 feet or thereabouts would not cost much more than half as much to build and could be built in about half the time, while there would be very much less risk connected with building it, and for large ships the transit would be quicker; while, taking into account the interest on the amount saved in building, the actual cost of maintenance would be less. After being built it would be easier to enlarge the lock canal than the sea-level canal. Moreover, what has been actually demonstrated in making and operating the great lock canal, the Soo, a more important artery of traffic than the great sea-level canal, the Suez, goes to support the opinion of the minority of the Consulting Board of Engineers and of the majority of the Isthmian Canal Commission as to the superior safety, feasibility, and desirability of building a lock canal at Panama.

The law now on our statute books seems to contemplate a lock canal. In my judgment a lock canal, as herein recommended, is advisable. If the Congress directs that a sea-level canal be constructed its direction will, of course, be carried out. Otherwise the canal will be built on substantially the plan for a lock canal outlined in the accompanying papers, such changes being made, of course, as may be found actually necessary, including possibly the change recommended by the Secretary of War as to the site of the dam on the Pacific side.

THEODORE ROOSEVELT.

THE WHITE HOUSE, *February 19, 1906.*

WAR DEPARTMENT,
Washington, February 19, 1906.

SIR: I have the honor to forward herewith the report of the Board of Consulting Engineers for the Panama Canal, convened by your order of June 24, 1905, with the views of the Isthmian Canal Commission and of the chief engineer of the canal.

The report shows that all plans heretofore proposed for a canal, with elevations varying from zero (sea level) up to 100 feet, have received careful consideration, but the Board was unable to reach a unanimous agreement. The majority of its members are in favor of a so-called sea-level canal, and the minority recommends a lock canal with a summit level 85 feet above the sea. A choice between the two must rest upon their relative advantages and disadvantages.

Both the majority and minority contemplate "safe and commodious" harbors in Limon and Panama bays. Though differing in details, such work in no way affects the type of canal, and consideration of the terminal harbors in connection therewith is here unnecessary.

The sea-level canal proposed by the majority consists of a continuous, winding waterway extending from Limon Bay to a properly-constructed dam near Panama Bay, provided with duplicate locks near Sosa Hill to overcome the difference in tidal fluctuations that exist at the two extremities of the canal. The canal prism has a depth of 40 feet, a minimum bottom width of 150 feet in earth and 200 feet in rock, with suitable side slopes for the former and practically vertical sides for the latter. The floods of the Chagres are controlled by a dam built at Gamboa to a height of 180 feet above sea level, provided with sluice gates for regulating the discharge, which is made through the canal. Dams and levees exterior to the canal are provided for diverting five of the twenty-seven streams that cross the canal line and for preventing overflows in the vicinity of Panama.

The 85-foot level canal recommended by the minority has a dam across the valley of the Chagres River near Gatun, with a crest 135 feet above sea level and 50 feet above the normal water surface of the reservoir or inland lake that is formed. The dam is provided with sluice gates for regulating the height of water in the reservoir, thereby controlling the floods of the Chagres. From Limon Bay to this dam the channel is 500 feet wide and 41 feet deep at mean tide. The difference of level from the channel at the foot of the dam to the surface of the lake (85 feet) is overcome by duplicate flights of three locks. The total length of this waterway is 30 miles, extending from the Gatun dam to Pedro Miguel. At Pedro Miguel duplicate locks, with one lift of 30 feet under ordinary conditions, connect the summit level with another waterway whose surface at normal stage is 55 feet above mean sea level. This waterway is created by dams placed across the valley of the Rio Grande and adjacent depressions, and extends nearly 5 miles to Sosa Hill. Descent to the channel—55 feet at mean tide—in Panama Bay is effected by duplicate flights of two locks to the west of Sosa Hill.

Under the act of June 28, 1902, Congress requires that the canal across the Isthmus—

> shall be of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use, and such as may be reasonably anticipated.

This law, in effect, fixes the minimum dimensions of the locks and the width and depth of the canal prism. The high-level canal employs locks with 900 feet usable length, 95 feet width, and 40 feet depth over the miter sills, somewhat smaller than the tidal locks recommended for the sea-level type.

Two ships now building for the Cunard Line will be, when completed, the largest afloat. Each is 800 feet in length over all and 88 feet beam, with a maximum loaded draft of 38 feet. As the smaller of the proposed locks is capable of floating vessels of 25 per cent greater tonnage than the new Cunarders, it is evident that the locks fully comply with the requirements imposed by Congress.

In the high-level canal, a vessel of the dimensions noted would have, with the exception of the 4.7 miles where the width is only 200 feet, ample leeway for safe navigation and good speed, without objectionable currents and without difficulties at the points where changes in course are necessary. There would also be ample depth throughout except at the approaches. It is true that the depth in the channel below the Gatun dam is 41 feet at mean tide (tidal range 2 feet) and in the channel, below the Sosa locks, is 45 feet at mean tide (tidal range 20 feet), but additional

depths in both approaches, because of the character of the bottom, can be easily and economically secured by dredging, when demanded by the needs of commerce.

With the proposed sea-level canal conditions are different. The depth is but 2 feet greater than the draft of the ship, not sufficient to permit her to proceed under her own steam except at great risk; 21 miles of the canal is not sufficiently wide for two such ships to pass; currents caused by the regulation of the Chagres and by the flow of other streams into the canal, and its many curves, combine to increase the difficulties and dangers of navigation. In short, the sea-level canal recommended is not "of sufficient capacity and depth" to "afford convenient passage for vessels of the largest tonnage and greatest depth," and can be made so only by materially increasing the depth and width, and at a considerable increase of time and money. If the suggested width of 150 to 200 feet is the greatest width economically permissible for a sea-level canal, the cost of the enlargement required must be prohibitive.

It therefore follows that the high-level canal more fully meets the requirements of Congress.

The majority of the Board makes objection that locks are unsafe for the passage of the great seagoing vessels contemplated by the act, due to the disastrous consequences that might result if the gates are injured by vessels entering; that the lifts proposed are beyond the limit of prudent design for safe operation and administrative efficiency; that locks delay transit.

Lock navigation is not an experiment. All the locks are duplicated, thereby minimizing such dangers, and experience shows that with proper appliances and regulations the dangers are more imaginary than real. The locks proposed have lifts of about 30 feet, or less than those heretofore advocated by engineers of such high standing that the objection is believed to be not well founded. The delays due to lockages are more than offset by the greater speed at which vessels can safely navigate the lakes formed by the dams than is possible in the sea-level canal, and the arguments on this point in the minority report seem to me to be the more weighty.

The advocates of the sea-level canal express doubt as to the stability of the dams at Gatun and at La Boca, if founded on the natural soil, and advance the opinion that "no such vast and doubtful experiment should be indulged in."

It appears, however, that the dams proposed are to be founded on impervious materials, thereby conforming to the views of the majority, and are to have such ample dimensions as to insure the compression of the mud and clay rather than its displacement. Furthermore, the estimates include an allowance for additional safeguards against seepage if subsequent detailed investigations show the necessity for extra precautions. The construction of earth dams to retain water 85 feet deep is not experimental, and as the dams proposed have greater mass and stability than similarly constructed dams of greater heights, it appears that the apprehensions as to the safety of the dams are unnecessary.

In the sea level-canal there are three stretches, aggregating 21 miles, out of about 43 miles between the shores of Limon Bay and Panama Bay, in which the bottom width is 150 feet; 19 miles have a bottom width of 200 feet; 1.5 miles near Panama have a width of 300 to 350 feet; the remainder, 1.5 miles near Mindi, has a bottom width of 500 feet.

Between the Gatun dam and Sosa locks, a distance of 41 miles, the high-level canal has a minimum depth of 45 feet; for 19 miles of this distance the least bottom width is 1,000 feet; 4.7 miles have a width of 200 feet; the remaining 17.5 miles have widths varying from 300 to 800 feet.

The sea-level canal gives tortuous navigation for the greater distance through a comparatively narrow gorge in which the largest vessels can not proceed under full headway, pass without risk

or turn about. The high-level canal, for the greater distance, gives practically lake navigation in which vessels can proceed at full speed along straight courses, pass each other without delays or risks, and can turn about, if necessary.

The high-level canal has the additional advantage of "greater safety for ships and less danger of interruption to traffic, by reason of its wider, deeper, and straighter channels."

It also follows from these considerations that quicker passage with larger traffic is possible with the high-level canal.

The estimated cost is $247,021,000 for the sea-level canal, and $139,705,200 for the 85-foot-level canal, a difference of $107,000,000. The Isthmian Canal Commission and the chief engineer regard the estimate for the sea-level canal as too low by at least $25,000,000, for reasons stated in their reports.

The advantage of less cost is greatly in favor of the 85-foot-level canal.

The estimated time for completing the sea-level canal is stated by the majority of the Board as from 12 to 13 years, by the Isthmian Canal Commission and the chief engineer from 18 to 20 years. The minority report estimates the time for completing the high-level canal at eight and one-half years, and this is regarded as conservative by the other competent authorities.

The advantage in "practical speed of construction" is in favor of the high-level canal.

The cost of operation and maintenance is an important consideration, and if measured solely by annual appropriations therefor the advantage is in favor of the sea-level canal. It is believed, however, that the difference is more than offset by the interest on the additional investment in the cost of a sea-level canal.

Besides serving the needs of commerce, the canal will give the military advantage to the country of providing a route for the speedy reinforcement of the fleet on either side of the continent, and military considerations must have due weight. Either type of canal is vulnerable—the high level the more so because of the lift locks which can be easily injured. Protection must be afforded in either case. A concentration of the locks simplifies the defense, and as guards are necessary they should be of sufficient strength to reduce to a minimum the danger of injury to locks and dams.

In view of the foregoing, I recommend the adoption of the type of canal proposed by the minority of the Board of Consulting Engineers, except so far as relates to the location of the locks at Sosa Hill.

The suggestion that the lake formed near Panama will be unsanitary does not seem well founded, as I am advised by the medical authorities of this Department that unsanitary conditions with respect to the lake can be avoided by proper precautions.

The great objection to the locks at Sosa Hill is the possibility of their destruction by the fire from an enemy's ships. If, as has been suggested to me by officers of this Department entitled to speak with authority on military subjects, these locks may be located against and behind Sosa Hill in such a way as to use the hill as a protection against such fire, then economy would lead to the retention of this lake. The lake would be useful to commerce as a means for relieving any possible congestion in the canal should the traffic be very great and would give, in case of need, a place for concentrating or sheltering the fleet. If, however, Sosa Hill will not afford a site with such protection, then it seems to me wiser to place the locks at Miraflores.

When I visited the Isthmus a year and a half ago and went over the site and talked with the then chief engineer, I received a strong impression that the work of construction upon which the United States was about to enter was of such world-wide importance and so likely to continue in

active use for centuries to come, that it was wise for the Government not to be impatient of the time to be taken or of the treasure to be spent. It seemed to me that the sea-level canal was necessarily so much more certain to satisfy the demands of the world's commerce than a lock canal that both time and money might well be sacrificed to achieve the best form, and this feeling was emphasized by reading the very able report of the majority. But the report of the minority, in showing the actual result of the use of the locks in ship canals, in pointing out the dangers of so narrow and contracted a canal prism as that which the majority proposes, and in making clear the great additional cost in time and money of a seal-evel canal, has led me to a different conclusion.

We may well concede that if we could have a sea-level canal with a prism from 300 to 400 feet wide, with the curves that must now exist reduced, it would be preferable to the plan of the minority, but the time and the cost of constructing such a canal are in effect prohibitory.

I ought not to close without inviting attention to the satisfactory character of the discussion of the two types of canal by the greatest canal engineers of the world, which insures to you and to the Congress an opportunity to consider all the arguments, pro and con, in reaching a proper conclusion.

Very respectfully,

WM. H. TAFT,
Secretary of War.

The PRESIDENT.

ISTHMIAN CANAL COMMISSION,
Washington, D. C., February 6, 1906.

SIR: I have the honor to transmit herewith the conclusions and recommendations of the Isthmian Canal Commission and the dissenting views of Admiral Endicott upon the majority and minority reports of the Board of Consulting Engineers, advance copies of which, together with the proceedings of the Board, were furnished to the Commission in December last. Appended to the findings of the Commission is a letter to the Commission from the chief engineer, Mr. John F. Stevens, giving his views on the relative merits of a sea-level and a high-level canal.

Very respectfully,

T. P. SHONTS, *Chairman.*

To the honorable the SECRETARY OF WAR.

ISTHMIAN CANAL COMMISSION,
Washington, D. C., February 5, 1906.

MR. SECRETARY: The Isthmian Canal Commission has the honor to transmit herewith two reports which it has received from the Board of Consulting Engineers appointed by the President June 24, 1905, to consider plans for the construction of a canal across the Isthmus of Panama. The board was unable to reach a unanimous agreement. One of the reports is signed by eight members, and recommends a canal at sea level. The other is signed by the remaining five members, and recommends a canal with a summit level 85 feet above the sea, to be reached by locks.

Before proceeding to a review of these two reports it is desirable to remove certain misapprehensions as to the meaning of the terms "canal at sea level" and "canal with locks" as defining the character of the completed waterway. In the popular mind the one means a waterway affording navigation without restriction, while the other means a waterway in which navigation is delayed and hampered by mechanical appliances, and decidedly inferior to the former. These conceptions are quite inaccurate.

The ideal waterway through the Isthmus would be a channel at the sea level, of which the width would be greater than the length of the vessels using it. With any less width it is liable to the accident of being completely blocked by the sinking of a vessel transverse to its axis. If vessels 900 feet long are to be accommodated, the width should be considerably greater than 900 feet. A channel of this size can not be considered and has never been proposed. The enormous cost of the excavation has compelled all engineers who have considered the question to reduce the width to that strictly necessary to pass the largest vessels at greatly reduced speed. A width of 150 to 200 feet is now proposed, and is believed to be the greatest width economically permissible for the sea-level canal. It is very far, however, from furnishing unrestricted navigation. The speed of very large vessels, like the new Cunarders, must be reduced to 4 miles per hour or less, while two such vessels could not pass each other in the canal. Between this and the ideal canal are many degrees of size and convenience.

In a canal with locks, artificial lakes are created in which for considerable distances the navigation is entirely unrestricted. The advantages thus gained may more than counterbalance the delay and risk in the use of locks, and it is quite conceivable that a canal with locks may be a better canal—that is, can be navigated in less time and with less risk than a canal at sea level.

A discussion of the relative advantages and disadvantages of the canal at sea level and the canal with locks is to be approached then without prejudice in favor of either as a means of transit.

SEA-LEVEL PLAN.

The plan recommended by the majority of the board is a canal at the sea level, following essentially the line heretofore adopted by Congress, except near the terminals, the depth to be 40 feet, and the width at bottom to be 150 feet where the side slopes are gentle, and 200 feet where the side slopes are nearly vertical, as in rock. The least area of cross section is 8,276 square feet. At the Panama end is a tide lock, having a usable length 1,000 feet, width 100 feet, and depth over the miter sills 40 feet. In Panama Bay the channel is to be 35 feet deep at extreme low water of spring tides, which will give the full 40 feet provided elsewhere in the canal, except upon rare occasions.

To control the Chagres River, a dam of masonry, or of earth and masonry, is proposed at Gamboa, just off the line of the canal, built to a height 180 feet above the sea, forming a reservoir called Gamboa Lake, of which the maximum flow line is to be at elevation 170, into which the flood waters are to be received, but no design therefor is submitted.

This dam is to be fitted with controlling sluices by which a maximum discharge of 15,000 cubic feet per second is to be admitted to the canal prism, all in excess of that amount being temporarily stored until the subsidence of the flood. Of the tributaries entering the Chagres below Gamboa, the most important are diverted entirely from the canal and conducted by separate channels to the sea. There will still remain a number of tributaries and other streams to be taken into the canal. Their volume is assumed by the Board to be such that, added to the 15,000 cubic feet to be admitted through the sluices, they will create currents of which the highest mean velocity is computed by the majority to be 2.6 miles per hour. Ordinarily the velocity will not exceed 1 mile per hour.

Extensive harbor improvements are proposed at Colon.

The cost of the canal under this plan is estimated by the majority at $247,000,000. From the nature of the case this estimate can not be made with great precision. The quantity of each class of work to be done can, as a rule, be accurately measured, but the unit price for each class must be largely a matter of judgment. It is the opinion of this Commission that the unit prices adopted by the Board are, upon the whole, judicious, except in the case of rock excavation under water, which seems to us low, but is accepted here for purposes of comparison; and that otherwise the estimates are as near an approximation to the truth as can now be reached, in all except two items. These items are the excavation in Culebra Cut below elevation +10, given on page 51 as $20,242,877.50; and the completion of river diversions, regulation of rivers flowing into the canal, etc., given on page 58 as $3,500,000.

The first item covers 16,194,302 cubic yards of excavation, of which 11,439,612 cubic yards is below and the remainder above the level of the sea. The majority of the Board has adopted a uniform unit price of $1.25 per cubic yard for the whole. This price seems fair for the portion above the level of the sea. For the portion below, it seems to the Commission that the price of rock excavation under water, $2.50 per cubic yard, should be applied here as it is in the adjacent sections of the canal by the Board. If that be done, the cost of this item will be increased $14,299,515, and adding the usual 20 per cent for contingencies, the estimate will be increased $17,159,418.

The estimate, $3,500,000, of the cost of completing the river diversions, formation of dams across tributary streams, regulation of rivers which flow into the canal, etc., is believed to be too low. To show the magnitude of this feature of a sea-level canal, a table is presented giving the names of the more important streams which enter the site of the canal, the distance of the point of junction from the Caribbean end of the canal, the height above sea level of their junction with the Chagres, Obispo, or Rio Grande rivers, and the volume of discharge at high stage as far as observed or estimated. It must be remembered that while gaugings of the Chagres at several points have been systematically carried through the river year covering both low waters and floods, nothing of this sort has been done on the other streams, where gaugings have only been made desultorily, at such times and for such periods as were convenient. The discharges given in the table are in many instances obtained by distributing

the total discharge of a considerable number of tributaries of the Chagres among the individual tributaries, according to the areas of their drainage basins. There is no certainty that this gives the maximum discharge for any one tributary, but the probability is that it does not.

Name.	Distance.	Greatest observed discharge.	Elevation at mouth above sea level.
Streams diverted:	*Miles.*	*Sec. feet.*	*Feet.*
Mindi	5	.....	.....
Gatun	6.2	16,100	.....
Trinidad	9.6	18,500	.....
Gigante, left bank	18.91	2,158	30
Cano, left bank	19.84	9,006	33
Streams not diverted:			
Aojeta	15.25	1,000	15
Agua Salude, right bank	16.30	2,306	25
Frijolito, right ba	17.36	1,000	20
Frijoles Grande, right bank	17.98	3,740	26
Agua Bendita, left bank	21.26	300	35
Caimito Mulato, left bank	22.32	300	35
Baila Monos, left bank	22.81	1,775	45
Culo Seco, left bank	23.87	300	40
Pisco, right bank	24.18	1,200	34
Juan Grande, right bank	25.11	1,200	38
Carabali, left bank	25.42	760	40
Quatre Calles, right bank	26.66	500	45
Obispo	27.90	3,700	160
Mandingo, left bank	28.80	1,500	45
Camacho, left bank	29.10	1,349	165
Sardinilla	30.30	800	165
Rio Grande, right bank	34.72	660	130
Mallejon, right bank	36.89	.....	33
Pedro Miguel, left bank	37.07	.....	15
Caimitillo, left bank	37.82	.....	13
Rio Cocoli	38.90	.....	.....
Rio Cardenas	39.40	.....	.....

The Cano and the Gigante, the latter including its principal tributary, the Gigantito, are to be cut off by dams. The Trinidad will occupy the old channel of the Chagres River and the Chagres diversion. The Gatun will be cut off from the canal by the partly finished Gatun diversion, into which also will be conducted the Mindi River, which has not been gauged, but which is a stream of considerable importance. The others are to be taken into the canal. They must, however, be temporarily diverted during the excavation of the canal; and in the case of the Rio Grande this involves a tunnel seven-eighths of a mile long. In all the diversion channels together, the amount of excavation and levee building, with the necessary muck ditches and riprap levee and bank revetments, tunnels, etc., can not be less than 10,000,000 cubic yards. In view of the facts that in many cases the work is isolated and the field of operations narrow and contracted, that much special work, such as revetment, is required, and that the operations of excavation for channels and embankments for levees are separate and distinct, and that the material is not uniform, involving both earth and rock, the unit prices will be high.

The Cano and the Gigante are to be cut off by dams, lakes being thus created which will overflow through spillways provided in the divide near the heads of those streams. In this scheme four dams and three spillways are projected. The dam to close the Gigante will be about 2,800 feet long, that to close its main tributary, the Gigantito, will be about 490 feet long, and that to close the Cano about 820 feet long, the height in each case being about 75 feet above the ground, the depth to which the foundations must be sunk being unknown. A dam about 535 feet long and 25 feet high will be required to close a depression in the rim of one of the lakes. These and the spillways are expensive works. Their locations have never been examined by

borings or exact topography, with the exception of the Gigante spillway. Their cost can not be accurately estimated without further examinations, but under favorable circumstances can hardly be less than $1,000,000.

The streams taken into the canal, whose beds at point of junction with the canal are considerably above the canal prism, are to "be discharged over masonry stepped aprons or through metallic discharge pipes, or these beds will be sloped and lowered so as to prevent objectionable currents at junction points." The elevation above sea level at which these streams reach the canal is given in the foregoing table, and varies from 13 to 165 feet. A provisional treatment of such important features of a sea level-canal should not be considered. From the point of view of thoroughness and permanency, the sloping and lowering of the beds so as to prevent objectionable currents at junction points would not be good practice. It may be surely anticipated that the accelerated velocity down the increased slope, unless its bottom and sides are lined with masonry, will operate with destructive effect both on the lowered channel and the bed and banks of the canal. Metallic discharge pipes are not adapted to this purpose on streams which are torrential in character and may bring with their flood drift trash and bowlders. The use of masonry-stepped aprons must therefore be considered, under the conditions presented by most of these streams, as the only advisable way of bringing them from a high to a low level. The construction of these would necessarily be very heavy and therefore very expensive. As in the case of the dams, the sites of these aprons have not been carefully examined, and the estimate of cost can only be a rough approximation. It is the opinion of the Commission that the sum of $3,500,000, assigned by the majority of the Board to the completion of the diversion channels, the construction of the dams and spillways, and the construction of these aprons, is inadequate, and should be increased by at least $6,500,000, which, with the usual 20 per cent added for contingencies, makes an increase of $7,800,000 to this item of the estimate.

If the foregoing increases be added to the $247,000,000 estimated by the majority of the Board, the cost of the sea-level canal will be found to be $272,000,000.

The time required to build the canal is estimated at twelve to thirteen years. The number of unknown factors which enter into this estimate is still greater than in the case of estimates of cost. There are two methods available for reaching a conclusion upon the subject. One is that followed by the Board, viz, to assume that the largest single piece of work—the Culebra Cut—will fix the time required, and that all other work can be completed while that is being executed, then to ascertain how many excavating machines can be employed at one time in the Culebra cut, and then assign to each machine its daily or annual working capacity, under the conditions which prevail there. There is great uncertainty about all of these elements. The number of steam shovels which can work to advantage in Culebra cut is not known, but is probably much less than the number mentioned in the report, 100; and there is no experience to show what the output of a steam shovel will be under all the extremely varying conditions which obtain there. The other method is to examine the results obtained in the great operations of the old French company in this same work. It is not unusual to hear that company spoken of lightly, but it is to be remembered that it had at its head men who had recently built the Suez Canal, that it had the advice of the best engineering talent in Europe, and that its pecuniary resources for some years were practically unlimited. After devoting the years 1881 and 1882 to preliminary work, it began operations on a large scale in the early part of 1883, and continued them until the latter part of 1888, about six years or seventy-two months. It excavated altogether about 72,000,000 cubic yards of material, or about 1,000,000 per month if we attribute the work of 1881 and 1882 to the later period, of which about one-third was the easy excavation with dredges in the coastal plains. In doing this it had every inducement that men could have to make haste. Its concession from Colombia for a limited period, its enormous interest charges, and the sanguine assurances of its promoters and managers, all urged the greatest possible speed. The wreckage along the line of the canal to-day is a demonstration of the feverish energy with which every species of machinery was lavished upon the work. To get the work done was the primary consideration, its cost secondary. The circumstances are now different in several important respects. There have been great improvements in excavating machinery, and means have been found to

remove the terror of yellow fever, both of which conditions favor an increase of output. On the other hand, there must be a much more careful adjustment of the means to the end. Extravagant duplication of machinery, or other reckless expenditure, can not be tolerated. It is hoped and believed that a considerable increase over the French rate of progress can be attained. What the percentage will be is a matter of judgment, and is not capable of exact computation, but it would seem that the chances of error here are less than where all of the factors are unknown. Here at least the difference between spasmodic and long-continued effort, and the reduction of efficiency due to climate and distance from supplies are eliminated. In the opinion of the Commission it would not be unreasonable to hope for an increase of 25 per cent, which would give an average output of 1,250,000 cubic yards per month. To excavate the 231,000,000 cubic yards of the sea-level canal at this rate would require one hundred and eighty-five months or fifteen and one-half years. There would be at least two and one-half years at the beginning before this rate could be reached, and at least an equal amount of time at the end, during which the contracted space at the bottom of the cut would compel a reduction of force. It is to be feared that the time required to construct a sea-level canal would be eighteen or twenty years, rather than the twelve or thirteen years estimated by the majority, even supposing that the total amount of excavation will not exceed the 231,000,000 cubic yards estimated. To reach that amount the majority of the Board has adopted steeper slopes in the Culebra cut than any previous board or commission has adjudged applicable. It may well happen that these slopes must be reduced, and the amount of excavation thus increased. The majority of the Board has made no provision for the necessary turning-out places and widening at curves. It is not safe to estimate the time required for the construction of a sea-level canal at less than twenty years.

PLAN WITH LOCKS.

The plan recommended by the minority of the Board is a canal with locks, following in general the same location as the other, but with slight variations therefrom in Limon and Panama bays. Its controlling feature is a dam to close the valley of the Chagres at Gatun, thus creating an artificial lake of which the surface is to be 85 feet above the sea and which is to constitute the summit level. The length of this dam will be 7,700 feet, and the height of its crest 135 feet, or 50 feet above the water surface. It will contain about 21,200,000 cubic yards of material, principally the spoil from the excavation of the canal prism. It is provided with ample spillways and regulating works. A channel 500 feet wide at sea level leads from Limon Bay to the Gatun dam, where is placed a double flight of three locks by means of which vessels are lifted into the artificial lake. The lake provides unrestricted navigation for a large part of its length, but becomes more contracted as the Continental Divide is approached until in the Culebra Cut the width at bottom is reduced to 200 feet. It finally terminates at Pedro Miguel, where the first lock on the Pacific side is placed, having a lift of 30 feet. By means of this lock vessels are lowered into another artificial lake created by a dam closing the valley of the Rio Grande, and by two other dams closing other depressions, the level of the lake being 55 feet above the sea. The crests of these dams are 80 feet above the sea. Communication between the lake and Panama Bay is effected by a double flight of two locks placed near the shore on the high ground called Sosa Hill. All locks are in duplicate and have a usable length 900 feet, width 95 feet, and depth over the miter sills 40 feet. The depth of the channel is everywhere at least 45 feet except in the locks and in Limon Bay, where it is 40 feet, the depth in Panama Bay, however, being measured from mean tide and not from dead low water. In the lakes the depth is often very much greater, being 75 feet near the Gatun dam, and nearly as much for many miles. The width is nowhere less than 200 feet at bottom, and at most places is very much more. The length of the canal from deep water in Limon Bay to deep water in Panama Bay is 49.72 miles. Of this 19½ miles is over 1,000 feet wide, 23 miles is over 800 feet wide, 35 miles is over 500 feet wide, and 42½ miles is over 300 feet wide. That is, for about half the distance navigation is entirely unrestricted, while for more than two-thirds the distance the channels are 500 feet or more wide, and for only one-seventh the distance, including the locks, are they less than 300 feet wide.

The cost of the canal under this plan is estimated by the minority of the Board at $139,705,200, and the time required to build it at nine years. We consider both of these estimates reasonable, subject to the remarks already made concerning unit prices.

The plan recommended by the minority of the board is of the same type as that recommended by the Commission of 1899–1901 and adopted by Congress, at least by inference, in the act approved June 28, 1902. It provides wider and deeper channels and larger locks than that plan and a different arrangement of dams, as well as a change in the Atlantic entrance, but the height of the summit level is the same, and the estimates of cost and of the time required for construction are very nearly the same. Some of the changes have been made necessary by new requirements for navigation, and others have been the result of further study by fresh minds. They are improvements, such as Congress could not possibly have intended to prohibit when it adopted the old plan. They are of importance, but they do not seem to us to be changes of such radical character as would require further action by Congress, as in the case of a canal at sea level.

The only features of this plan which do not fall within the limits of every-day practice are the height and size of the dams and the size of the locks. No question has been raised as to the stability of the Gatun dam, and, indeed, none can be raised while there are in successful operation in this country earth dams of less cross section retaining a greater head of water. The great quantity of material available has made it possible to give this dam dimensions which are much greater than are strictly necessary. The majority of the board, however, do question the effectiveness of that dam in retaining water, expressing the fear that the subfoundation may be found so porous that seepage will be excessive. The minority point out that the material under the dam is exceptionably favorable, that for a depth of 200 feet it is practically impervious, and that the more porous material which is found for a short distance below that depth is covered with this impervious blanket 200 feet thick for a long distance upstream. They express the opinion, in which we concur, that there would be no appreciable seepage under the dam. In the case of the Rio Grande dam, the majority goes further and states that the earth dam proposed for that locality is in " danger of being pushed bodily out of place by the pressure due to the head of water in the reservoir," unless it be made very massive. In the opinion of the minority, in which we concur, the dam, as designed, is so massive that this is impossible. In this case, the greatest depth to rock is 64 feet, and all seepage can be cut off by sheet piling, if necessary; but the borings thus far indicate impervious material under the dam, and it is not expected that that device will be required.

The locks are larger than any which have heretofore been built, and the majority of the Board express the opinion that they are beyond the limit of prudent design. As a matter of fact, larger locks have been designed with the greatest prudence and with mathematical certainty. It can no more be said of lock building that it has reached the limit of judicious construction than of ship or bridge building or any other branch of engineering construction. A modern bridge of long span is a safer structure than the short span bridge of former days, because of better knowledge of the materials and improved methods of uniting them. So the proposed locks can be made safer than the Poe lock at the Sault, because they are designed after nine years of practical experience with that lock, an experience which shows it to be a safe place for a vessel.

It is our opinion that the entire feasibility of constructing the canal under the plan proposed by the minority of the Board can not be successfully questioned.

RELATIVE EFFICIENCY OF COMPLETED CANALS.

The majority of the Board express the opinion that the canal at sea level is the only one giving reasonable assurance of safe and uninterrupted navigation, and question the safety of large vessels in passing locks.

The most important ship canal in the world is that at the Sault Ste. Marie, at the outlet of Lake Superior. The tonnage which it carries per annum is about three times that carried by the Suez Canal, and is greater than the aggregate tonnage of the Suez, Manchester, Kiel, and

Amsterdam canals combined, although navigation is suspended several months each year by ice. One of its locks is the largest in existence, and during the season of navigation this lock alone carries three times the tonnage per month that the Suez Canal carries. It has been in successful operation since 1896, and has carried with ease and safety the largest vessels on the Great Lakes, some of them measuring 569 feet in length with 56 feet beam. The navigation interest has no fear of this lock. That interest is growing with marvelous rapidity, and is clamoring for deeper channels between the lakes, so that larger vessels may be used and larger locks built. No engineer who is familiar with this lock has any misgiving about its safety, or about the entire feasibility of building larger locks which shall be equally safe.

The majority of the Board have attempted to belittle this experience. They say it is not a "maritime canal." They explain that masters of vessels passing to and fro every few weeks acquire familiarity with the canal and locks, which leads to a degree of skill and safety which could never be attained in the Panama Canal, which would be visited only at rare intervals, forgetting that this acquired skill simply makes unnecessary the services of a pilot, and can never be equal to the skill of the special pilots who would be employed at Panama. They attach importance to the fact that navigation at the Sault is closed by ice for several months each year, at which time the locks can be pumped out and repaired, not stopping to consider that at Panama there are two sets of locks, one of which can be pumped out and repaired at any part of the year. They point to the three accidents which have occurred to the locks within the last nine years, and make certain speculations as to how near these were to being serious and what would have happened if the lift had been as great as that proposed for Panama, omitting to note that during the same period the open channels below were completely blocked three times, besides being partially blocked at other times, by the sinking of vessels. During each of the complete blockades in the open channel navigation was entirely suspended from two and a half to five days, and during the partial blockades all vessels were delayed from five to twenty-four hours, this state of affairs lasting in one case ten days. It is true that locks are subject to accident, but so are narrow channels without locks. In addition to the evidence just given, mention may be made of the steamer *Chatham*, by which the Suez Canal was wholly blockaded for nine days, and partially blockaded for about a month in September and October, 1905. We can not concur in the opinion that a canal at sea level 150 feet wide gives "safe and uninterrupted navigation," least of all if, as in this case, that canal is liable to currents of 2.6 miles per hour. Moving in the same direction with such a current, it is doubtful whether one of the largest vessels now in use could navigate the canal at all with her own power. Nor can we concur in the opinion that a lock properly constructed and managed is in any sense a menace to the safety of vessels. Practical experience has demonstrated the contrary beyond dispute.

The volume of water contained in the proposed sea-level canal is about 100,664,000 cubic yards; that contained in the proposed canal with locks, omitting all below 45 feet depth and all beyond 1,000 feet width, is about 303,614,000 cubic yards. It is a fair statement that one waterway is three times the size of the other, and that but for the locks it affords three times the facilities for navigation.

In the canal at sea level there are many curves; in that with locks all the courses are straight, changes of direction being made at the intersection of tangents, where additional width is given. These straight courses can be marked with ranges, which greatly facilitate navigation, particularly at night.

In the canal at sea level there is often a considerable current, which at times becomes obstructive. In the canal with locks there is no such obstruction.

The time required to pass through a canal of either type differs with the size of the vessels and the number of vessels. Following the method described in the report of the Isthmian Canal Commission of 1901, the minority of the Board find that for a small ship the canal at sea level has the advantage by about thirty-six minutes, provided the number of ships does not exceed 10 per day. If the number of ships exceed 30 per day, the canal with locks has the advantage by about three hours. For large ships the canal with locks has the advantage whatever be

the number per day. If the number be 10, the advantage is about thirty-six minutes; if it be 30, the advantage is over three and one-half hours. We believe these results to be approximately correct, assuming that there is no current in the canal. Should there be a current of 2.6 miles per hour, such as the sea-level canal is subject to, the time of passage through that canal might be greatly increased. It is assumed also that numerous turning-out places are provided in the sea-level canal, although for these no provision is made in the plan or the estimate.

The majority of the Board claim that locks limit the traffic capacity of the canal, that lockages perhaps can not exceed 10 per day for each lock, or 20 per day for the pair. The minority point to the experience at the Sault, which shows that this estimate is not in accord with American practice, and they show that with the double flight of locks proposed, a traffic of at least 80,000,000 tons per annum can be accommodated. Additional locks may be built hereafter if needed.

The majority in one place express the opinion that the canal at sea level "will endure for all time," page 64, and in another give weight to "the comparative ease and economy of enlarging the prism of the sea-level canal to accommodate any additional demands of the future," page 64. We estimate that to widen the sea-level canal 100 feet without deepening it will cost at least $87,000,000. To deepen it involves excavation under water throughout its length. The canal with locks may be deepened easily and cheaply by simply raising the crests of the spillways and the height of the locks.

The majority express the opinion that the cost of operating and maintaining a sea-level canal will be very much less than that for a canal with locks; and using the figures of the Commission of 1899–1901, they give the cost of operating and maintaining the locks at about $525,000 per annum. That estimate is probably as near an approximation to the truth as can now be given. The canal at sea level will require more dredging than the other, and it has one lock to be maintained. It must also be furnished with turn-out places and attendance there. A reasonable allowance for these expenses is $225,000, leaving $300,000 per annum as the apparent advantage in operating expenses of the sea-level canal. Against this is to be placed the interest on the additional investment. If the canal at sea level will cost $132,000,000 more than the canal with locks, as we believe it will, the interest on that sum is an additional fixed charge, and at 2 per cent amounts to $2,640,000 per annum; that is, the annual fixed charges of the canal at sea level will be $2,340,000 more than those of a canal with locks.

The majority of the Board point to the ease with which an enemy might in time of war disable the locks with a few sticks of dynamite and lay much stress upon the disastrous results which would ensue to the United States should the passage be interrupted. The difficulty of defending the canal was clearly pointed out by the Commission of 1899–1901, who closed their discussion as follows, viz: "It is the opinion of the Commission that a neutral canal, operated and controlled by American citizens, would materially add to the military strength of the United States; that a canal, whether neutral or not, controlled by foreigners, would be a source of weakness to the United States, rather than of strength; and that a canal not neutral, to be defended by the United States, whether by fortifications on land or by the Navy at sea, would be a source of weakness." In that opinion we concur. It applies equally to a canal at sea level and to a canal with locks. In the former, the great dam at Gamboa and the other great dams, the steep slopes at Culebra, and the tide lock at Sosa all present points of attack, less favorable, no doubt, than the locks, but sufficiently so to make the canal entirely vulnerable. The canal at sea level can be blocked by sinking a vessel at any part of its length, while the canal with locks, for a large part of its length, can not be blocked in that manner at all. Should the United States depart from its true policy of making the canal neutral, it will not gain anything in a military point of view by adopting the canal at sea level in preference to the one with locks.

There is one valid argument, and one only, which can be brought against the canal with locks, and that is the difficulty of fixing the dimensions of the lock chambers to provide for the possible enlarged vessels of the future. The majority of the board propose a length of 1,000 feet, a width of 100 feet, and depth over the miter sills of 40 feet; while the minority propose a

length of 900 feet, a width of 95 feet, and 40 feet over the miter sills. In the following table is a list giving the dimensions of 12 of the largest ships in the world and the ratio of their length and beam to their draft:

Name of steamer.	Steamship line.	When built.	Length over all.	Beam.	Maximum loaded draft.	Ratio of draft to beam and length.
			Feet.	*Feet.*	*Feet.*	
Kaiser Wilhelm der Grosse	North German Lloyd	1897	648.4	66.0	28.5	1:2.31:22.75
Kaiser Wilhelm II	do	1902	706.5	72.0	30.5	1:2.36:23.16
Kronprinz Wilhelm	do	1901	663.3	66.0	30.0	1:2.20:22.11
Oceanic	White Star	1899	705.6	68.4	35.7	1:1.91:19.76
Celtic	do	1901	697.5	75.4	36.8	1:2.04:18.95
Cedric	do	1903	697.5	75.4	36.9	1:2.04:18.90
Baltic	do	1903	725.9	75.4	37.3	1:2.02:19.46
Deutschland	Hamburg-American	1900	687.5	67.3	31.0	1:2.17:22.17
Caronia	Cunard	1904	680.0	72.6	35.0	1:2.07:19.42
Carmania	do	1904	680.0	72.6	35.0	1:2.07:19.42
Two new ships, unnamed	do	1905–6	800.0	88.0	38.0	1:2.31:21.05
Average ratio						1:2.14:20.65

From this table it appears that the proportions suggested by the minority are more in accord with late practice than those suggested by the majority. If the locks are to be 1,000 feet long and 100 feet wide, apparently there should be greater depth over the miter sills. The minority point out that the dimensions proposed by them will provide for ships having 25 per cent more tonnage than the new Cunarders, and will permit the passage of battle ships having 13 feet greater beam than any ship now in the United States Navy. Inasmuch as the new Cunarders are not yet completed, are very much larger than any other vessels in existence, and must still be regarded as experimental, it seems to us that this is looking as far into the future as is expedient. If ships too large for these locks should hereafter be developed, it will be possible to add new and larger locks to accommodate them. The total estimated cost of all the locks and approach walls in the present project, including the contingency item of 20 per cent, is $44,425,000. They can therefore be entirely renewed for about half what it would cost to widen the sea-level canal 100 feet.

The water supply for the canal with locks as projected is sufficient to accommodate a traffic of about 50,000,000 tons annually. Should that traffic be exceeded in the future, the addition of a dam at Alhajuela will provide a supply sufficient for 100,000,000 tons. Should it be found necessary in the future to provide for the passage of a still larger tonnage, the Chagres River and its tributaries will furnish additional water.

The Board of Consulting Engineers is unanimous in the opinion, in which we concur, that if a sea-level canal is ever to be constructed it should be constructed as such from the first.

A report from the chief engineer, Mr. John F. Stevens, giving his views upon the subject under consideration, is hereto appended.

CONCLUSIONS AND RECOMMENDATIONS.

From the foregoing it appears that the canal proposed by the minority of the Board of Consulting Engineers can be built in half the time and a little more than half the cost of the canal proposed by the majority of the board, and that when completed it will be a better canal for the following reasons:

(1) It provides greater safety for ships and less danger of interruption to traffic by reason of its wider and deeper channels.

(2) It provides quicker passage across the Isthmus for large ships or a large traffic.

(3) It is in much less danger of damage to itself or of delays to ships from the flood waters of the Chagres and other streams.

(4) Its cost of operation and maintenance, including fixed charges, will be less by some $2,000,000 or more per annum.

(5) It can be enlarged hereafter much more easily and cheaply than can a sea-level canal.

(6) Its military defense can be effected with as little or, perhaps, less difficulty than the sea-level canal.

It is our opinion that the plan proposed by the minority of the Board of Consulting Engineers is a most satisfactory solution of the problem of an isthmian canal, and, therefore, we recommend that the plan of the minority be adopted, subject, of course, to such changes as may be found desirable during construction and with the understanding that the works in Limon Bay are to be deferred for the present. The entrance now in use at that place must, for the present, be used in any event, in order to secure harbor room for the landing of supplies immediately needed. The question whether or not it should be changed and what changes should be made can better be determined hereafter.

Respectfully submitted.

T. P. Shonts, *Chairman.*
Charles E. Magoon.
Peter C. Hains,
Brigadier-General, U. S. Army, Retired.
O. H. Ernst,
Colonel of Engineers.
B. M. Harrod.

Hon. Wm. H. Taft,
Secretary of War, Washington, D. C.

MINORITY REPORT.

The undersigned does not concur in the preference for a lock canal, expressed by the Commission, but regards a sea-level canal, as proposed by the majority of the Board of Consulting Engineers, a better canal for commercial and military purposes.

First. Because, whilst for exceptionally large vessels, such as built for Atlantic liners, the time of transit might be as long as or longer than in the lock canal, the average time of transit of the class of vessels which will use the canal for a long term of years will be less than in the lock canal.

Second. Because the risks of interruption to traffic from accident are deemed greater in a high-level canal with six locks than in a sea-level canal with a tidal lock, notwithstanding the greater distance in the latter canal, which might be obstructed by a sunken vessel.

Third. Because the cost of maintenance and operation of the sea-level canal will be less.

Fourth. Because in the enlargements to accommodate increase in traffic the relative advantages of the sea-level canal will increase

It is the history of important canals that very soon after completion, when traffic becomes established, the increasing demands of commerce call for enlarged provisions, and when the location is upon established lines of trade or where commerce finds a more direct route than those previously obtaining, such increase makes rapid strides. It seems quite certain that such will be the history of the canal across the Isthmus of Panama. Either of the projects under consideration will admit of enlargement, but in that for a sea-level canal, which will consist of enlargement of its cross section and the addition of tidal locks, its progressive improvement will be in the direction of greater and greater freedom of transit, a lessening of such risks as may be inherent in a canal of its type, and an approach to what must be admitted as an ideal canal; whilst the enlargement of the high lock level canal, although decreasing the restrictions in its narrower portions, will multiply and perpetuate the locks and leave in existence all the obstructions, delays, and risks attending their use.

Fifth. Because it is a better, safer, and more capacious canal from a military standpoint.

I regard the sea-level canal, according to the project of the majority of the consulting board, as affording greater immunity from hostile injury in time of war than a canal of high level with several locks.

The danger of a vessel being sunk in the canal is inherent in both; in a less degree in the lock canal because of a portion of its length being lake navigation, but a derangement of the operating mechanism of the locks or the direct crippling of a few of the gates is much more easily accomplished, and would ordinarily prove a far greater calamity and one far less quickly and easily remedied.

In both projects locks occur at the side of Sosa Hill, near the shores of Panama Bay, a flight of two locks in the high-level plans and one tidal lock in the sea-level plans. Both are equally subject to destruction by a hostile fleet, but such destruction, in the case of the high-level canal, would be extremely disastrous, in that it would ruin the canal for military or commercial purposes for several years; whilst in the case of the sea-level canal the débris could be dynamited and removed in a few days and the canal remain navigable, since for at least one-half of each twenty-four hours the tidal lock always stands open for the passage of vessels without locking, and during neap tides, which extend over one-half of the month, when the rise and fall are least, it would allow of the continous transit of vessels in an emergency without the offices of a lock.

Again, the transit of a fleet of naval vessels, or an expeditionary force of army transports under convoy of a fleet, would be able to move with much more expedition than if compelled to pass through a lock canal. A war vessel acting singly could pass through the canal and proceed at once upon its way, but the movements of a fleet would probably be in unison, and in the case of a fleet of transports under convoy such would almost inevitably be the case, and the departure of the whole force would be delayed until the last vessel had made its exit from the canal. In the case of the lock canal this would cover a delay extending from the time the first vessel passed the last lock until the fiftieth, or some other last vessel corresponding to the numerical size of the fleet; whilst in the case of a sea-level canal for one half the hours of the twenty-four during one-half of the month, and for all the hours of the twenty-four during the other half the vessels would file through in rapid succession without locking. A transit which in the lock canal would take several days might, in the sea-level canal, be a matter of hours and less than a single day.

In military affairs tremendous consequences often hang about the question of time; and when to the inevitable delays to a fleet passing through a lock canal is added the danger of the latter being entirely disabled for a long period, the great advantage of a sea-level canal over a lock canal from a military view is strongly emphasized.

There is no question that a sea-level canal is per se far superior in all respects to a lock canal, and where feasible and the cost not prohibitive it should be constructed. One is entirely feasible at the Isthmus of Panama and the cost estimated by the board of consulting engineers or by the Commission is not prohibitive.

The time necessary for the construction of a sea-level canal is estimated at twelve to thirteen years by the majority of the Consulting Board and not less than fifteen by the minority, in which latter estimate I concur, and which I do not regard as militating against the advisability of adopting such type.

The great cost to transform a high-level lock canal into a sea-level canal as estimated by the Consulting Board—about $209,000,000—and the difficulties of the same render it impracticable. A sea-level canal reached by this method would cost at least $340,000,000.

An 85-foot summit lock canal once constructed means a lock canal always. If a sea-level canal is desired, it must be built directly without first building a lock canal.

Believing that a sea-level canal substantially according to the project of the Consulting Board would best serve the present and future commerce of the world and the military necessities of this nation, I have the honor to recommend its adoption.

Respectfully submitted. MORDECAI T. ENDICOTT.

WASHINGTON, D. C., *January 26, 1906.*

SIR: In reply to your request for a statement of my views on the question of a sea-level or a high-level canal, as applicable to Panama, and my conclusions as to the relative value of each type, as discussed in the reports of the Consulting Board of Engineers—

As indicated in my letter of December 19, 1905, which was written prior to the receipt or inspection by myself of any report from the Consulting Board, my judgment was and is yet in favor of a high-level canal, and it has only been strengthened by the very able presentation of the facts and deductions made therefrom in the minority report.

I can therefore conscientiously and fully approve the adoption of the high-level type, and strongly recommend that the Commission give its official voice in favor of such a type as is described in the minority report, and there seems to be nothing that I can add to such report, in view of its clearness and completeness, more than that I am heartily in favor of its adoption.

As between a sea-level canal and any canal with a summit elevation of 30 feet or above, I decidedly prefer the high level, and believe the one with a summit level of 85 feet more fully meets the conditions and requirements than one at any lower level.

In my letter of December 19, I disapproved of the suggestion to change the present alignment of the canal at either ocean terminal. In relation to the northern terminal, at Colon, I am free to say that I now believe that either plan as recommended by the Consulting Board of Engineers in covering this question is preferable to the present alignment, and that the abandonment of the proposed seawall from Colon to English Point and the adoption of a plan for breakwaters parallel, or nearly so, to the proposed entrance channel (if such breakwaters are found necessary) much simplifies the situation.

I believe, however, that the construction of a large basin or inland harbor at or near Mindi, or at a convenient location which exists below the Gatun dam, such basin to be supplied with coaling and other proper outfitting facilities, will be found advisable, the material excavated in the construction of such a basin to be used in the construction of the Gatun dam.

As regards the plan and alignment of the canal at the Pacific end, I am still inclined to my former expressed opinion that, on account of the military and sanitary features, the location of all the locks at Miraflores and Pedro Miguel, instead of part of them at La Boca, with the necessary dam at the same place, will be found more satisfactory; but as the latter plan will cost about $6,000,000 less to construct than the former one, I am ready to waive my views in favor of the latter plan, although simply on account of the difference in the estimated cost.

The minority report of the consulting board has discussed so fully the relative merit of the two types that it would seem entirely unnecessary for me to endeavor to extend the arguments.

I will, however, express my belief that some of the estimates as to the length of time and cost, as set forth by the report in favor of the sea-level type, are hardly justified. I believe that the estimated cost of the auxiliary works, such as diversion channels, dams, and spillways, may very readily exceed by several times the amount allowed, and that the danger to the canal by the existence of such works would be much greater than apparently appreciated.

It is perhaps possible that the unit price per yard allowed for the removal of material in the prism of a sea-level canal below +10 (40 feet of it being all rock and below sea level) is ample; but I seriously doubt it. This unit cost might easily be double the estimate as allowed, and such an increase alone would add $20,000,000 to the cost of the sea-level canal.

A difference alone of $100,000,000 in the cost of the canal means, at 2 per cent interest, an addition of $2,000,000 per year to fixed charges, which sum, of course, must be added to the cost of carrying charges and operation in estimating the relative value of the two types of canal. I believe the excess cost of the sea-level type, instead of being $107,000,000, as indicated in the reports, would be at least $135,000,000, and it might be very much more.

I also believe that the difference in the time required for the construction, as between the two types, will be much greater than reported, and I would not care to set a less time than eighteen or twenty years for the building of a sea-level canal, while I am firmly of the belief that the time, as shown in the minority report, for the construction of the high or 85-foot summit level is ample.

The sum of my conclusions is, therefore, that, all things considered, the lock or high-level canal is preferable to the sea-level type, so called, for the following reasons:

It will provide as safe and a quicker passage for ships, and therefore will be of greater capacity.

It will provide, beyond question, the best solution of the vital problem of how safely to care for the flood waters of the Chagres and other streams.

Provision is made for enlarging its capacity to almost any extent at very much less expense of time and money than can be provided for by any sea-level plan.

Its cost of operation, maintenance, and fixed charges will be very much less than any sea-level canal.

The time and cost of its construction will be not more than one-half that of a canal of the sea-level type.

The element of time might become, in case of war, actual or threatened, one of such importance that measured, not by years but by months, or even days, the entire cost of the canal would seem trivial in comparison.

Finally, even at the same cost in time and money for each type, I would favor the adoption of the high-level lock canal plan in preference to that of the proposed sea-level canal.

I therefore recommend the adoption of the plan for an 85-foot summit-level lock canal, as set forth in the minority report of the Consulting Board of Engineers.

Very respectfully,

JNO. F. STEVENS, *Chief Engineer.*

Mr. T. P. SHONTS,
Chairman Isthmian Canal Commission,
Washington, D. C.

WASHINGTON, D. C., *January 26, 1906.*

SIR: In reply to your request for a statement of my views on the question of a sea-level or a high-level canal, as applicable to Panama, and my conclusions as to the relative value of each type, as discussed in the reports of the Consulting Board of Engineers—

As indicated in my letter of December 19, 1905, which was written prior to the receipt or inspection by myself of any report from the Consulting Board, my judgment was and is yet in favor of a high-level canal, and it has only been strengthened by the very able presentation of the facts and deductions made therefrom in the minority report.

I can therefore conscientiously and fully approve the adoption of the high-level type, and strongly recommend that the Commission give its official voice in favor of such a type as is described in the minority report, and there seems to be nothing that I can add to such report, in view of its clearness and completeness, more than that I am heartily in favor of its adoption.

As between a sea-level canal and any canal with a summit elevation of 30 feet or above, I decidedly prefer the high level, and believe the one with a summit level of 85 feet more fully meets the conditions and requirements than one at any lower level.

In my letter of December 19, I disapproved of the suggestion to change the present alignment of the canal at either ocean terminal. In relation to the northern terminal, at Colon, I am free to say that I now believe that either plan as recommended by the Consulting Board of Engineers in covering this question is preferable to the present alignment, and that the abandonment of the proposed seawall from Colon to English Point and the adoption of a plan for breakwaters parallel, or nearly so, to the proposed entrance channel (if such breakwaters are found necessary) much simplifies the situation.

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Very respectfully,

JNO. F. STEVENS, *Chief Engineer.*

Mr. T. P. SHONTS,
Chairman Isthmian Canal Commission,
Washington, D. C.

REPORT

OF THE

BOARD OF CONSULTING ENGINEERS

FOR THE

PANAMA CANAL

S. Doc. 231, 59-1——4

MEMBERS OF THE BOARD OF CONSULTING ENGINEERS FOR THE PANAMA CANAL.

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E. QUELLENNEC, Ingénieur en Chef des Ponts et Chaussées; Ingénieur Conseil de la Cie. du Canal de Suez, France.

J. W. WELCKER, Hoofdingenieur-Directeur van den Ryks-Waterstaat, The Netherlands.

JOHN C. OAKES, Captain, Corps of Engineers, General Staff, U. S. Army, *Secretary.*

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WASHINGTON, D. C., *January 10, 1906.*

The ISTHMIAN CANAL COMMISSION.

GENTLEMEN: The Board of Consulting Engineers for the Panama Canal, having completed the consideration of the question submitted to it in pursuance of the order of the President dated June 24, 1905, has the honor to submit its report.

The President's order is as follows:

EXECUTIVE ORDER.

It is hereby ordered that a Board of Consulting Engineers, consisting of
General George W. Davis,
Mr. Alfred Noble,
Mr. William Barclay Parsons,
Mr. William H. Burr,
General Henry L. Abbot,
Mr. Frederic P. Stearns,
Mr. Joseph Ripley,
Mr. Herman Schussler,
Mr. Isham Randolph,
Mr. Wm. Henry Hunter, nominated by the British Government,
Herr Eugen Tincauzer, nominated by the German Government,
M. Guérard, nominated by the French Government,
M. Quellennec, consulting engineer, Suez Canal, and one engineer to be designated by the Government of the Netherlands,

shall convene in the City of Washington, at the rooms of the Isthmian Canal Commission, on the 1st day of September, 1905, for the purpose of considering the various plans proposed to and by the Isthmian Canal Commission for the construction of a canal across the Isthmus of Panama between Cristobal and La Boca; and that the deliberations of the Board of Consulting Engineers shall continue as long as they may deem it necessary and wise before they make their report to the Commission.

The Isthmian Canal Commission is directed to have all the proposed plans in such detailed form, with maps, surveys, and other documents sufficient to enable the Consulting Engineers to consider and decide the questions presented to them. Should it be deemed necessary by the members of the Consulting Board, they may visit the Isthmus before making their final report. If there is a difference of opinion between the members of the Consulting Board, minority reports are requested.

General George W. Davis is hereby designated as chairman of the Board of Consulting Engineers. Instructions more detailed will be given in time to be presented to the Board when it first convenes on the 1st of September.

The chairman is charged with the duty of communicating to the other members of the Board this order and the other details that may be necessary.

THEODORE ROOSEVELT.

THE WHITE HOUSE, *June 24, 1905.*

SUMMARY OF PROCEEDINGS.

The Board met in the office of the Isthmian Canal Commission, Washington, D. C., on September 1, 1905, all the gentlemen named in the order being present with the following exceptions:

Mr. Herman Schussler, who notified the chairman of the Board that on account of previous engagements and undertakings that could not be changed he felt obliged to decline the appointment.

Mr. J. B. Berry, chief engineer, Union Pacific Railroad, who had been named by the President as a member in place of Mr. Schussler, declined the appointment on account of his responsibility to the railroad company, which required all of his time.

Prof. Jacon Kraus, chief of waterstaat, Netherlands Government, who had been named as the representative of Holland on the Board, was shortly thereafter called to a position in the ministry of the Government, and he therefore was obliged to decline the appointment.

To fill the place thus made vacant, Mr. J. W. Welcker, chief engineer of waterstaat, was nominated by the Government of the Netherlands. Mr. Welcker sat with the Board as the Dutch member.

After organization and the reading of the order of the President, the Chairman announced that Capt. John C. Oakes, Corps of Engineers, General Staff, U. S. Army, had been detailed by the War Department to act as secretary to the Board, and he has so acted.

The Board received the following communication from the Chairman of the Isthmian Canal Commission:

ISTHMIAN CANAL COMMISSION,
Washington, D. C., September 1, 1905.

THE BOARD OF ENGINEERS ADVISORY UPON PLANS FOR THE PANAMA CANAL,
Washington, D. C.

GENTLEMEN: In accordance with the directions of the President, dated April 1, 1905, the Isthmian Canal Commission has the honor to lay before you physical data concerning the Isthmus of Panama, and to solicit your opinion as to the best plan to be followed in the completion of the Panama Canal within reasonable limits of cost and time.

As you are aware, this question has been the subject of prolonged and elaborate studies for many years by numerous able engineers. A vast amount of labor has been expended in the collection of information concerning the physics of the Isthmus, and in digesting it and formulating it into plans for the canal. The results of all these labors, both in the field and in the office, down to a recent date are given in the reports of two distinguished commissions, viz, the Comité Technique, of which the report is dated at Paris, November 16, 1898, and the American Commission of 1899–1901, of which the report is dated at Washington, November 16, 1901. A careful perusal of these reports, and examination of the maps and documents which accompany them, will afford as satisfactory a view of the entire subject, at the dates when they were written, as can now be given. They have been reprinted, each in a separate pamphlet, and in that form are now handed to you marked "Part I," and "Part II," respectively.

During the last year additional surveys and observations have been made upon the Isthmus, the results of which are laid before you. It may be stated here in general terms that the information which they furnish does not involve any radical change in the plans previously favored. Among the observations alluded to may be included the experience of the last year in excavating the Culebra cut, from which some of our engineers have drawn unwarranted conclusions as to the probable cost of the work. There is nothing in this experience to justify the belief that the unit prices used in previous estimates were too high, or that the estimate of the time required for completing the work was too liberal. Nevertheless, this experience has been used as an argument in favor of a sea-leval canal, which plan had been condemned by the two commissions mentioned above. It becomes necessary to consider once more the sea-level scheme. The principal information available for a decision as to the merits of that project has been printed in the form of a third pamphlet, which is now handed to you, marked "Part III," and in which will be found the more important results of the recent surveys.

These three pamphlets are commended to your careful consideration. With the large map, scale 1:5,000, of which a copy is also handed to you, it is hoped that a fair idea may be obtained of the conditions on the Isthmus, and of the relative merits of the three plans proposed. There are on file here many other maps, reports, and drawings, any or all of which will be placed at your disposal should there be any point which requires further elucidation.

The plan described in the first pamphlet is the one which was adopted by Congress, at least by inference, in the act approved June 28, 1902. It is the plan under which the work is now progressing, and under which all work of construction has been done since the United States acquired the property. It closely resembles the plan of the Comité Technique, described in the second pamphlet, in many essential particulars, but differs from it in the height of the Bohio dam and the important results which flow therefrom. The advantages which its authors expected to derive from this change were:

1. To take fuller advantage of the topography of the country, by which it was possible to make the Gigante spillway automatic, instead of mechanical, and adequate for the discharge of the greatest floods, with only one channel to the sea instead of two.

2. To increase the distance of lake navigation from seven to nearly thirteen miles.

3. To reduce the estimated cost of the canal by about $15,000,000.

The disadvantages of the change are the somewhat greater difficulties in constructing the higher dam and the locks of greater lift—difficulties, however, which are by no means insuperable.

A disadvantage which the two plans have in common is that the rapid developments of naval architecture make it difficult to determine the proper dimensions of the lock chambers. It is to be considered, however, that up to the present time such development has not been greatly hampered by deficient depth in the harbors of the world, and that development hereafter will have that obstruction to contend with. Moreover, it is not possible to dispense with locks entirely. Even with the sea-level canal a tide lock will be required at the Panama end.

In addition to the plans above mentioned, a pamphlet has been prepared by Mr. Lindon W. Bates, which gives in outline a sketch of a plan proposed by him, which is interesting on account of its novelty, and is, therefore, laid before you. It does not give detail enough for a close analysis, nor for estimates of cost. To obtain this, extensive additional surveys, to occupy at least a year's time, would be necessary.

A paper has been submitted to the President by Mr. P. Bunau-Varilla which explains a method by which a canal constructed at first with locks may be subsequently altered to a sea-level canal. This paper also is submitted for your consideration.

These last two documents are described in a fourth pamphlet, marked "Part IV," which is now handed to you.

It is to be noted that the law by which Congress ordered the construction of an Isthmian Canal contained the following proviso, viz:

"The President shall then, through the Isthmian Canal Commission hereinafter authorized, cause to be excavated, constructed, and completed, utilizing to that end, as far as practicable, the work heretofore done by the New Panama Canal Company, of France, and its predecessor company, a ship canal from the Caribbean Sea to the Pacific Ocean. Such canal shall be of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use, and such as may be reasonably anticipated, and shall be supplied with all necessary locks and other appliances to meet the necessities of vessels passing through the same from ocean to ocean; and he shall also cause to be constructed such safe and commodious harbors at the termini of said canal and make such provisions for defense as may be necessary for the safety and protection of said canal and harbors."

The Commission expects to visit the Isthmus of Panama, sailing from New York during the last week in September, the exact date to be fixed hereafter. You are cordially invited to accompany them.

This method of presenting the subject to you, by offering several well-digested plans, has been adopted because it seemed to be the method by which all essential information could be conveyed in the most condensed possible form. It is needless to say that the Commission desires your opinion not only upon these plans, but upon any variation of them, or upon any entirely different plan which may suggest itself to you. It requests your views as to what plan it is most expedient, all things considered, for the United States to follow in the completion of the Panama Canal.

Yours, very respectfully,

T. P. Shonts, *Chairman.*

The order of the President required that there be submitted to the Board for its consideration and discussion "the various plans proposed to and by the Isthmian Canal Commission." The Commission transmitted to the Board:

1. A plan prepared by the old commission on isthmian routes, created in pursuance of the act of Congress approved March 3, 1899.

2. A plan proposed to the New Panama Canal Company November 16, 1898, by the Comité Technique assembled by that company.

3. Three projects prepared by Mr. Lindon W. Bates, of New York.

4. The more important results of recent surveys, containing the principal information available for a decision respecting a canal at tide level.

There was also submitted a paper prepared by Mr. P. Bunau-Varilla, explaining a method of construction of a lock canal to be subsequently transformed to one at sea level.

At a subsequent meeting there was received from the Commission a paper entitled "The Panama Canal: Some serious objections to the sea-level plan," prepared by Maj. Cassius E. Gillette, Corps of Engineers, U. S. Army, and another entitled "The Gatun Dam," prepared by Mr. C. D. Ward, C. E.

On the other hand, the Board received no plans originating with the Commission. Therefore, and because the requirements of the act of Congress respecting the dimensions and capacity of the canal, together with the new information collected by surveys and examinations conducted during the last two years prevented the adoption of plans of former commissions, the Board was obliged to prepare plans and estimates based on such information and on other data collected at its request, and to act as a creative body as well as a consulting board.

In order to conduct its business systematically the Board determined to hold regular stated meetings at such times as the work required, and thirty of such meetings have been held. The proceedings of these meetings were recorded and the minutes will be found as Appendix A to this report. Although these meetings were executive in character, the members of the Isthmian Canal Commission were invited to be present at any or all of them, an invitation which was frequently accepted. To facilitate the work of the Board there were appointed:

An executive committee, consisting of the Chairman, General Abbot, and Mr. Hunter.

A committee on the preparation of plans for a sea-level canal, consisting of the Chairman, Messrs. Guérard, Hunter, and Burr, to which Messrs. Parsons and Quellennec were subsequently added.

A committee on the preparation of plans for a lock canal, consisting of the Chairman, Messrs. Stearns, Tincauzer, and Ripley, to which General Abbot and Mr. Noble were subsequently added.

A committee on unit prices for purposes of estimate, consisting of Messrs. Parsons, Welcker, and Randolph.

On September 11 the President received the Board at Oyster Bay, and addressed them as follows:

What I am about to say must be considered in the light of suggestion merely, not as direction. I have named you because in my judgment you are especially fit to serve as advisers in planning the greatest engineering work the world has yet seen; and I expect you to advise me, not what you think I want to hear but what you think I ought to hear.

There are two or three considerations which I trust you will steadily keep before your minds in coming to a conclusion as to the proper type of canal. I hope that ultimately it will prove possible to build a sea-level canal. Such a canal would undoubtedly be best in the end, if feasible, and I feel that one of the chief advantages of the Panama route is that ultimately a sea-level canal will be a possibility. But while paying due heed to the ideal perfectibility of the scheme from an engineer's standpoint, remember the need of having a plan which shall provide for the immediate building of a canal on the safest terms and in the shortest possible time.

If to build a sea-level canal will but slightly increase the risk, and will take but a little longer than a multilock higher-level canal, then of course it is preferable. But if to adopt the plan of a sea-level canal means to incur great hazard and to insure indefinite delay, then it is not preferable. If the advantages and disadvantages are closely balanced, I expect you to say so. I desire also to know whether, if you recommend a high-level multilock canal, it will be possible after it is completed to turn it into or to substitute for it, in time, a sea-level canal without interrupting the traffic upon it. Two of the prime considerations to be kept steadily in mind are—

(1) The utmost practicable speed of construction;

(2) Practical certainty that the plan proposed will be feasible—that it can be carried out with the minimum risk.

The quantity of work and the amount of work should be minimized so far as is possible.

There may be good reason why the delay incident to the adoption of a plan for an ideal canal should be incurred; but if there is not, then I hope to see the canal constructed on a system which will bring to the nearest possible date in the future the time when it is practicable to take the first ship across the Isthmus; that is, which will in the shortest time possible secure a Panama waterway between the oceans of such a character as to guarantee permanent and ample communication for the greatest ships of our Navy and for the largest steamers on either the Atlantic or the Pacific. The delay in transit of the vessels owing to additional locks would be of small consequence when compared with shortening the time for the construction of the canal or diminishing the risks in the construction.

In short, I desire your best judgment on all the various questions to be considered in choosing among the various plans for a comparatively high-level multilock canal, for a lower-level canal with fewer locks, and for a sea-level canal. Finally, I urge upon you the necessity of as great expedition in coming to a decision as is compatible with thoroughness in considering the conditions.

On September 27 the Board visited the Wachusett dam and other works in Massachusetts constructed by the Metropolitan Water and Sewerage Board, and on September 28 sailed for the Isthmus, where the work already done and in progress was thoroughly inspected and the conditions affecting the type of canal and future construction examined and considered.

Messrs. P. Bunau-Varilla and Lindon W. Bates, who, through the Isthmian Canal Commission, had submitted projects for canals, appeared before the Board and further illustrated their projects by oral explanations. The explanations, subsequently revised by the authors, appear in an appropriate place in the appendix to this report. (Appendixes F and G.)

The Board invited Mr. John F. Wallace, who had acted as chief engineer to the Commission from June 9, 1904, to June 30, 1905, to appear before the Board and give it the benefit of his experience and study. This invitation was accepted by Mr. Wallace, and his communications, both written and oral, are given in full in Appendix J. These communications are of great value as embodying the results of the longest continuous study by one man since the taking over of the work by the Government, and consideration of them is therefore invited.

While on the Isthmus the Board invited Mr. John F. Stevens, the present chief engineer to the Commission, to appear before the Board and aid it with such information as he had or such

suggestions as he might care to offer. His testimony is given in full in Appendix J, wherein it is stated that since he had been connected with the work only two months, during which time his whole attention had been given to matters of organization, he had given no consideration to the cost or type of canal, and therefore had no advice to offer. Mr. Stevens gave all the information he had at hand.

There also appeared before the Board while on the Isthmus, or subsequently at Washington, Messrs. Dauchy, Maltby, and Dose, division engineers, and Mr. Bertoncini, expert draftsman in charge of the French engineering records on the Isthmus, and their remarks are attached hereto (Appendix J). Col. W. C. Gorgas, U. S. Army, chief sanitary officer, gave the members of the Board the benefit of his great experience with tropical diseases, especially those most to be feared at Panama.

After the return from the Isthmus and the receipt of the additional information asked for by the Board, the question of the type of canal to be recommended, the character and size of the channels, locks, harbors, and other works, and the cost of the same, both in time and money, were considered by the Board.

As a basis for all plans the Board resolved by eleven affirmative and two negative votes that locks should have as minimum usable dimensions a length of 1,000 feet, a width of 100 feet, and a depth of 40 feet. The two members voting in the negative were Messrs. Noble and Ripley. The Board also decided unanimously that in order to make its estimates comparable in respect to totals with the estimates of previous commissions there should be added to the estimated cost of construction an allowance of 20 per cent to cover administration, engineering, and contingencies; but exclusive of interest during construction, sanitation, expense of Zone government, and collateral costs. The Board also decided not to attempt to make any estimate of cost of the lands to be flooded by the canal or lakes in connection therewith, on account of the impossibility of procuring any reliable data upon which to base such estimates. The Board wishes to point out, however, the possibility of such cost assuming large proportions, especially if lands near the terminal cities or lands including the larger interior villages should be required.

The Committee on Sea-Level Canal submitted a project for a canal, a description of which is given in full in another part of this report, from which it will be seen that in accordance with the instructions of Congress that the canal "shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use and such as may be reasonably anticipated," the committee recommend a canal whose dimensions, both as to width and depth and consequent cost, exceed similar dimensions heretofore recommended by other commissions.

The Committee on Lock Canal submitted four projects to the Board:

Project No. 1 contemplates a summit level at elevation 85 feet, to be maintained by a flight of three locks at Gatun on the Atlantic side, and with one lock at Pedro Miguel and two locks in flight at Sosa Hill adjoining La Boca pier on the Pacific side, the estimated cost of which is $141,236,000.

Project No. 2 is the same as No. 1, except that on the Pacific side there are two locks in flight at Pedro Miguel and one at Miraflores rather than at Sosa. The estimated cost of this project is $148,272,000.

Project No. 3 is based on an elevation at summit level of 60 feet, maintained on the Atlantic side by a flight of two locks at Gatun and on the Pacific side with a single lock at Pedro Miguel and another at Miraflores. For the purpose of control of the Chagres River and to furnish a water supply there is included a dam at Gamboa. The total estimated cost of this project is $171,190,000.

Project No. 4 proposes a summit level at elevation 60 feet, to be maintained by a dam with single locks at Gatun and Bohio on the Atlantic side, and with single locks at Pedro Miguel and Miraflores on the Pacific side, with a dam at Alhajuela, at a total estimated cost of $175,929,720.

All elevations are stated with reference to mean sea level.

These four estimates include 20 per cent for contingencies.

It is well to note that in each of the above projects the proposed terminus of the canal near Panama differs from the terminus proposed in the sea-level plan, and is in each case less convenient.

In the above estimates no allowance is made for the value of lands overflowed by the lakes to be formed by the proposed dams at Gatun, Bohio, La Boca, Gamboa, or Alhajuela. On the other hand the estimates do include duplicate locks at all places, whether single or in flights of two or three. In submitting these projects to the Board the committee stated that it made no recommendations, the committee having been divided in its preferences. In a separate report, given elsewhere in detail (Appendix P), the committee agree as to the impracticability of converting a lock canal to one at sea level, in the immediate future, on account of the difficulty and danger of the operation and of the excessive cost. This view was concurred in by the Board.

After considering the four types of lock plans submitted by the committee, the Board determined, by a vote of eight to five, to adopt, for comparison with a sea-level canal, a canal the summit level of which should be at elevation 60 feet, the vote in the affirmative being Messrs. Hunter, Welcker, Guérard, Tincauzer, Abbot, Burr, Parsons, and Davis, and in the negative Messrs. Ripley, Randolph, Stearns, Quellennec, and Noble. The Board decided that on the Pacific side there should be one lock at Sosa and one at Pedro Miguel; on the Atlantic side that there should be one lock at Gatun and one at Bohio, all in duplicate; and that there should be a dam for the regulation of the Chagres at Gamboa identical with that proposed for a sea-level canal. This plan is attached to and described in another portion of this report (p. 35). It is to be noted, however, that this plan, like the plans submitted by the Lock-Canal Committee, is not the most feasible which could be devised for subsequent conversion to sea level, the Board believing that such conversion would probably not be carried out. A motion to adopt such a type of lock canal by placing the locks immediately next to the continental divide, probably near Obispo on the Atlantic side and at Miraflores on the Pacific, with the canal constructed at sea level between such locks and the oceans, was defeated.

In regard to the question of time required to construct these two proposed canals, the Board resolved by a vote of seven (Messrs. Hunter, Welcker, Guérard, Tincauzer, Burr, Parsons, and Davis) to six (Messrs. Ripley, Randolph, Stearns, Quellennec, Abbot, and Noble)—

That the Board declare in its report that the time of finishing the sea-level canal depends on many contingencies that can not be definitely estimated in time; that under efficient management and not seriously affected by extraordinary and unforeseen difficulties, political obstructions, or bad sanitation it may be regarded as feasible to complete the work in about twelve or thirteen years; that adverse conditions may lengthen that period, while favorable circumstances and continuous first-class direction may make it possible to shorten that period by one or two years.

It was unanimously resolved in language similar to the resolution in connection with the sea-level canal that the canal with locks on the plan prepared by the Board may be constructed in the period of ten to eleven years.

The Board having adopted a type of sea-level canal and a type of canal with locks as seemed most suitable under all conditions involved, and having decided that it was not expedient to adopt any of the plans which had been submitted or proposed to the Board, the following resolution was moved and adopted by a vote of eight to five, those voting in the affirmative being Messrs. Davis, Parsons, Burr, Hunter, Guérard, Quellennec, Tincauzer, and Welcker, and those in the negative being Messrs. Abbot, Noble, Stearns, Randolph, and Ripley:

Whereas in the judgment of this Board, a sea-level canal is feasible, following a line with dimensions and such arrangements that the transit between the two oceans shall be secured in a permanent manner for all time under the best conditions for navigation and safety, for vessels of the largest tonnage and greatest draft now in use, or such as may be reasonably anticipated: Therefore

Resolved, That the Board adopt and recommend to the President of the United States the plan of a sea-level canal with a depth of 40 feet, a width in rock of 200 feet, a minimum bottom width in earth of 150 feet, with a double tidal lock at Ancon whose usable dimensions shall be 1,000 feet in length and 100 feet in width, and with a dam at Gamboa for the control of the Chagres River.

The remarks by members explaining their votes on this resolution are given in the minutes of proceedings. (See Appendix A, twenty-fifth meeting.)

In accordance with the sense of this decision, the Board submits herewith a general plan for a sea-level canal and recommends the same for adoption.

PHYSICAL CHARACTERISTICS OF THE PANAMA ROUTE.

The combination of a very narrow isthmus with low summit is found at Panama. The route practicable for a canal there is not half as long as the Suez Canal. The portion of this route that is higher than the highest cutting at Suez is about seven miles in extent.

The drainage of the Isthmus throughout about three-fourths of its width is effected through the Chagres River and its tributaries to the Caribbean, and of the remaining one-fourth through the Rio Grande to the Pacific. The proposed Pacific terminus is about 20 miles farther east than the Caribbean terminus, for at the Panama Isthmus the trend of the two coasts, there approximately parallel, is about east and west.

The drainage to the Pacific is now effected through the Rio Grande, a small stream discharging into Panama Bay to the west of Sosa Hill and about two miles west of the city of Panama.

The tidal oscillation in Limon Bay, the initial point of the canal route, is about two feet, while at Panama it is about 20 feet. The harbors are not naturally good, but they have been made to suffice for the limited traffic seeking this route.

The geologic features of the Isthmus are very well described by two eminent French scientists, a translation of whose report on this subject, together with the deductions from the existing facts as affecting proposed engineering operations, and especially the stability of the banks of the channel and slopes, are very lucidly set forth in a paper which will be found in Appendix B, while climatic conditions are treated in the section of this report which is devoted to this important subject.

As before stated, the drainage toward the Atlantic is naturally effected through the Chagres, the canal line by all plans being located in the immediate valley of that stream for about 21 miles. One of its tributaries, the Obispo, drains the extension of the canal line for about five miles toward the Culebra summit. The Chagres is a torrential stream, and drains a basin of an estimated total area of about 1,200 square miles, about half of which is above the point where the proposed canal line leaves the river. Its sources are in the San Blas Mountains to the northeast. The course of the Chagres is, in a general way, parallel to the Caribbean coast as far as the mouth of the Obispo, where it turns to the northward and follows a somewhat tortuous but on the whole fairly direct course to the Atlantic rim of its upper basin at Bohio, about 13 miles below the mouth of the Obispo. At Gatun, about 10 miles below Bohio, following the general course of the valley, the direct distance to the Atlantic at the head of Limon Bay is only three miles, but the river deviates to the westward, and after a further course of about seven miles, passing to the west of Limon Bay, discharges into the sea at the old village of Chagres, about five miles west of Point Toro.

Above Bohio the Chagres Valley is undulating or hilly, the declivities becoming steeper toward the sources of the river, where the country is mountainous. At Alhajuela, about eight miles in a direct line above the mouth of the Obispo, the low-water surface of the river is about 95 feet above sea level, and at the mouth of the Obispo 45 feet; but at Bohio, 13 miles farther down, it is practically at sea level. From Bohio to the sea the surface of the ground for considerable areas in the vicinity of the river is but little above sea level. In this low region the Chagres receives several tributaries, of which the Gatun from the eastward and the Trinidad from the westward are of considerable size.

There are several notable topographic features of the Chagres Valley which have a very important bearing upon the canal problem. In the upper courses of the stream and its tributaries the bottom in the waterway is the original rock formation, and the channel is strewn with bowlders, pebbles, and sand which have been loosened by erosion. Borings have been made in this valley at several points from Alhajuela to Gatun, with a view of determining the character of the earth and depth to rock. It is found that at Alhajuela there is a depth of about 29 feet of gravel overlying the rock in midstream. The rock outcroppings in the bluff appears to be of a firm and homogeneous structure, of volcanic origin. At this point the hills on either side contract the valley in a marked degree. At Gamboa, which is just above the junction of the Obispo, the

gravel covering of the rock bed is about 50 feet in depth. At San Pablo the bed of gravel, sand, etc., is about 90 feet in thickness; at Buena Vista it is over 139 feet below sea level to rock, and a little farther downstream, 142 feet; at Bohio the rock is 168 feet below tide level, and the drills penetrated wood at various depths to 150 feet. At Gatun, the depth to what in this report is sometimes classed as rock—an indurated sandy clay—is 258 feet in the deepest place, and at another, on the same section, the depth of the sand, clay, gravel, etc., is about 240 feet. Here also buried wood was brought up by the drills.

It seems, therefore, to be certain that what may be called the geological valley of the Chagres—that is to say, the rock bottom of that stream—is represented by a deep groove or channel, now entirely or partly filled by the products of erosion and drift. If there has been a regional subsidence of the Isthmus, which the geologists suggest as possible, it may be that the ancient Chagres discharged into the sea through an ancient valley, which, with the land adjacent thereto, was some 300 feet higher in relation to the ocean than the present valley. The rock penetrated at Bohio and above, also that showing in the river banks and outcropping in neighboring hillsides, is all volcanic and much denser than the so-called rock at Gatun.

The Obispo flows over a rocky bed in a part of its lower course and at one point there is a natural cascade of a few meters over a rock shelf. The general surface on the upper course of the Obispo is more nearly level, with hills rising in its drainage basin and on its margins to the height of from 100 to 1,000 feet above the general surface. The general aspect of the central isthmus is one of great irregularity—the hills are numerous and have very steep slopes, while the valleys are narrow. Culebra is one of these hills, its summit being some 700 feet above the sea. The geologists suggest that the drainage area of the upper Obispo was once a lake of considerable size, for within this area are found a few sedimentary rocks containing fossils, also calcareous and carboniferous deposits, but the greater part of the material is of volcanic origin, the central masses of the hills containing hard volcanic rock and dikes of basalt.

Between, above, and below these hard-rock masses are softer rock and dark, indurated clay, while the upper covering of the superficies is composed of the same volcanic material, but much changed by exposure to the weather, and where cut through, as it is by the canal excavation all the way for seven miles through the dividing ridge, the covering is seen as a red clay, occasionally containing bowlders, having a varying thickness to 30 feet and at one place to more than 40 feet, but generally its thickness is but 10 to 20 feet. It is in this top layer of reddish clay that all the larger slides have taken place.

Toward the Pacific the slope is, for half the distance to the bay, much more rapid than in the Chagres Valley, but the physical characteristics are similar. The Rio Grande Valley, through nearly half its length, is a tidal estuary filled and emptied twice daily by the tides. The same or a similar rock to that showing in the upper Chagres Valley is the prevailing rock in the Rio Grande region, with but a few feet of earth covering. At Pedro Miguel and Miraflores the rock is near the surface. Near Panama are two isolated hills of considerable height showing volcanic rock outcrops of a very much denser character than any other on the Isthmus.

The facts being as stated, it follows that the streams draining the isthmian region have a much more permanent regimen in their upper courses than nearer the sea. The rock near the surface a few miles from the oceans is conveniently situated for foundations for locks, dams, etc., and is sufficiently dense to make good concrete material, while sand suitable for use in masonry structures is found in great abundance on the beaches of Panama Bay, and probably that found in some of the gravel beds in the Charges will also be suitable for the same purposes.

The hill and mountain slopes are covered with a tropical jungle, but there is no good timber for construction purposes found on the Isthmus near the railway.

CLIMATE.

The climate of any locality is determined by certain influences, the principal of which are latitude, altitude, proximity of oceans, high mountain ranges, humidity, and rainfall.

A detailed description of the climate of the American Isthmus is quite unnecessary, for it is well known, but its adaptability as a residence for human beings employed in manual labor or

in a supervisory capacity is not generally very well understood. The state of the atmosphere respecting heat and moisture and meteorological conditions generally has a very important influence upon the health and contentment of the inhabitants.

That this question of climate has a very important bearing on the canal problem is acknowledged by all who have carried on engineering works in tropical countries and by those who are familiar with the history of such operations.

Temperatures at the Isthmus as low as 72° or as high as 98° are unusual. It is correct to say that the average daily range of the thermometer is from 75° to 84°. The highest recorded temperature in the Chagres Valley is 97° and the lowest 64°. The number of days in the year when the heat at night is less than 75° and greater by day than 84° are very few. In other words, the daily range in temperature is only about 10°, with little variation between summer and winter, wet and dry seasons. But the atmosphere is generally quite damp, ranging in relative humidity from 80 per cent in the dry season to 87 per cent in the rainy season. With a temperature of approximately 80° and a relatively high humidity the air is damp and muggy, and therefore exhausting and oppressive to the white race unaccustomed to tropical conditions. These conditions are common to many tropical regions near the sea level.

The rainfall on the Isthmus is greater than in some parts of the tropics and much less than in others, the annual precipitation varying from about 140 inches at Colon and the lower Chagres Valley to 95 inches in the interior and to about 70 inches on the Pacific side. But the precipitation is very unequally distributed throughout the year. During the four dry months—January, February, March, and April—and the eight wet months the average monthly rainfall and the average yearly total are as follows:

	Atlantic side and Chagres Valley.	Interior.	Panama, Naos, and La Boca.
	Inches.	*Inches.*	*Inches.*
Dry season	3.7	1.56	1.74
Rainy season	15.3	11.08	7.89
Total for year	137.2	94.87	64.70

These data are the result of observations covering a period of 33 years at Colon, 21 years at Gamboa, and from 3 to 10 years at the points on Panama Bay. The heaviest rainfall in any one month was 20.9 inches at Colon.

The number of days given in each year from 1889 to 1904 during which there was some fall of rain was, at Colon, 196; Bohio, 246; Alhajuela, 198; Gamboa, 190; La Boca, 141; but on many of these days the fall at all points was very slight.

It is well known that high winds having the character of hurricanes are very rare at the Panama Isthmus. Northers occur at rare intervals in the Caribbean. One or two of considerable violence have at times been felt in a year at Colon. Sometimes a whole year passes without a wind of greater velocity than a strong breeze; on the other hand, northers have occurred in which the wind velocity has reached 50 miles an hour, but there have been no accurate measurements made of these storms. These blows are never felt in the interior or on the Pacific side.

The observed monthly mean velocity of the wind at Colon from October, 1898, to May, 1899, varied from five to eight miles per hour, the maximum monthly mean observed being eight and one-half miles, while the strongest observed on any day in eight months was 24 miles. There is generally a pleasant breeze every day from a northerly quarter, and this applies throughout the Isthmus. At Panama there is no record of a severe storm of any kind, and the winds are generally from the north and offshore.

A member of the Board, who since 1898 has resided nearly six years in the tropics, one year of which was spent at Panama, stated that he had observed no marked difference between the climate of Panama and that of other tropical countries.

SANITATION AND HYGIENE.

The Isthmus of Panama was not well known to the inhabitants of the United States until it became a favorite route of travel for the California immigration after the discovery of gold in the Sacramento Valley in 1848. Since then this route has been much used, not only by Americans but by Europeans and the inhabitants of the west coast of Central and South America.

After the gold discovery lines of steamers and sailing vessels on both oceans conveyed travelers to and from the Isthmus, the transit at first being effected by canoes on the Chagres River in connection with riding and pack animals between that stream and Panama Bay. The transfer from the Caribbean to the Pacific occupied from five to ten days, and very often much exposure and suffering resulted. In the light of present knowledge respecting the cause of yellow and malarial fevers it is not surprising that sickness and mortality were experienced among those who traversed the Isthmus in those early days. What has been called Chagres fever is now recognized as a malignant type of intermittent fever, otherwise known as malaria, which, as well as yellow fever, is believed by sanitarians to be communicated to man only by certain species of mosquitoes.

What the extent of the mortality among those early travelers was we do not know, but judging from what history records respecting the frightful losses among the French and English troops serving in the West Indies during the eighteenth and first half of the nineteenth centuries, particularly in Santo Domingo, Cuba, Nicaragua, and the Lesser Antilles, we can very well believe that the suffering on the Isthmus in the early days was very great, for the emigrants hurrying to California were but ill provided against hardships, were ignorant of the conditions, and were not controlled or governed by any constituted authority.

The construction of the Panama Railroad was undertaken in 1850, but the promoters of that enterprise understood local health conditions no better than did those who had preceded them. Workmen from the United States who were entirely unacclimatized were employed in large numbers and many succumbed to the local fevers, others to exposure and diseases due to intemperance and disorderly living. The road was open throughout its 45 miles in 1855, and thereafter the California immigration was spared the difficult canoe navigation of the Chagres and the land journey between Cruces and Panama.

It has been often stated that the mortality among the railroad workmen reached an aggregate which equaled in numbers the cross-ties used in the railway roadbed—that is to say, 150,000—but the chief engineer of that road, the late Col. George M. Totten, stated repeatedly that the total number of persons employed in building the road never exceeded 7,000 at any one time, and that the number of laborers and workmen who died in the whole five years did not exceed 1,200 in all.

To what extent yellow fever figured in those statistics is not known, but as this disease was then prevalent throughout the American tropics and warmer temperate latitudes there is little doubt that it was one of the principal causes of sickness. There is no doubt whatever that malarial fevers of all types—intermittent, malignant, and pernicious—were prevalent.

From 1855, the date of opening the all-rail route across the Isthmus, to 1881, when work was begun on the Panama Canal, the transit was used for transferring travelers, freight, mails, etc., between the Atlantic and Pacific oceans, and nearly all the superior employees of the corporation were Americans, but the annals of the Isthmus give us very little information respecting health conditions. We know that during this quarter of a century some hundreds of thousands of travelers used the transit, and many hundreds of citizens of the United States were employed by the company in operating its road. Some of these men remained on the Isthmus ten or twenty or more years and enjoyed good health. At the time the United States took over the Panama Canal there was a very considerable number of Americans employed on that road, who continued strong and vigorous when they observed ordinary sanitary rules. Of course they were well sheltered, their food was adequate and suitable, and medical attention and hospital treatment, with medicines, were available.

Work on the canal was begun in 1881. In 1882 the force employed was 1,910, and in 1884 the average number for the year was 17,615, although the maximum was 19,243, in October. The aggregate of the numbers of those reported yearly as employed in the whole period is 86,812, or an average of 10,881 per year. By computation it is found that the total number treated for sickness during the eight years was 52,814. It is also found by reference to Tables 1 and 2, recently compiled (see Appendix O), that the number of deaths of employees in the same period was 5,627, showing a rate of mortality among the sick of 10.62 per cent, and among the employed of 6.48 per cent. These important data, together with the recently compiled statistics for the city of Panama never yet published, are a very valuable contribution to our knowledge of the health conditions as they formerly existed on the Isthmus, not only during the activity of the old company but also for the years which have since elapsed, for the system of recording vital statistics instituted in 1881 has been continued to date.

The methods adopted by the health authorities on the Isthmus twenty years ago for combating tropical diseases which caused great sickness and mortality were such as were deemed most effective by the sanitarians of the period. The French company erected fine hospitals of large capacity, with up-to-date equipment, and their physicians and nursing force were competent and efficient, but modern methods for preventing sickness were then unknown. The old company, a private corporation, had no power to compel observance of health ordinances by the resident population, or by their own employees. The local authorities and permanent residents of the Isthmus were immune to yellow fever, and the people and municipal authorities were indifferent. Yellow fever was believed to be due to a poison, ever present, to which a certain proportion of newcomers, especially Europeans, was expected to succumb, as they had always done. It was believed that the disease was contagious and that the malady was transmitted by personal contact with the sick or their excreta, and the preventive measures employed to protect the new arrivals consisted of attempts at isolation of the sick, as is now done with those afflicted with smallpox.

Malaria was believed to be caused by a miasma exhaled from the soil or by decaying vegetation, and it was accepted that newly upturned soil caused the disease to spread. As the name implies, the disease was believed to be due to bad air. But discoveries of the very greatest importance to the human race have put an end to these misconceptions, and malaria and yellow fever are no longer a mystery to science. The mosquito theory of the transmission of these two diseases is now generally accepted as the solution of the mystery by all the leading sanitarians and physicians.

The knowledge of the discoveries of Reed, Lavaran, and Ross has been given world-wide publicity, and gradually has been accepted and acted upon in many parts of the world.

The yellow-fever record on the Isthmus since the United States took over the canal works is as follows: In May, 1904, there was 1 case; in June, 1; in July, 2; August, none; September, 1; October, 1; November, 3; December, 6; January, 1905, 18; February, 14; March, 11; April, 9; May, 33; June, 62; July, 42; August, 27; September, 7; October, 3; November, 5, one of which was from a point 30 miles distant, making a total in the nineteen months of 246 cases. Of these, 84 terminated fatally, or about 34 per cent.

Commenting upon these figures, Col. W. C. Gorgas, U. S. Army, the chief sanitary officer of the canal works at Panama, remarks in his October report as follows:

> I consider this (the October record) as indicating the near approach of the disappearance of the disease. * * *
>
> Panama has often in its past history been free from yellow fever, but the only disappearance was when there were no nonimmunes to contract it. At all times in its past history when there were nonimmunes here they had yellow fever as long as the nonimmunes remained. We had during October all the natural conditions favorable to this disease, a larger number of nonimmunes probably than had ever before been present on the Isthmus—in the neighborhood of 5,000—with a wet and hot month.
>
> Apparently, from the records, the season in Panama does not have much influence upon yellow fever. The weather in January is as favorable to the breeding of the Stegomyia as July, and the past records seem to show that if we have nonimmunes in Panama in December we will have as much fever as we would in July. It has altogether in the past depended upon the supply of nonimmune human beings. The only yellow-fever period when there was anything near to approximating as many nonimmunes on the Isthmus as we have at present was at the time during

the French régime when they had their maximum force. This occurred in October, 1884, when they had 19,243 men on their rolls, of whom 2,706 were nonimmunes. Among these they had 21 deaths from yellow fever in that month and approximately 84 cases. During October of this year our force has also reached its maximum, about 22,000,[a] of which number about 4,000 are nonimmunes. Among these 4,000 employees we had not a single death from yellow fever and only a single case. Of the three cases occurring on the Isthmus, two were people not employees of the Commission.

Here we are comparing two periods in which there was a large number of nonimmunes present—the same season of the year and the same climatic conditions generally—the only difference being that in the year 1905 modern tropical sanitary methods were enforced all over the Isthmus by some 2,200 men. * * * Twenty years ago these methods were unknown, malaria and yellow fever were a mystery to science, and our predecessors were unable to do anything for their control.

The results obtained, I maintain, are solely and entirely due to the sanitary measures put in force. And be it remembered at the same time that we have at present with us fully one-third more people subject to yellow fever (nonimmunes) than the French had in October, 1884.

You can pick out in the history of Panama Octobers when there were no deaths from yellow fever, such as October, 1901, or October, 1895, or October, 1896; but during these Octobers there was nobody in Panama who could have yellow fever. Take any other October when there was present any considerable number of nonimmunes and they always had yellow fever to a considerable extent. In this October when we have more people liable to the disease than ever before we had only three cases.

* * * * * * *

The showing with respect to the sick rate of employees generally is very good. Among 22,000 men we have a daily average of about 450 in hospital. This gives us a constant sick rate of 21 per thousand. We could not hope to show a lower rate than this if our canal were being dug between Washington and Baltimore. The French in October, 1884, with their 19,243 employees, had 161 deaths, making a rate for that year of 100 per thousand. We, with a force of about 22,000, have had 61 deaths, which would give us for the year a death rate of 32 per thousand. I have no doubt that when the sanitary improvements at present going on, such as street paving in Panama and Colon, waterworks in these cities and along the line, and comfortable screened buildings for employees at all points, shall have been completed the health conditions will be still further improved; but I am inclined to think that the sanitary question of Panama has been settled, as we have shown that a force of laborers as large as we are likely to have and as unfavorably situated as they ever will be can work on the Isthmus without suffering from yellow fever, and that the general health of this same force can be kept as good as if they were digging a canal in a healthy part of Maryland.

In the city of Panama it is a requirement of law that all burials shall take place in the city cemetery, and that the records of burials shall show the name, age, sex, nativity, cause of death, and the name of the physician certifying to cause in every case. These records have been carefully kept since 1882, and the chief sanitary officer of the Canal Zone has recently had every individual record of burial for the city of Panama examined, tabulating the result so far as it relates to those who succumbed to yellow and malarial fevers. The result of this inspection appears in Table 3, Appendix O, wherein is set forth the mortality for those twenty-two years caused by the two fevers, the figures being given for each month of the whole elapsed period.

The stated population of the city is the closest approximation which can be obtained from the public officers of the Republic of Panama, for since 1871 there has been but one census, that of 1904 made by the sanitary staff of the Canal Zone.

During this period of twenty-two years there were three or four occasions when there was an influx to the Isthmus of a large nonimmune population. The first was in 1881–82 and continued to 1889. The next was in 1895 when a regiment of troops from the interior highlands of Colombia arrived for service on the Isthmus. The next year there was another increase of military force from the same locality, those men also nonimmunes. The last was in 1901 when there was a further large increase consisting of a body of Colombian troops sent to Panama to operate against insurgents. On each of these occasions there was a large increase in the mortality from yellow and malarial fevers, as may be seen by the table. During the intervening months or years there were very few cases. The rule held true continuously until full effect was had from the sanitary measures taken by the United States health authorities in the Canal Zone, but it required a year and a half to secure full beneficial effect of the preventive means adopted. The records of the Panama cemetery are cited by the United States health authorities as furnishing evidence

[a] Including those employed on the Panama Railroad.

of the accuracy of their declaration that it is not only possible but feasible to banish yellow fever from the Isthmus and to maintain the whole force of employees in a good state of health.

A few years ago the abandonment, as a canal headquarters, of the city of Ismaïlia, situated on the line of the Suez Canal, was seriously considered because of the general sickness of the European inhabitants and the canal officials. The population was 9,000, of which the European inhabitants were 2,000. Among these there were 1,400 cases of malarial fever annually, of which many resulted in death. The mosquitoes (anopheles) were killed and their breeding places destroyed in 1902. The number of cases of malaria since has been, yearly, 214, 90, and in ten months of 1905, 46, with no deaths. Those who have had malaria subsequent to the sanitating of the place are those who had been chronic sufferers from the disease previously.

Recent reports received by the Commission contain interesting data concerning general health conditions, from which much knowledge is gained respecting health and disease, and indicate that the maladies prevailing on the Isthmus are generally the same as are common in the temperate climates.

In the largest hospital in the Zone, that at Ancon, there were treated in October 1,118 persons. Included in this number there were eight cases of typhoid fever, a very small number considering the population of the Zone—a total of 63,084—and the squalor, indigence, and indifference to sanitary rules of a large part of the inhabitants. In this hospital there were 19 cases of dysentery, 30 of beriberi, 17 of pneumonia, 6 of bronchitis, 4 of consumption, 15 of venereal diseases, 6 of measles, 19 of piles and hernias, 33 abscesses, 24 wounds, and 13 of general debility. There was no case of either smallpox or plague.

In the whole Zone, including the cities of Panama and Colon, there were deaths as follows: Ninety were from fevers of all kinds; beriberi claimed 26; dysentery, 9; cerebral hemorrhage, 6; convulsions (children), 6; tetanus, 4; consumption, pneumonia, and bronchitis, 92; gastric disorders, 33; liver diseases, 5; genito-urinary diseases, 13; childbirth, 6; accidents, 9; dropsy, 7 heart diseases, 5.

To the ordinary observer the appearance of the city of Colon is much worse than that of Panama, yet its record for disease is better. Yellow fever has been comparatively rare there. Its better record may be due to its situation on an island, the surface of which is awash with sea water throughout a considerable part of its superfices. We are told by the sanitary officers that the mosquitoes which cause yellow fever and malaria do not breed in salt water. This has significance and weight in determining the general drainage system for the canal works.

The inability of the French companies' officers to enforce sanitary rules has been referred to, but this inability was not an important matter, for the then best-known health measures, no matter how thoroughly enforced, would have accomplished little of real benefit in reducing the sick list, for no one in France or elsewhere then had any conception of the present theory respecting the cause of these two maladies which decimated the newcomers at Panama. But for the United States the situation is different. The discovery of the probable cause of yellow fever, and the knowledge of the measures adopted by sanitarians to control and prevent its ravages, have simplified the task of those who are to make the canal.

The United States not only has the right granted by treaty to enforce all necessary rules of sanitation and for the preservation of order, but the authorities of the Republic of Panama have shown the most ready willingness to cooperate and assist in the efforts taken to rid the Isthmus of disease and prevent its importation.

Notwithstanding the fact that near-by Pacific ports have for several years been infected with bubonic plague, the health officers of the Canal Zone have, by means of a rigid quarantine, so far prevented this pest from obtaining a foothold on the Isthmus, and there seems to be good reason for the confidence of these officers in their ability to exclude that disease permanently. We now know that men from temperate climates living in the tropics, including Panama, can and do escape the great danger which twenty-five years ago could not be evaded, and that the danger does not appear to be greater than exists in many parts of the United States.

WORK DONE AND PRESENT CONDITIONS.

The present state of the canal work is but little different from that in which the old Panama Canal Company left it in 1889. The liquidator, who had control of the assets of the company under the decree of the French court from 1889 to 1894, did no work on the Isthmus other than that of preserving the property under his care. When the New Panama Canal Company was incorporated in 1894 it recommenced the work of excavation at the divide on a small scale and maintained those operations, with a force varying from a maximum of 3,800 men to a minimum of a few hundred, until the property was taken over by the United States Government in May, 1904. That company performed no other work in furtherance of the actual construction of the canal than the continuation of excavation at the summit divide and the dredging of about 3,000,000 cubic yards at the La Boca pier and approach thereto, although it maintained a sufficient force to care for the mass of materials and plant stored along the line of the canal.

The total work actually performed upon the canal can best be appreciated by keeping in view the plans contemplated by the French companies. In accordance with the decision of the International Scientific Congress held at Paris in May, 1879, the old Panama Canal Company adopted a sea-level plan for the canal. When, however, it became apparent that it would be financially impossible to carry out the work on that plan, a number of projects with locks and with various summit elevations were carefully considered. It was the purpose at that time to devise a project which would permit lock-canal navigation to be opened at the earliest possible date, and by the subsequent removal of the locks to ultimately realize the original conception of a canal at sea level. While these modified projects were under consideration the collapse of the old company occurred and all work ceased.

All subsequent studies conducted both by the liquidator and the New Panama Canal Company were also directed to the determination of lock plans. Both the Commission d'Études, created by the liquidator, and the Comité Technique, appointed by the New Panama Canal Company, rejected the sea-level plan and devoted their efforts to the development of a lock plan best adapted to the limiting financial conditions under which the new company would have to complete the work. The Comité Technique finally recommended a plan for a canal with a maximum summit elevation at nearly 101 feet above the sea, the bottom width of the canal being 98.4 feet in earth and 111.5 feet in rock, and with a minimum depth of water of 29.5 feet. This plan required a double flight of two locks at Bohio and another similar arrangement of locks at Obispo on the Caribbean side of the continental divide. On the Pacific slope there were contemplated duplicate single locks at Paraiso southerly of and close to the great Culebra cut, a double flight of two locks at Pedro Miguel, and duplicate single locks at Miraflores, the latter being partially tidal locks, in order to control in the canal the varying heights of the tide in the bay of Panama. In connection with these locks the plan included a Caribbean sea-level section 14.84 miles long; an intermediate level between Bohio and Obispo 13.37 miles long, in which the water surface would vary in elevation from 52.49 feet to 65.62 feet above the sea; a summit level 6.22 miles in length from Obispo to Paraiso with a maximum elevation of 100.89 feet; an intermediate level 1.32 miles long from Paraiso to Pedro Miguel with a water surface at a maximum elevation of 76.28 feet; another intermediate level 1.32 miles long from Pedro Miguel to Miraflores with a maximum elevation 20.51 feet above mean tide, and a Pacific sea-level section 7.38 miles in length, the lengths of the various levels being given exclusive of the lengths of locks. The excavation made by the New Panama Canal Company at the summit was continued, to serve the execution of this plan, although it was thought possible that a lower summit level at 65.5 feet above the sea might ultimately be adopted, so as to eliminate the locks at Obispo and Paraiso.

There was also contemplated by the New Panama Canal Company the creation of a large reservoir for feeding the summit level of its adopted plan by constructing a masonry dam across the Chagres River at Alhajuela, about 11 miles by the feeder line from Obispo. A feeding canal, or aqueduct, with suitable appurtenances, was to be formed on this line in order to connect this reservoir with the summit level above Obispo. No work, however, was ever performed either

in the construction of the dam or on the line of the feeder, but surveys and investigations were made and the necessary works were all completely planned.

The old Panama Canal Company made extensive surveys and soundings, and erected many buildings, shops, hospitals, etc., but confined its operations along the canal line wholly to the work of excavation, except for the construction of a small dry dock near the Colon terminus, and some docks or piers in the same vicinity required for the discharge of materials and machinery shipped to the Isthmus for the purposes of the work.

The country along the canal line from Colon to Obispo is nearly all low, in places marshy, and the material can generally be removed by dredging. The old company availed itself of this physical condition and, with the exception of Culebra, the greatest volume excavated in a limited distance was confined to this portion of the line. Between Cristobal Point (behind which the old company planned its canal entrance) and the mouth of the Mindi, a distance of about three miles, there is a small quantity of coral rock and a much larger quantity of hard sandy clay, which may be classed as soft rock, still remaining in place.

The depth of the excavation near Mindi and at one or two other points was about 29 feet below sea level; but the average depth for about one-half the distance from Colon to Bohio was not more than two-thirds of that amount below mean tide, while the depth of excavation for the remainder of the distance under consideration did not vary much from 25 to 27 feet. On account of the rising surface of the ground the depth below sea level was but a few feet at a distance of two miles from Bohio and decreased to nothing at that point. This stretch of canal, about 11 miles long, with an original bottom width of about 72 feet, is still open, although some sediment has been deposited, and can be navigated throughout its entire length, save at one point, by vessels drawing from eight to ten feet, and much more in that portion of it between Mindi and Gatun.

In consequence of the fact that this portion of the canal line intersects the Chagres River at a number of points, thus forming a direct course, and for the further reason that diversion channels and small dams have been constructed, the water of the Chagres River flows through this excavated channel from a point about two miles below Bohio to Gatun, a distance of about seven miles. From Gatun its flow divides, a part of it, estimated as one-third at ordinary stages of the river, passing to the sea in the old channel and the remainder flowing into Limon Bay through the canal channel and the mouth of the Mindi. The portion of the old company's canal work between Colon and Bohio and the work of excavation in the Culebra cut are the two largest and most impressive features of the accomplished work in its present condition.

At Bohio an extensive mass of volcanic rock outcrops. This rock has been used for structural purposes at Colon and along the railroad line, and in a portion of this outcrop the old canal company made an excavation of considerable magnitude for the locks which it proposed to locate there after it was compelled to abandon the sea-level plan. This excavation, like many other portions of the company's work, may be utilized in subsequent construction.

Between Bohio, 15 miles from the Colon terminus of the canal, and Miraflores, about 41 miles from the same point, the ground is relatively high, rising gradually on the Caribbean side to the continental divide at Culebra, then falling rapidly to 15 or 20 feet above sea level at the Rio Grande between Pedro Miguel and Miraflores. Throughout this distance, with the exception of that portion between Obispo and Culebra, a distance of about seven miles, the excavation made by the old company consists of a shallow but nearly continuous cutting. At several relatively high points the cuttings are deeper, but the amount in the aggregate is relatively small. From Bohio nearly to Obispo the canal line frequently intersects the course of the Chagres; but at a point a little less than a mile from Obispo the Chagres Valley trends abruptly to the northeast, almost at right angles to the line of the canal, which here follows approximately up the course of the Obispo in a southeasterly direction toward Panama. At Gamboa, less than a mile from Obispo, a short distance upstream from the point where the canal line leaves the river, both the old and the new companies at different times projected the construction of a dam for the purpose of controlling the Chagres floods and feeding the summit-level locks, but finally abandoned the idea of a dam at that site.

The present condition of the seven-mile cut through the continental divide shows that a large amount of material has been excavated in that locality, principally by the old company, but to the extent of about 7,000,000 cubic yards by the new company and nearly 1,000,000 cubic yards by the Isthmian Canal Commission during 1904–5. The maximum depth of this cutting below the original surface—333 feet above sea level—is about 165 feet. The excavated material has been deposited mainly in the Lirio marsh, about a mile northeast from the deepest part of the cut, and to a less extent in the Rio Grande Valley near Cucaracha, immediately south of the southerly end of the cutting.

The alignment adopted by the old and the new companies for the Pacific sea-level section of the canal followed approximately the course of the Rio Grande from Miraflores to La Boca. It intersected the course of the river a number of times and required small diversion channels at either side, but the Pacific terminus of the canal was practically identical with the mouth of the river. The valley of the lower Rio Grande is a salt marsh or swamp, although if the canal should be excavated to a depth of 40 feet below the sea level some rock will be encountered in the channel. The old company excavated the canal for a distance of about two miles from La Boca to an average depth of about 20 feet from the original surface, which is at nearly extreme high water. As the extreme range of tide at the Pacific terminus of the canal is from about 10 feet above mean sea level to 10 feet below, the old company planned to make the Pacific sea-level section of the canal from Miraflores to deep water 39.4 feet deep below mean tide. Less than one-third of the total requisite excavation was made between La Boca and Miraflores, nor was a channel to full depth completed by that company from La Boca to the deep water of Panama Bay. This latter work would have required the excavation of a considerable quantity of hard rock.

The old company not only excavated for the channel of the canal proper, but it also excavated diversion channels parallel with the axis of the canal on both sides of it and distributed throughout nearly its entire course, to the aggregate length of 20.2 miles on the easterly side of the canal and 13.16 miles on the westerly side. These diversion channels were constructed for the purpose generally of intercepting the flow of the streams which would otherwise discharge into the canal, and they were to be permanent features of the work. A few short lengths were designed to serve a similar purpose only during construction. The largest of these diversion channels are mostly found between Obispo and Colon, as it was necessary under the French plans to divert the entire flow of the Chagres throughout some portions of that distance. Among these is the Gatun diversion. The excavation already done in it amounts to nearly 2,700,000 cubic yards. Its length is 6.13 miles. It was designed to discharge 17,600 cubic feet per second.

The diversion channels on the easterly side of the canal line were designed with bottom widths varying from about 52.5 to 131 feet, with side slopes having in general an inclination of about 45°. The maximum depth of water contemplated in these channels was nearly 15 feet. On the westerly side of the canal line some of the diversion channels are of smaller section, varying in bottom width from about 20 feet to the same maximum of 131 feet as on the easterly side. At one point, near Obispo, a tunnel 1,203 feet in length and about 16½ feet wide and of equal height was nearly finished for diversion of the Obispo, which in flood now flows through it. A few of these diversion channels were finished, but the greater number were only partially completed. Some of them have received the waters for which they were intended and have been scoured to an increased depth, while others have been partly filled with sand or silt moved by freshets.

A total amount of about 80,000,000 cubic yards of all classes of materials has been excavated throughout the entire line of the canal, making almost continuous work from one end to the other. By far the greater portion of this excavation was soft material or earth largely removed by dredges, but a comparatively small portion of it may be classed as rock. This means that the principal portion of the remaining material to be taken out must be considered rock, and much of it as hard rock. A substantial portion of this 80,000,000 cubic yards of excavation has been so deposited along the proposed line of canal that it will have to be again moved in the work of construction, because of the greatly increased cross section of prism now required.

It is difficult if not impossible to state what portion of this excavation will be available in future construction. The entire excavation made at the divide is of this useful character, but it is probable that the aggregate of all the useful portions of the work done will not exceed 40,000,000 cubic yards.

The aggregate volume of excavation in the diversion channels will probably not exceed 5,000,000 cubic yards, but it is practically all available for the construction of a sea-level canal. The portion of the same aggregate which would be useful in the construction of a lock canal would depend upon the plan adopted.

The general location and alignment of the canal is, on the whole, satisfactory. There are places, like that in the summit cut extending from Emperador to a point near Cucaracha, where the alignment may be improved without much change of location, but necessitating increased cutting both in the hill at Emperador and that at Culebra, and an equal saving in other places. The curvature generally is sufficiently easy, the minimum radius being 8,202 feet. There is some objectionable curvature at the termini, especially near Colon, which the plan proposed by the Board will remove.

In addition to this work of excavation there were immense quantities of material, machinery, and appliances required for the prosecution of the work of construction received and distributed along the entire line. The book value of this great quantity of construction material, nearly all of which still remains upon the Isthmus in various degrees of repair, is about $29,000,000. Much of it is housed and in good order, although now nearly useless in consequence of its obsolete character, while other and larger portions of it are found exposed along nearly the entire canal in all conditions of disuse and decay.

Over 2,000 buildings—mostly houses for the employees of the old company, excellent hospitals, and some storehouses or shops—still remain, some in good condition and others in need of much repair. These buildings are generally capable of being put into service.

There are also six machine shops, some of considerable capacity, the principal of which are at La Boca, at Matachin, and at Colon. These shops contain a considerable quantity of usable machinery. They were put into service during the summer and autumn of 1904, and have since been somewhat enlarged and developed. They constitute a valuable asset, and will be of great service in repairing machinery, rolling stock, and other appliances required in the work of construction of the canal, and they have sufficient capacity for the purpose of building some of the simpler forms of plant required in the work.

NEW FIELD WORK.

The Board has had access to all the data on file in the office of the Isthmian Canal Commission. Very accurate cross sections of the canal prism included between Obispo and Paraiso, seven miles and a half, were obtained. These cross sections were taken at very close intervals where the slopes are changing; in those portions where the grade is nearly uniform and the topography unmarked by notable features the cross sections are considerably farther apart. These cross sections are used in the estimates of the Board.

It early became apparent that additional information was desirable relating particularly to the possible dam and lock sites at Mindi, Gatun, and in the vicinity of La Boca. The Board requested the Isthmian Canal Commission to have further examinations made, as follows:

1. On the Mindi line the examination to be topographic with respect to the ridge line to the east of the Mindi through to Jaramillo Hill, thence to the shores of Limon Bay, in order to develop any low passes communicating with the Chagres River, and over the Jaramillo Hill near the high ridge line to the Chagres River and across the same, connecting with the high land to the west of the Chagres. This examination to be carried up to elevation 50.

2. Borings and topography at Gatun, south and west from Gatun Hill, over the hill opposite, across the diversion channel, and to high land beyond. Also to develop lock foundations in the hill east of Gatun.

3. A survey showing the necessary relocation of the Panama Railroad in case of a terminal lake formed by a high dam at Gatun.

4. A line of soundings across the Rio Grande Valley from Sosa Hill, passing by La Boca pier, to the high land above the mouth of the Farfan River.

5. A survey and soundings on the shortest line from Ancon Hill across the high land to the east, to show the physical conditions that would influence the construction of a dam to raise the water in the Rio Grande Lake to elevation of about 65.

6. Borings to rock on saddle between Ancon and Sosa hills, and across the Rio Grande from Sosa Hill to the nearest high land, to develop the practicability of a lock between Ancon and Sosa and a dam for raising water 30 feet above sea level. Also borings along a line for the proposed Pacific section of the canal, this line leaving the old route about kilometer 63, passing straight to the saddle between Ancon and Sosa hills, thence in a straight line to deep water in the bay to or near the entrance channel now in use.

With reference to the Mindi location Mr. F. B. Maltby, division engineer, reported:

> On the west side of the canal the high ground is continuous from the Jaramillo Hill to the Chagres River. * * * From a personal examination I am quite sure that a point can be found in this vicinity where the distance across the Chagres Valley to an elevation of at least 50 feet is not more than 3,000 feet. I think it more than probable that surveys would develop a possible crossing of a shorter length. On the east side of the diversion at Mindi the hills are simply isolated knolls for a distance of half a mile east from the diversion channel. From these there is a continuous ridge which is very much broken in elevation, but in which there is no point which has an elevation of less than about 40 feet. * * * It therefore seems possible that, should such a project be contemplated, a dam might be built from the Jaramillo Hill across the canal connecting the various hills as far as the east diversion opposite Mindi. From there for a distance of half a mile it is probable that a dam having a base at an elevation of only five or six feet above the sea would require construction for half the distance. In addition to this there would be a dam across the Chagres River of about 3,000 feet in length.

In response to the request of the Board, some topographic work was done in the vicinity of Gatun, outside of the limits of the French maps. Borings were taken across the valleys along the lines indicated, and this information was forwarded for consideration of the Board. The topography and the location of the borings are shown on Plate XI, and the section as determined by these borings on Plate XII. These borings were completed across the entire valley and taken at intervals along the surface of the ground up to an elevation of about 85 feet at each end. It is noted that the elevation of the indurated clay follows very closely the irregularities in the surface of the ground. The borings were also made on the hill to the east of the Chagres for the purpose of determining a site for a lock, and this same condition generally holds, the clay being found between 15 and 20 feet below the surface of the ground.

Mr. Stevens reports, with reference to the Gatun site:

> Extreme depth, to so-called rock or indurated clay, was found in the valley at 258 feet below mean tide level and on the bank of the west diversion. Apparently there are two deep and distinct valleys or gorges in this material, with the indurated clay rising a considerable distance above the mean low tide between them. A flow of water was reached in several of these holes. Most notable ones were at station 54+51 and at station 52+67. The flow of water at the former was quite a strong one, and indicated emphatically the imperviousness of the soil overlying the gravel.

See section, Plate XII.

The borings in the vicinity of La Boca and Ancon Hill, as well as those of the marine section, are given on Plate VII. They show the practicability of a lock in the Ancon-Sosa saddle and also at the westerly foot of Sosa Hill.

The geological sections also show depths to rock at several points that have been suggested as suitable for dams required in maintaining a terminal lake in the Rio Grande Valley.

The Commission and its engineering staff responded with great promptness to every request made upon it for additional physical data.

PROJECTS OF MR. LINDON W. BATES.

Mr. Bates presents three projects, designated A, B, and B′. He does not appear to attach great importance to the elevations of the lake surfaces shown in those projects, as the latter, including the elevation of the summit levels and terminal lake levels, where those features are found, are modified to almost any extent under his general presentation.

The feature of terminal lakes is not new, indeed it is as old as the International Scientific Congress at Paris in 1879, one of the many plans proposed at that time suggesting a dam at Gatun. Again, in 1880 Mr. C. D. Ward, member of the American Society of Civil Engineers, advocated the creation of a reservoir formed by a dam at Gatun for the purpose of securing interior lake navigation. Nearly two years ago he again agitated the same question in communications to members of the then Isthmian Canal Commission, and published a paper upon the same subject in the Transactions of the American Society of Civil Engineers for May, 1904. (See Appendix I.)

Mr. Bates appears to express a preference for project B, which contemplates two terminal lakes, one on the Caribbean side formed by a dam at Mindi called Lake Chagres having a maximum elevation of water surface of 33.5 feet above mean tide, another at the Panama end formed by a dam connecting Ancon and Sosa hills with each other, and a second dam from Sosa Hill to the high ground on the westerly side of the Rio Grande estuary. A third dam would also be needed to prevent escape of water over low land east of Panama, the waters thus impounded to be called Lake Panama, with a maximum elevation of water surface of 27 feet above mean tide. He also has an intermediate lake formed by a dam across the Chagres at Bohio called Lake Bohio, with the summit level at a maximum elevation of 62 feet extending through the continental divide to Pedro Miguel.

This plan provides four lockages—one at Mindi, one at Bohio, one at Pedro Miguel, and another between Ancon and Sosa hills. A variant of the plan contemplates the removal from Bohio to Gatun of the dam forming the intermediate lake or summit level.

This project also includes two terminal harbors, one called Balboa, a small protected area formed behind a proposed breakwater from the easterly side of the southerly portion of Limon Bay consisting of two parts, the opening between forming the entrance for the deep approach channel from deep water outside to the entrance of the canal proper, which he locates at the mouth of the Mindi.

Another possible variant of this plan is indicated by placing a breakwater in two parts directly across Limon Bay from Manzanillo Point to Toro Point, with an entrance between them about 1,000 feet wide, but in the hearing before the Board Mr. Bates stated that he did not consider this breakwater necessary, and its cost is not included in his estimate of cost. (Project B.) For the reasons already stated in the section on harbors in this report it is the judgment of this Board that the outer harbor, through which the dredged approach channel lies, must be protected practically from the point of its beginning in deep water to the southerly limit of Limon Bay. This may in a measure be done by the outer breakwater shown on Mr. Bates's plan, in which case the inner one could be omitted. In making up the estimate of cost of this project the additional cost of this breakwater should therefore be included.

The general project of the harbor of Panama, forming the Pacific terminus, is much more elaborate than the harbor of Balboa. The former is to be inclosed by two great breakwaters, one starting at Guinea Point and running in a southeasterly direction to the island of Naos, and the other starting at Paitilla Point, extending first nearly due south, then southwesterly to the island of Perico. He proposes to dredge an entrance channel to the canal between the islands of Perico and Naos and running straight to the lock in the dam between Sosa and Ancon hills, the canal line nearly to Miraflores constituting a straight extension of the center line of the approach channel. This harbor is an ambitious one and includes a naval station on the north side of Ancon Hill. An entirely new site, formed by filling with the excavated material from the canal, is proposed for an extension of the city of Panama many times in extent the area occupied by the present city. He proposes some minor modifications of these projects for new harbors, but they do not affect materially the character of his harbor plans. These proposed terminal harbors are common to his three canal projects.

Project A has a summit level of 27 feet only above mean tide, maintained by two dams, one at Mindi and one connecting Ancon and Sosa hills with the high ground above Farfan Point, both of these being identical with the terminal dams of project B in location, but the former is of less height. The peculiarity of this plan is the low summit level, 27 feet above mean tide,

extending from Mindi through to the Panama terminus, a single lift lock being placed at Mindi and another in the Ancon-Sosa saddle.

The remaining project, B′, bears approximately the same relation to project B that B does to project A. As B is derived from A by inserting an intermediate lock and summit level between the terminal lakes, so B′ may be said to be derived from B by raising the summit level, introducing an intermediate lake between the Caribbean terminal lake and this level, and providing a second lock at Pedro Miguel. This project, therefore, contemplates two terminal lake levels formed by dams at Mindi and at Sosa Hill, already described in project A, with the elevation of water surface behind those dams 27 feet above mean tide; a dam at Gatun, behind which the elevation of water surface is brought up to 62, and finally a summit lake held by a dam at Bohio forming the summit elevation at 97 feet above mean tide, retained at the Pacific end by a dam and flight of two locks at Pedro Miguel. There are thus found six locks in this project, one at Mindi, one at Gatun, one at Bohio, a flight of two at Pedro Miguel, and one at the Ancon-Sosa saddle, it being understood that duplicate locks are contemplated throughout.

After a comprehensive examination and study of these various projects the Board was unanimously of the opinion that if project A alone were to be considered it could not be preferred to a sea-level plan. The low elevation of its summit brings the volume of excavation so near to that necessary for a sea-level plan that the work required, combined with that involved in the construction of the two dams and the locks, possesses no economical advantages over that required for the canal at sea level. The Board, therefore, unanimously disapproves project A.

This disapproval leaves projects B and B′ only to be considered. As Mr. Bates himself indicates a preference for project B, the Board has centered on it the greater part of the consideration given to these two plans. The Board is unanimously of the opinion that the summit level of 97 feet above mean tide of project B′ should not receive approval.

The papers, including plans and other information first submitted by Mr. Bates, did not include a detailed statement of the amounts of work required to be done or of the items of cost of the different classes of work included. Upon request of the Board, however, Mr. Bates submitted supplementary profiles and sections of prism of the three projects or parts of those projects, with a tabulation of approximate quantities of excavation required under the three different plans. These approximate quantities were not given in sufficient detail to enable the totals to be satisfactorily checked or confirmed, nor were those approximate quantities so classified as to exhibit the amounts of hard and soft material required to be excavated or the amounts of the different classes of work to be performed for the appurtenant structures such as locks, dams, and other main features. It has, therefore, been impracticable to verify the lump or partially detailed estimates of cost set forth in the papers and plans submitted by Mr. Bates. Under such circumstances it is impossible to deduce close approximate quantities of work required to be performed in the execution of the plans, or a reasonably close estimate of cost of the entire work or of its various parts. The Board has made as close a comparison as possible between the total itemized quantities of excavation submitted by Mr. Bates and the more or less corresponding quantities computed by the Board for its own purposes. It has further coordinated for use in estimating the cost of the work under plan B its own estimates of costs for such appurtenant works as locks, dams, breakwaters, and other similar main features of the canal project.

The items of excavation given in his supplementary "Graphic diagram of approximate quantities" appear to be less than those which the Board would estimate for the same purpose, but if the unit prices adopted by the Board be applied to the quantities for project B as given by Mr. Bates, the total cost of excavation alone, after deducting the useful French work, will be $85,289,500. To this sum is to be added the estimated costs of the dams and locks at Mindi, Gatun or Bohio, Pedro Miguel, near Panama, Ancon-Sosa, La Boca, and other large features of the plan, besides the breakwaters and other works at the two terminal harbors, and the regulating dams at Gamboa and other points on the Chagres, as indicated in his plans. His allowances for these various main portions of the work other than excavation seem to be insufficient. If these

works be allowed for on the same basis as corresponding works in the Board's plans the total cost of the entire project B, without adding any percentage for contingencies or other allowances, will approximate about $160,000,000. To this must be added a large but indeterminate sum for the great extent of country flooded by the terminal lakes, particularly Lake Chagres or Lake Bohio if Gatun rather than Bohio be adopted for the location of the dam creating the summit-level lake. This inundated land includes a large portion of the most valuable lands in the Canal Zone and its near vicinity. It would include many villages along the line of the railroad between Mindi and La Boca, besides lands devoted to grazing and dairy purposes as well as many banana plantations. It is quite impossible at this time to estimate the damages which the United States Government would have to pay for these submerged lands, but if past experiences in this field are any guide in making this estimate the sum would be very large. This question is also complicated by the doubtful validity of titles of many parcels of land claimed to be owned by private parties.

The land damages alluded to do not cover the lands which would be required for the regulating lakes at Gamboa and above that point on the Chagres River. While compensation would have to be made for these damages, that district is comparatively uninhabited and the amount of compensation would be relatively small; but this is an outlay practically common to all projects in which the control of the Chagres is to be effected at Gamboa or at points above.

The extended examination which the Board has given to Mr. Bates's project B fails to indicate that the work embraced by it can be completed for a sum much less than an amount nearly 50 per cent in excess of his estimate of $134,000,000, including the additional cost for the outer breakwater in Limon Bay and the same 20 per cent for contingencies, sanitation, and policing used in the other estimates of this Board. There can, therefore, be no material economy in the adoption of this plan.

At Obispo, where the Chagres cuts the canal line, Mr. Bates introduces a feature which he calls the Obispo triangle, designed to divide the flood waters of the Chagres entering the canal into two equal portions, one to flow through the canal prism toward Panama and the other toward Colon. The accomplishment of this result is practically an impossibility.

The assumption is unwarrantable that a large volume of water introduced at the middle point of a channel over 20 miles long, which in the dry season is an ordinary canal and which in the rainy season receives lateral contributions varying with the locus of local downpour, will automatically divide itself into two equal volumes flowing in opposite directions.

Water levels will determine the flow at the central point, and local deposits with erosions caused by the excessive discharges will completely destroy the conditions necessary for the equal and opposite flows which he assumes.

That some of the waters, the quantity to be determined by experience, would seek exit to the south through the canal prism is probable, and the sea-level plan contemplates such a southern diversion, but it is not claimed that it would be automatic and equal. As the distance to the Pacific is less than to the Caribbean the hydraulic gradient will be steeper, and the flow in the sea-level canal would be controlled by the regulating sluices proposed; but the diversion of any part of the Chagres flow to the Pacific is not an essential feature of said plan.

Furthermore the Board believes that the proposed method of control of the Chagres, by a number of small reservoirs at Gamboa and above that point on the river, will be less effective and more expensi maintain than that resulting from the construction of a single larger reservoir with a suitable dam at Gamboa. It is the further judgment of the Board that the proposed designs for the dams, dikes, or barrages proposed to be constructed at La Boca, Mindi, Gatun, or Bohio do not show the incorporation of such features of construction as will give reasonable assurance of their stability or efficiency for the purposes contemplated, and that a proper provision for those features would greatly swell the costs indicated by Mr. Bates.

Again, Mr. Bates has outlined no method and has apparently given no consideration to such procedures as would be required to transform the work executed under his project B to a sea-level canal, nor has he made any estimates of cost whatever for such transformation. It is

obvious, however, that the work of transformation would be very costly and that the expense of that work would swell to an excessive or even prohibitory amount the ultimate cost of the sea-level canal so attained.

This project is less well adapted for transformation to a sea-level canal than the lock plan with a summit elevation of 60 feet above mean tide adopted by the Board for comparison, although the difference between the two is not great. Such difference as exists is found chiefly in the more costly structures of Mr. Bates's project, such as the dam and spillway at Pedro Miguel and the works at the Obispo triangle, and in the less effective system of control of the Chagres floods. Much more elaborate harbor constructions and the more costly character of their appurtenant works chiefly account for the excess of the estimated cost of Mr. Bates's project B over that of the 60-foot summit level lock plan of the Board, to which allusion has already been made.

Finally, this Board believes that on the grounds of both first and ultimate economy, for safety in construction and operation, and in adaptability for transformation to a sea-level plan, the lock plan above referred to, adopted by the Board for purposes of comparison, is to be preferred to Mr. Bates's project B.

It has been urged by Mr. Bates that the health conditions would be much improved if the plan he proposes should be adopted of submerging the valleys of the Chagres and Rio Grande and converting those broad areas into fresh-water lakes. It is now the generally accepted theory of sanitarians that the mosquito which causes yellow fever breeds only in vessels and pools of fresh water in the houses and in their immediate proximity. If this is accepted as fact we should not expect that the existence or nonexistence of broad expanses of fresh water would have any influence upon the occurrence and spread of yellow fever. In the margins of lakes and ponds the malaria mosquito would breed, and on the other hand the submergence of the sites of present villages would deeply flood and destroy the present habitat of the anopheles, but they would find new breeding places in the shallow margins of the lakes; since these lakes could not be formed until the canal is completed, the health conditions as affected by the malaria mosquito would not be changed during construction. If the sea-level plan be accepted, the ultimate drainage will be far below the earth's surface nearly throughout, and the desiccation of stagnant pools and marshy surfaces near the canal will be easy. There will be no lake margins near, and the canal will at all times be the ultimate receptacle of all surface drainage and will contain only clear water flowing through a channel with steep sides, which water will, near the termini, be salt or brackish and in the dry season salt throughout. All things considered, it is not probable that the conditions as respects malaria would be materially different whichever be the plan adopted; but if there is a difference, the sea-level waterway will be more favorable to health conditions.

That the Isthmus would continue to be pest ridden unless the transit be effected through submerged valleys is rejected by the Board as without any basis of sound argument or fact. The present transit of the Isthmus, which, with voluntary and necessary detentions usually occupies at least a day, has not, so far as disclosed, for a quarter of a century been attended with jeopardy to health, and under no conceivable conditions of transit by ocean steamers is it believed that serious dangers would be incurred by the passengers and crews of the vessels. The health of the marine battalion that has been serving on the Isthmus for two years has been uniformly good. No member of the command has contracted yellow fever and there has been no death from malaria.

For all the above reasons the Board disapproves the adoption of project B of Mr. Bates's system for the construction of the Panama Canal.

PLAN OF MR. P. BUNAU-VARILLA.

Mr. Bunau-Varilla proposes to construct a lock canal with a high summit level, and after its completion to proceed with its transformation into a sea-level canal. He estimates the time required to complete the lock canal at four years, with a summit level at elevation 130. The

transformation will require a widening as well as a deepening of all channels above sea level. The widening above water is to be done first by the ordinary methods for excavation in the dry, but all excavation below water is to be by dredging. By using water power to develop electricity for the dredges and other machinery he estimates that the work can be done at a very low cost.

In a succeeding section the Board has indicated its judgment that any lock canal may be transformed in some manner into a sea-level canal, so that, if time, cost, and danger be left out of consideration, the change can be made without sensible interference with traffic. If the latter condition were observed rigidly the time and cost would be greatly increased, and it is probable, in order to avoid such extraordinary increase, that some interference with traffic would be tolerated in the process of transformation, as in many canals or navigated waterways the depths and widths of which have been increased.

Mr. Bunau-Varilla has outlined to the Board a very ingenious procedure to be followed in effecting such a transformation, with special reference to the difficulties of eliminating the locks successively and of disposing of the excavated materials. If the locks were of single lifts (as would be the case in the lock-canal project with summit level at elevation 60), he would modify their construction by placing the gate sills for the upper ends of locks at the level of the canal bottom below instead of above the lock, the latter being the usual practice. This would result in adding greatly to the weight of these gates, making them a little less convenient to operate. With locks so arranged the canal above the lock could be deepened in moderate stages, of five to ten feet for example, during which process the full depth of 40 feet of water would be maintained in the canal and no excavation would be required in depths exceeding 45 or 50 feet. After this amount of deepening throughout the summit level the water would be lowered by the same amount and the process repeated sufficiently to depress this level to those adjacent, when all the gates in the upper level could be thrown open. Before any further lowering could be commenced it would be necessary to remove the floors of the duplicate locks, one lock at a time, while open navigation would be maintained through the other.

If the locks were in flights of two or more, the modification in the original construction would not be so simple; in each lock below the upper one an additional pair of gates would be placed near the upper end, so that when the gates and floor of the upper lock were all removed and the site deepened the additional pair could be used as upper gates. Until the completion of the change the provision of additional gates would lengthen the locks about 100 feet, and thus increase the time required for filling and emptying and encroach on the water supply. The process of transforming the canal would be the same as for a canal with single locks up to the point when the gates of the upper lock are thrown open after the level above has been lowered by an amount equal to the lift of that lock. The transformation would then become more difficult, because if one lock were closed to remove the floor there would be lock navigation instead of open navigation through the other one, and if the traffic were heavy it might be necessary to build a third flight so as to have two in constant use; and the provision of a third flight might be demanded for the security of the navigation so that duplicates might always be in readiness, except during short periods when one was being repaired or the machinery refitted. It seems probable that it would be judicious to provide the third flight of locks before beginning the transformation, and if this were done any desired change could be made in the same by successively closing them to navigation until the changes were made, and with such third flight the modifications suggested by Mr. Bunau-Varilla, which would be objectionable in a lock canal, would be dispensed with.

For disposing of materials excavated during the transformation Mr. Bunau-Varilla proposes to construct a flight of locks which would connect the elevation of sea level with the surface of Lake Gamboa, and use this lake as a dumping ground for materials dredged from the canal. Such of these locks as were below the surface of the summit level of the lock canal would have to be built before any raising of the water in the Chagres, and all would have to be built before beginning the transformation. The lower locks would be submerged, and would not be used until they emerged with the successive lowering of the summit level. With this communication

with Lake Gamboa it would not be necessary at any time to pass barges loaded with excavated materials through the canal locks, and interference at the locks with navigation would be entirely avoided.

This method of disposing of dredged material is feasible but not inexpensive, and although the disposal of a large volume in Lake Gamboa would reduce to some extent its efficiency for flood control and for catching silt, the volume of the lake would be so great that this reduction would not be important. If a lock-canal project with a small terminal lake on the Atlantic side should be adopted, alternatives to the plan of disposal submitted by Mr. Bunau-Varilla would be to pass the barges with excavated material through the canal locks to sea, from which some interference with navigation might result, or to rehandle the greater part of the dredged material at various points along the canal and deposit it on the areas above water level, which would be expensive. With summit level at elevation 85, extending northward to Gatun, a vast amount of excavated material could be dumped in the low areas in Lake Gatun above Bohio until the summit level were lowered to about elevation 60, and between Bohio and Gatun until the summit level were lowered to about elevation 30. Of the relatively small amount of material then remaining, the portion suitable for suction dredging could be pumped to higher elevations and the remainder could be passed through the canal locks to sea without very serious or prolonged interference with navigation; or, if this limited interference were found inadmissible, it could be transferred from barges to cars and disposed of at some suitable dumping ground. Although the unit cost of such rehandling would be considerable, the volume would be small compared with the amount to be disposed of in a similar manner if the 60-foot level were adopted for the summit and the 30-foot level for the stretch between Bohio and Gatun.

The claim made by Mr. Bunau-Varilla that the excavation required for the transformation can be done at low cost rests mainly on the expectation that by the use of electric power, developed at the Gamboa dam and distributed along the line, the expense for fuel for generating steam will be eliminated and the cost of all mechanical operations reduced by what appears to the Board to be a much exaggerated estimate of the economies thus effected, and on the further expectation that excavation can be made at very much less cost by dredging than in the dry. This reduced cost of dredging is probably true for sand, clay, or other materials that can be moved without being shattered by some preliminary process, but nearly all the materials to be dredged for the transformation are classified in the Board's estimates as rock, and will have to be loosened by blasting under water, by breaking or pulverizing, as in the Lobnitz method, or by such other methods as may be devised. Moreover, it must be remembered that the greater part of the dredging is to be done under 40 to 50 feet of water, which will add much to the cost. The unit prices adopted by the Board represent its best judgment in regard to the cost of excavating the several classes of materials which the transformation would require with the best methods and appliances now in use. Comparison of the cost of first constructing a lock canal and then lowering it to sea level with the cost of making the latter canal at once, on the basis of adopted unit prices, shows that the removal of nearly all the material under water by subaqueous blasting or otherwise shattering, and then dredging, would cost much more than if taken out in the dry; and hence, as is shown in a following section of this report, the final cost of a sea-level canal ultimately secured by the process of transformation, and of the channel dimensions adopted, would be about $100,000,000 greater than by immediate construction, without taking into account the loss of the costly locks and other structures abandoned or demolished after reduction to sea level.

The advantages claimed to be secured by Mr. Bunau-Varilla by his method of excavation of successive strata without occupation of the navigation channel would be realized only when the side slopes are not steep, the advantages increasing with gentle slopes and disappearing as the slopes become more nearly vertical. Inasmuch as by far the greater part of the under-water excavation in his process of transformation would be made in material classed as rock, large portions of the side slopes might be as steep as four vertical on one horizontal, and a very small portion, if any of them, will be less steep than three vertical on two horizontal. It is therefore probable that little would be gained through this special feature of Mr. Bunau-Varilla's plan.

While it is possible that the actual cost might be lessened by improvements in means and methods yet to be developed, it would not be prudent to assume this and reduce the estimate given above.

Mr. Bunau-Varilla estimates the time required to build a high-level lock canal at four years. Although smaller locks than those proposed by the Board or those required by the act of Congress under which the canal construction has been commenced might be defended for a canal built for temporary purposes, they would have to accommodate war ships of the largest size as well as large commercial ships, and could not be made as small as those proposed by the New Panama Canal Company, which were to be 82 feet wide with a useful length of 738 feet. The Comité Technique estimated that the construction of the Bohio locks would require four years after the excavation was practically completed, and no shorter period has been suggested by any later commission. Mr. Bunau-Varilla's project not only provides more locks along the canal line than any other plan, but also requires the construction, as part of the original work, of those locks of the flight leading from sea level to Lake Gamboa which are founded below the summit level of his plan. Making due allowance of time to provide suitable excavating plant and to make the excavations at the several lock sites, the term of four years is far too short for the work to be done.

After a full and careful consideration of all the features of Mr. Bunau-Varilla's plan, the Board is of the opinion that it should not be adopted for the Panama Canal for the following reasons, which have already been indicated:

1. The construction of the large locks required under the present law and necessary for the accommodation of the traffic seeking the canal after its completion makes it quite impossible to complete the preliminary lock canal even nearly within the period stated.

2. The excessive cost of transformation added to the loss of costly locks and other appurtenant structures required by the preliminary lock canal.

3. If the lock canal is likely to be retained for many years it should be made for the most efficient service and not be encumbered with modifications in lock construction which would prove inconvenient in use.

PLAN OF THE ISTHMIAN CANAL COMMISSION, 1901.

This plan was submitted to the Board and has received careful consideration. The plan as described in detail in the reports of the Commission is here referred to only as respects certain features.

The depth proposed for the excavated channel was 35 feet and the bottom width 150 feet, except in Colon Harbor where 500 feet was proposed, in Panama Bay 200 feet, and in submerged excavated channels in Lake Bohio 200 feet. The summit level was to be at a maximum of 90 feet, attained by two locks on the Atlantic side at Bohio, and on the Pacific side by one at Miraflores and two at Pedro Miguel. The locks were to have a clear length of 740 feet and width of 84 feet. An earth dam with masonry core wall at Bohio was to form a lake in the Chagres Valley above that point, with elevation of surface varying from 82 to 90 feet. The alignment was the same as that of the French lock plan. The entrance to the canal at Colon required a double curvature, the radius of one of the curves being 3,281 feet. The total cube of excavation was estimated at 94,863,703 cubic yards; the cost, with 20 per cent for contingencies, was fixed at $144,233,358, and the time of completion ten years.

As stated in another part of this report, the Spooner Act authorized the construction of an isthmian canal and fixed certain conditions respecting dimensions and capacity which were not within the cognizance of those who recommended the plan of 1901. If the canal then contemplated were now in existence it would not afford passage to the largest ships now in course of construction.

The plan contemplated five lift locks—works which the Board believes should not be used if a convenient and safe passage is to be provided for the largest existing and expected vessels at a cost in time and money which is reasonable; the plan under consideration would not fulfill present and future requirements.

The Board has therefore found itself unable to recommend the Isthmian Commission's plan of 1901 for adoption by the Government, nor does it believe that any modification of that plan involving the use of lift locks should be adopted for the Panama Canal.

PLAN OF MAJ. CASSIUS E. GILLETTE, U. S. ARMY.

Among the papers submitted to the Board was an article by Maj. Cassius E. Gillette, Corps of Engineers, U. S. Army, which had been printed in the Engineering News of July 27, 1905. The article is entitled "The Panama Canal: Some serious objections to the sea-level plan." Under this heading occurs a general description of the various canal plans, ending with a description and recommendation by the author of a plan for a 100-foot summit level canal.

He states that the engineering work is best which accomplishes the desired object at the least expense, and also that the cost of a canal is made up of the first cost, with that of operation and maintenance, and the cost of enlargement, the latter being a very important matter, as is shown by the history of all existing canals. Mention is made of the work being done on existing canals at the present time, and, in the opinion of the author, the best canal would be one that could be most easily enlarged. He thinks that the lock canal can be more easily changed and its capacity increased.

He points out the advantages to be obtained by a canal with a high dam at Gatun, with reference to the elements of cost, time of construction, serviceableness, and ease of enlargement.

In his opinion the question of sediment has not been heretofore sufficiently considered, and a description of the topographical features of the country as affecting sediment in the streams is given. The problem of disposing of sediment with a sea-level canal is, in the author's opinion, a serious one.

It is alleged that large ships would have difficulty in navigating the present Atlantic entrance in the high winds which prevail in that vicinity, on account of the sharp reverse curve necessary to enter the canal. He recommends practically a straight line for the canal from Gatun to deep water in Limon Bay, almost exactly the line which has been recommended by the Board in the sea-level plan.

Objection is made to a high earth dam with a masonry core at Gamboa. He suggests that a masonry core really converts a dam from an earth and rock structure into an inefficient masonry work, and that by the stoppage of all seepage water the rock and clay above the dam become thoroughly saturated, and the large proportion of soluble clay in its composition would make it, so far as pressure is concerned, heavier than water and increase the thrust.

Major Gillette advocates a 100-foot summit level canal with a dam at Gatun. This will provide, in his opinion, a lake having an area of at least 100 square miles, subject to very slight fluctuations, and capable of settling for ages all the mud that the streams would bring into it; it would also supply all the water necessary for lockages and would give a straight channel between Bohio and Gatun.

The proposed dam at Gatun is of earth, with a core of impervious material. To prevent seepage under the dam a method is suggested of using steel sheet piles driven to a depth of about 60 feet, and then to drive, in sections to bed rock immediately alongside of this sheeting, three-inch pipes, five to six feet apart, through which is to be forced cement grout.

The project under discussion assumes a flight of three locks whose usable dimensions are 900 feet in length by 90 feet in width, with lifts of 35, 35, and 30 feet. The author thinks the prejudice against locks of greater lifts than 35 feet, based upon difficulties inherent to gates with miter sills, may be overcome by the use of floating caisson gates. The estimate for the flight of locks at Gatun is $4,900,000. It is evident that this is for a single flight of locks.

Many of the criticisms of the various suggested canal plans are the same which have been made in the sessions of the Board, whose plan is the logical development as a correction of the defects of previous plans. The Board has adopted a line for the canal from Gatun to deep water which is practically the one recommended by Major Gillette.

His criticism of a high earth dam with a masonry core at Gamboa is worthy of attention. This matter has been considered by the Board, and in its plans the proposed estimate

of the Gamboa dam has been made large enough for the construction of a dam of masonry throughout.

The dimensions of the Gatun dam are very similar to those recommended by several members of the Board in its discussion, for example, of the 85-foot summit level plan. His estimate of cost, however, appears to be too small. The Lock-Canal Committee of the Board estimated for a dam at Gatun for a lake level of this height, with its spillway and regulating works but without any arrangements to stop seepage under the dam, a total of $8,000,000. Major Gillette, for his 100-foot summit level, estimates $2,800,000. It is probable that one cause of this discrepancy is the fact that the Board has had the advantage of recent surveys, which show that the maps from which Major Gillette worked were inaccurate.

The objection to a dam at this site has already been set forth in the discussion on dams.

The Board is unable to approve the suggested method of preventing seepage under this dam on account of its cost and doubt as to its effectiveness as applied to that site.

The Lock-Canal Committee of the Board, in its estimate for the 85-foot summit level with flights of three locks each, having less lift but somewhat greater length and width, viz, 1,000 by 100 feet, arrived at the sum of $7,410,000 for each flight. It is very evident to the Board that the estimates of cost given by Major Gillette throughout his paper are very much too small.

THE 60-FOOT SUMMIT LEVEL PROJECT ADOPTED FOR COMPARISON WITH THE SEA-LEVEL PROJECT.

This plan provides for a summit level of moderate height and for corresponding dams. Such a canal could be built in somewhat less time than one at sea level. It would have duplicate locks throughout of one lift only between adjacent levels, and could be transformed into a sea-level canal with less difficulty than one with a higher summit level. For these reasons it is preferred by the Board to any other lock-canal project before it.

The proposed harbor on the Atlantic side is to be the same as described in the sea-level plan. The canal between Mindi and Gatun is to be 500 feet wide, as in the harbor, giving a broad waterway and furnishing material for an earth dam at Gatun of sufficient height to sustain a head of 30 feet. The lift at Gatun will be made with one lock. From Gatun to Bohio the channel is to be 300 feet wide, the banks generally submerged. At Bohio another dam and a lock of the same lift as at Gatun would raise the level to elevation 60. Sluices for the discharge of surplus water are provided in connection with both dams.

For the control of the floods of the Chagres and the storage of water for canal supply a dam is proposed at Gamboa identical with that for the sea-level canal. From Bohio to San Pablo, about eight and four-fifths miles, the canal is to be 500 feet wide, with channel banks generally submerged; from San Pablo to Obispo, nearly seven miles, it is to be 300 feet wide, and at the latter place reduced to 200 feet, which is to be continued for a distance of seven and one-half miles through the Culebra cut to Pedro Miguel.

The descent to the Pacific is to be made by two locks, one being at Pedro Miguel, the other six miles beyond, on the west side of Sosa Hill, near the shore of Panama Bay. The canal is to be 300 feet wide between these locks with water surface at elevation 27, the lift at Pedro Miguel being 33 feet, that at Sosa varying with the tide, being about 34 feet at ordinary low water. A spillway to discharge surplus water is proposed at the Ancon-Sosa saddle. The level between Pedro Miguel and Sosa is to be maintained by an earth embankment of considerable dimensions across the Rio Grande opposite Sosa Hill, and smaller ones in the Ancon-Sosa saddle and between the Ancon Hill and high ground to the eastward. These embankments, as well as the Gatun and Bohio dams, are to have unusual width and height above water.

In Panama Bay a short distance beyond the Sosa lock the line joins the line of the French company, and the width of 300 feet is maintained from the Sosa lock to the seven-fathom contour. The location of the canal is the same as that of the sea-level canal except a small variation at Gatun and the greater one from Pedro Miguel to the terminus in Panama Bay resulting from locating the tidal lock on the west side of Sosa instead of in the Ancon-Sosa saddle. In the narrow channel through the Culebra cut the sides of the wet section are to be vertical or nearly so; elsewhere they have slopes suitable for the material passed through. The widths above

given are bottom widths. Excluding the locks, only one-sixth of the canal is to have a bottom width of less than 300 feet. (See Plate IV, Maps and Diagrams.) It is estimated by the Board that the cost of the canal thus described, including 20 per cent for contingencies, would be $176,000,000.

SAFETY AND PROTECTION.

The general question of defense of the Isthmian transit will be in no way affected by the type of the canal.

Dismissing, then, any consideration of the question of general military defense, the Board is of the opinion that the safety and protection of the canal will be sensibly influenced and affected by its type; in estimating these influences the following considerations should be noted:

As having very important bearing upon the type of canal to be recommended for adoption, it is assumed to be of primal importance in the design of the waterway that the military necessity of the United States demands a passage between the two oceans, whereby the navy in the Pacific might be quickly transferred to the Atlantic, and vice versa; which necessity, in 1898, became so important that it had a controlling influence upon public opinion respecting the canal and had a decided influence in crystallizing ideas and in hastening final action by Congress on the whole project for interoceanic communication.

In the Spooner Act of June 28, 1902, already quoted in part, is found the only Congressional legislative requirement respecting the dimensions and protection of the canal. In that act it is provided that the canal must afford a passage for the largest existing vessels as well as for those which may be reasonably anticipated, and that this passage must be a "convenient" one, so that all "necessities" of shipping may be met. Necessary measures must be taken to insure safety and protection. The harbors to be provided must be "safe and commodious" for said existing largest vessels and for those to be expected in the future. It therefore behooves the Board to show that the type of canal recommended for adoption possesses the features best subserving adequacy in capacity, convenience and safety in use, and capability for protection.

According to Sir W. Laird Clowes's Naval Pocket Book for 1904, the largest war vessel afloat in March, 1904, had a length of 454 feet. The greatest beam noted is of 80 feet, and the deepest draft 27 feet 2 inches. However, several battle ships and cruisers are building of from 14,000 to 20,000 gross tons, and at least one of 22,000 tons, but the authority consulted does not give particulars as to size of this last, although war ships of such tonnage may well have dimensions closely approximating those of the largest existing commercial vessels. The largest war vessel building of which particulars are available has a beam of 83 feet 6 inches, but as yet there is no indication that the commercial and passenger steamers will not continue to lead in size, and therefore it results that if the channels, anchorages, and locks are adequate for the largest ocean liners and freighters, then the largest naval vessels will find adequate dimensions for convenient passage.

The beam of modern seagoing vessels furnishes a fair indication of tonnage and other dimensions. By reference to Lloyd's Register of Shipping, 1905–6, and the before-cited Naval Pocket Book, it is seen that as respects beam the large commercial and war vessels may be classed as follows:

Beam of large ocean steamers.

Beam.	Commercial ships in use.	War ships in use or projected.	Total.
40 to 45 feet	2,101	201	2,302
45 to 50 feet	1,993	139	2,132
50 to 55 feet	692	110	802
55 to 60 feet	177	83	260
60 to 65 feet	53	44	97
65 to 70 feet	26	123	149
70 to 75 feet	6	85	91
75 to 80 feet	3	81	84
80 to 85 feet		8	8
Total	5,051	874	5,925

The largest commercial steamers recently put in service are generally of less breadth than the newest naval vessels, but the former are of greater length. However, the Cunard Company has now under construction two steamers 800 feet in length and 88 feet in beam.

It has been urged in some quarters that the express passenger steamers will not make commercial use of the canal. If this contention be admitted as true, it does not follow that the capacity of the canal should be restricted as to dimensions, so shutting out this class of the ocean marine. It is understood that the requirement imposed by the statute that the canal must conveniently accommodate the largest existing and expected ships contemplated, in the opinion of the law-making power, the existence of a necessity for such dimensions which would arise in the event that the military needs of the United States may require the transfer from one ocean to the other of large bodies of troops with their equipment and supplies. In such contingency the largest express steamers obtainable would certainly be employed as transports. Military exigency requires, and it therefore results, that the dimensions of the canal and its appurtenances must be adequate for the largest vessels upon the oceans.

Between 1867 and 1906 the Cunard Steamship Company constructed 16 large ships. It is interesting and instructive to note the increasing measurements of this fleet. The ships placed in service between the years 1862 and 1874 showed 29 per cent increase in length over those in use before, and 4⅕ per cent increase in beam. In the next decade the new ships were 12 per cent longer and 30 per cent broader than in 1874. The increases in the third decade were 20 and 14 per cent. The new ships launched up to 1905 were 8 per cent longer and nearly 11 per cent broader than the largest of 1893, while those laid down in 1905 were 23 per cent longer and of 21½ per cent more beam than those in use the year before. There seems to be no recognizable tendency to discontinue this expansion of dimensions of deep-sea vessels.

The voyages from the North Atlantic ports to those of Australasia and the Orient will be the longest existing between great terminal ports and commercial marts, and if larger vessels are generally more profitable than small ones, or if very large freight and passenger vessels are used anywhere, it would seem to be certain that they will ultimately, and probably as soon as the canal is available, seek the interoceanic transit at Panama. That the convenient passage there will, within a quarter of a century, be used by ships 900 feet long and 90 feet beam seems not at all improbable.

The modern lock for ocean-going vessels is a work which an enemy, through stratagem, could with no great difficulty put out of use in an hour or in even a few minutes. If a small detachment from the enemy's fleet, armed with high explosives, landing secretly by night at some nearby shore or inlet, hiding in the neighboring jungle, should surprise the canal guards, or if a few malicious individuals in disguise should succeed in exploding against a lock gate under high water pressure as much explosive as they could carry, they could disable the lock, and could probably cause damage of such colossal magnitude as would put the canal out of use for months. This danger is one that very strict watch and guard might prevent in great measure, but it is well-nigh impossible to provide effectually and always against such peril. Sovereign rulers, bridges, railway trains, buildings, and ships, all under very strict watch, have been destroyed by lawless individuals. Guards would, of course, be always on duty at the danger points and every protective measure possible would be adopted, but if a few desperate characters should set out to disable the canal, and persist in the attempt, regardless of consequences to themselves, the peril would be very great.

As respects vulnerability of the canal or its works to injury and interruption of traffic by a few lawless individuals, the means and results are not difficult to foresee and estimate.

(*a*) The wrecking by explosives of the lock gates while under unequal water pressure, or of the valve chambers where the lock filling and emptying mechanism is situated: The remedy in the one case would consist in the removal of the wreckage and the replacement of the gates; in the other, in possibly very extensive repairs requiring much time. If the controlling gates of an upper lock should be destroyed the summit level would be drained, and if the gates were wrecked so as to afford a free outlet to the water the locks below and the canal itself would be ruined or at the least greatly damaged. In case the gates or controlling mechanism of a lock

were ruined, and free exit for the upper waters was permitted through the chamber, the lock alongside would also be emptied and put out of commission until its neighbor was repaired.

(*b*) The blowing up in a lock of a vessel offered for transit, but designedly laden with high explosives for ignition at the proper moment: In that event the lock would be destroyed, and if it was a lift lock a year or more would be required for repairs.

(*c*) The detonation of some high explosive against or under some portion of a dam built to maintain a summit level: This would be a much more difficult undertaking and one less likely to be attempted. The wrecking by explosives of the controlling and discharging sluices in dams would be easier, but a good many men and considerable time for a successful operation would be necessary. This might be a serious jeopardy at one point for a sea-level canal, but provisional repairs with timber could always be quickly effected.

(*d*) The sinking of a large vessel in the canal prism by any means: Recently the steamship *Chatham*, of 2,500 tons displacement, laden in part with blasting gelatin, met with an accident in the Suez Canal and later was sunk. It had to be blown up and removed before transit could be resumed. The time during which the canal was closed to vessels was ten days. In case of a similar incident at Panama, whether resulting from an accident as at Suez or from design, the consequences, so far as interruption of transit is concerned, might be expected to have a similar result.

The plan proposed by the Board for the isthmian transit will have twin tidal locks near the Pacific terminus which, if disabled, one or both, as under (*a*), would still be usable (after removal of wreckage) for a part of each day (the period of spring tides) in each lunar month, and probably throughout the whole twenty-four hours during the remainder of the lunar month (neap tides).

The plan also contemplates a dam at Gamboa for Chagres control, provided with regulating sluices. There are to be three small dams for the control of minor streams, but there are to be no lift locks, for these, it is claimed, both single and especially in flight, are much more vulnerable than any other essential accessory that has been proposed to be used in any type of canal that has been considered by the Board, and this jeopardy is considered to be a very grave one.

Respecting the liability of the canal to injury and the importance of its defense, the Isthmian Canal Commission in its report dated November 16, 1901, said:

> It is always to be borne in mind that during the excitement of war the canal will not be a safe place for the man-of-war of any nation, no matter who is nominally in control. A small party of resolute men, armed with a few sticks of dynamite, could temporarily disable it without very great difficulty.

The Board believes that this jeopardy will exist at all times during the stress of war.

If an interruption to traffic from any cause should occur while military and naval operations by the United States were in progress, calamitous results would inevitably ensue. If the two belligerents did not include the United States—the custodian of the canal—the closing of the passage might be attempted by one or both the contending powers, and while it would not be done openly, their secret agents would probably conspire to its accomplishment. Such an attempt was feared at Suez while the Russian fleet was passing through that canal en route to the East, and special precautions to guard against the danger were taken by the canal officials and the Egyptian Government. That the risks would be very much greater for a canal in which lift locks are an essential feature is self-evident, and in the opinion of the Board such devices should be rigorously excluded from the design of the canal.

TRANSFORMATION OF A LOCK CANAL INTO A SEA-LEVEL CANAL.

The instructions of the President to the Consulting Board under date of September 11, 1905, contain the following inquiry:

> I desire also to know whether, if you recommend a high-level multilock canal, it will be possible after it is completed to turn it into, or to substitute for it, in time, a sea-level canal without interrupting the traffic upon it.

The Board is of opinion that is is possible to transform a lock canal into a sea-level canal without material interruption of traffic and without serious delays to navigation, although the

operation would not be an easy one, nor can a trustworthy estimate of its cost be made at the present time. The work evidently involves the excavation of immense quantities of rock and earth, much of it at depths considerably exceeding 40 feet below the surface of the water. The Board, having in view the removal of rock at depths less than 40 feet, has adopted as the price for excavating rock under water $2.50 per cubic yard, while for rock excavated "in the dry" it has adopted $1 and $1.15 per cubic yard, except in the Culebra divide cut, where for all classes of materials above elevation 10 a price of 80 cents per cubic yard has been adopted, and for all classes of materials below elevation 10 a price of $1.25 per cubic yard. For the dredging of earth from the canal a price of 25 cents per cubic yard was adopted as against 40 cents per cubic yard for earth in the dry.

As rock is the predominating material to be excavated in depressing the canal from a lock level, it is obvious from the unit prices adopted that a sea-level canal obtained by first building a lock canal would cost very much more than a sea-level canal constructed by a direct process.

An approximate estimate of cost of reducing a lock canal with a terminal lake on the Atlantic side formed by a dam at Gatun, with three locks on the Atlantic side and three on the Pacific, and with a summit level 85 feet above mean tide, to a sea-level canal with the dimensions of prism adopted for the sea-level plan, may be made as follows:

64,500,000 cubic yards earth, kilometer 8 to kilometer 46, at $0.25	$16,125,000
13,400,000 cubic yards rock under water, kilometer 8 to kilometer 46, at $2.50	33,500,000
14,200,000 cubic yards excavation above water in Culebra section, at $0.80	11,360,000
6,500,000 cubic yards rock excavation in Culebra section from surface of water to 25 feet below, at $1.50	9,750,000
35,300,000 cubic yards rock excavation in Culebra section more than 25 feet below water surface, at $2.50	88,250,000
Add for dams and diversion channels and for transforming section of canal between Pedro Miguel and Miraflores, say	25,000,000
Add for removing the locks at Gatun and Pedro Miguel, for modifying the lock at Miraflores, and for removing the regulating works at the Gatun dam and at Miraflores, say	25,000,000
Total cost of transforming lock canal to sea level, on basis of canal sections of Sea-Level Canal Committee, without allowance for contingencies	208,985,000

After a full and careful consideration of all phases of this question the Board has reached the following conclusions:

1. That it is possible to turn any lock canal which it has considered into a sea-level canal without interrupting the traffic upon it.

2. That it is practicable from an engineering standpoint to transform any lock canal which it has considered into a sea-level canal; but that the cost and difficulty of such transformation would be so great as to render such a change impracticable from a financial standpoint until the traffic should have so increased as to tax the capacity of the lock canal, or until other good and sufficient reasons existed for such a change.

3. That if a sea-level canal is to be constructed in the near future it should be built directly without first building a lock canal.

4. That the date for developing a sea-level from an existing lock canal would be so remote, and that there would be so little difference in the time and cost of the transformation for different types of lock canals with a common summit level, that the design of a lock canal should not be controlled by the view that it is subsequently to be so transformed.

5. That the Board is unable to express any definite opinion as to the time required to effect such a transformation into a sea-level canal.

CAPACITY OF CANAL FOR TRAFFIC.

The Board considered that the provisions of the law of Congress by which the construction of an isthmian canal was authorized required that this law should furnish the basis upon which all deliberations should proceed and upon which every conclusion should be established.

The terms of the particular portion of the law which affected the conclusions arrived at by the Board in respect to the dimensions which should be given to the canal locks and prism were conveyed to the Board in the letter signed by Mr. Shonts and printed on pages 10 and 11

of this report, in which the Isthmian Canal Commission laid before the members certain projects for the construction of the canal which had already been submitted to the Commission. The terms relate to the excavation, construction, and completion of a "ship canal from the Caribbean Sea to the Pacific Ocean," and proceed "such canal shall be of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use, and such as may be reasonably anticipated, and shall be supplied with all necessary locks and other appliances to meet the necessities of vessels passing through the same from ocean to ocean."

Having these terms as well as "the rapid developments of naval architecture" referred to by the Commission in the letter of its Chairman in view; having noted that steamers of a length of 740 feet over all and a breadth of 75 feet are at present engaged in ocean navigation, while vessels of a length of 800 feet by 88 feet in breadth are now actually being built, and having the assured opinion that naval development has by no means come to an end, the Board arrived at the following conclusions:

1. That the locks on a canal of any type should be of such usable dimensions as will afford a length of 1,000 feet, a breadth of 100 feet, and a depth of 40 feet.

2. That the prism of the canal for the length to be excavated through the divide (i. e., the length usually known as Culebra cut) should have a depth of 40 feet, a bottom width of 200 feet, and sides with slopes of about ten vertical to one horizontal.

It is considered that with such dimensions the Panama Canal will meet the necessities of the traffic which will use it and the requirements of the law which authorized its construction. It is further considered that if the canal were formed with smaller dimensions than these, experience would prove it to be regrettably deficient in capacity.

The following particulars of existing maritime canals may be useful for the purpose of comparison when regard is had to the fact that not one of these canals is capable of accommodating steamers of the largest draft now employed in the world's trade:

Suez Canal, Egypt.—The Suez Canal presents the nearest analogy to the case of the Panama Canal. It is a sea-level canal without locks, and has a depth of 31 feet 2 inches, which is now being increased to 34 feet 5 inches. The bottom width in the canal proper varies from 108 feet, where the side slopes are very flat, to 118 feet, where the side slopes are steeper, with garages or passing places at intervals for vessels of very large size, as vessels are not allowed to pass each other while both are in motion. In order to avoid this difficulty widening operations are in progress, by which the passing places will be united and the bottom width of the canal increased to a minimum of 147 feet 6 inches.

The largest commercial vessels which navigate the Suez Canal are about 600 feet in length over all by 67 feet 3 inches in beam, with a draft of 27 feet. War vessels of 76 feet beam have passed.

Amsterdam Canal, Holland.—The Amsterdam Canal has only one pair of locks, at Ymuiden, which form the entrance to the canal from the North Sea. The dimensions of the largest lock are 738 feet by 82 feet by 31 feet 2 inches.

The bottom width of the canal is at present 115 feet, which is being increased to 164 feet, and the depth is 27.9 feet, which is being increased to 32 feet 2 inches. The total length of the canal is 15.4 miles.

Manchester Ship Canal, England.—The entrance to the Manchester Ship Canal is controlled by tidal locks, of which the largest is 600 feet long by 80 feet wide. The locks in the length of the canal beyond the influence of the tide are 600 feet in length and 65 feet wide. The falls at the locks (i. e., the differences between the respective high and low levels) vary from 15 feet to 13 feet.

The ruling width of the bottom of the canal is 120 feet, which is gradually being increased to 180 feet, and the depth at low water is 26 feet, which is now being increased to 28 feet.

The length of the tidal portion of the canal is 21 miles and of the portion beyond the influence of the tide, 14 miles, making a total length of 35 miles.

The largest vessels which now navigate the Manchester Ship Canal are 490 feet in length over all by 58 feet 2 inches beam.

Kaiser Wilhelm Canal, Germany.—The Kaiser Wilhelm Canal is furnished with tidal locks at each terminus. The dimensions of the locks are 492 feet by 82 feet by 32 feet.

The bottom width of the canal is 72 feet, with frequent passing places, and the depth is 29 feet 6 inches at mean water level.

The length of the canal, which, as will be seen, affords a single-way navigation, is about 60 miles.

St. Marys Falls Canal, United States.—The St. Marys Falls Canal is not a maritime highway. It connects Lake Superior with Lake Huron and thus forms a link in the great lake navigation system of North America.

It was opened to navigation for vessels of 12 feet draft in 1855. There were then two locks in flight, each 350 feet long and 70 feet wide. Enlargements to meet the growing needs were begun in 1870, and in 1881 the canal was completed, so enlarged in dimensions as to pass vessels of 16 feet draft, and a lock was constructed 515 feet long and 80 feet wide. The capacity of the new waterway was soon seen to be insufficient, and in 1887 the first locks were removed and in 1896 a new one was put into commission 800 feet long, 80 feet wide, and 22 feet over the miter sill, the canal approaches being deepened to 25 feet.

In 1895 a canal on the Canadian side of the boundary was opened with a lock 900 feet long, 60 feet wide, and 22 feet over the miter sill. But the passage has again become inadequate, and a lock with a length of 1,400 feet, a width of 80 feet, and a depth of 25 feet is about to be constructed on the American side, for which purpose the 515-foot lock is to be removed, the new one to occupy its site.

The canal proper is only one and three-fifths miles in length, but the improvement in the lake channels extends over a length of 34 miles. The width of the canal varies from 108 feet at the narrowest place to 1,000 feet at the lower entrance. The widths of the river channels vary from 300 to 600 and 1,500 feet. The depth of the canal is 25 feet and that in the channels is 21 feet. The largest vessels which now use the St. Marys Falls Canal are 569 by 56 feet, with a draft of 20 feet.

It will be observed that in the case of each of the foregoing canals (except the Kaiser Wilhelm Canal) operations are in progress for the widening and deepening of the waterways, experience having shown that growth in the dimensions of ships has advanced far more rapidly than was conceived to be possible when the canals were projected, and therefore that their original dimensions were insufficient for the exigencies of modern traffic. There is, so far as the Board is aware, no example on record of the promoters and designers of a maritime highway having had occasion to regret that they had given too great dimensions to the highway, but there are many cases in which they have found that dimensions originally regarded as ample have been proved to be far too meager.

As this report is being written the public press announces that orders have been given by the Imperial Government of Germany for the preparation of plans for the enlargement of the Kaiser Wilhelm Canal.

A just estimate of the growth of traffic on the Panama Canal can not be formed from the statistics of the growth of trade on any existing waterway. The unprecedented increase in the population of the world which has taken place as civilization has advanced—it is generally agreed that the civilized population of the world was doubled in the course of the nineteenth century—and the movement of the surplus population westward, i. e., from Europe to North and South America, must of necessity not only proceed but proceed at an accelerated rate, so that the growth of trade on the interoceanic highway will not be, as in the case of the Suez Canal, merely due to the expansion of the volume of commerce which takes place year by year as facilities are presented for the movement of commodities, but to that expansion multiplied by the increasing requirements of a constantly expanding industrial population.

It is therefore essential that the Panama Canal should furnish a double road for traffic throughout, and we consider that the locks should be built in pairs; that twin locks should lie side

by side, and that the different lengths of the canal should be of such dimensions as to permit two of the ordinarily large-sized commercial steamers to pass each other at any part of the journey.

When the canal is used for the transit of large line-of-battle ships or commercial vessels of largest size, all other vessels should be moored to one side so as to leave those great vessels as clear a course as practicable.

THE CONTROL OF THE CHAGRES AND OTHER STREAMS.

The Chagres has been considered to be an element of great difficulty in the construction of the Panama Canal from the earliest stages of discussion of the project. Its general character above Bohio is that of a clear mountain stream, although that observation is more applicable above Gamboa than below that point, its watershed being much more mountainous in its upper portions than between Gamboa and Bohio. The entire area drained by this stream has never been determined, even with approximate accuracy, but it has been considered under various estimates to range from 700 to 875 square miles above Bohio, or from 450 to 625 square miles above Gamboa. The adoption of the latter as the site for the dam of the great controlling reservoir makes it necessary to consider, in connection with the problem of control of the Chagres, only the watershed above the dam, but provision has been made for the control or diversion of all the streams contributary to the Chagres from Gamboa to the Colon terminus.

The entire watershed of the river above Gamboa is bold and quick, so that a heavy downfall of rain within its limits results in a rapid rise of the river. Inasmuch as the total annual precipitation in the Chagres watershed may reach from 100 to 125 inches, it is obvious that under existing conditions of run-off severe floods may be expected, although the river is not a large one. Nearly the entire watershed under consideration is heavily wooded, with a density of vegetation characteristic of a tropical country, and the steep clayey and rocky slopes afford all the conditions required for a rapidly varying stage of river in the rainy season.

At the site of the Gamboa dam, 30 miles from Colon, the river bed has an elevation of about 50 feet above mean sea level, but the deepest rock is at practically sea level, making it necessary to sink the foundations of a dam to a maximum depth of only 53 or 54 feet below water at the low stages of the river before finding material on which to form a suitable foundation bed. At the proposed site of the dam the high hills approach each other within 2,020 feet at an elevation of 180 feet and within 1,170 feet at the bottom of the valley. The earth overlying the rock is of moderate depth, so that the conditions are favorable for the construction of any type of dam which may be adopted.

Fortunately for the solution of the problem of control of the river, more data regarding rainfall and river flow have been collected by observations at Gamboa than at any other point in the river's course. The location is also well adapted for the construction of a dam to serve the purposes of controlling floods or feeding the canal, and for the development of a power plant to drive electrical machinery for lighting, operating the Panama Railroad, and for other purposes, as it is the point at which the river in its flow toward the sea first cuts the line of the canal. If, therefore, the control of floods is satisfactorily accomplished at Gamboa, there remains to be considered only the discharge of contributary streams below that point, which in the aggregate is relatively so small that its control is a matter of little difficulty or expense.

Observations, more or less complete, of the discharge of the Chagres River at Gamboa have been maintained from 1882 to the present time. Its flow in the dry season may fall to less than 300 cubic feet per second, while in the flood of 1879 it is supposed to have risen for a short period to nearly 80,000 cubic feet per second. During the past fifty years there have been six severe floods, all of which have occurred in the months of November or December—that is, toward the end of the rainy season. The following table gives some of the main elements of these various floods as they have occurred at Gamboa:

Date of flood.	Cubic feet per second.		Height above low water at Gamboa.	Period when discharge was above 20,000 cubic feet per second.
	Maximum.	Maximum average in 48 hours.		
November—			*Feet.*	*Hours.*
1879	78,614(?)	65,000(?)	36.65(?)	.....
1885	64,488	43,404	31.50	46
December—				
1885	44,923	32,421	24.11	43
1888	58,132	48,278	31.37	58
1890	65,371	34,752	31.82	35
1893	43,086	27,971	25.33	32

The data relating to the floods between 1885 and 1893 have been deduced from accurate observations; but such is not the case with that of 1879, the greatest of all. No hydrographic observations along the river were made at that time, but certain high-water marks were approximately determined subsequent to the flood, largely from such information as could be obtained from the memory of ordinary observers. These have been compared with high-water marks of floods since 1879, whence maximum discharges at Bohio have been estimated and corresponding maximum discharges at Gamboa inferred from them. The approximate results given in the above table for the 1879 flood are those which have been found in this manner by the careful work of Gen. Henry L. Abbot, member of the Board.

Certain general results of value in connection with the problem of the Chagres River at Gamboa follow from an inspection of the preceding tabulation. It is seen at once that the maximum discharge of any flood of record during the past fifty years has not exceeded about 65,000 cubic feet per second, but that the approximate maximum discharge of the 1879 flood reached nearly 79,000 cubic feet per second. Inasmuch as there have been but six severe floods in half a century, it is obvious that they are of infrequent occurrence.

The next important conclusion established by this long record is the fact that these floods are of short duration. A discharge in excess of 20,000 cubic feet per second has never been observed to last more than 58 hours, although that limit may have been exceeded in 1879. It is convenient, in view of this fact, to deduce the maximum average discharge for a period of 48 hours in each case, as the resulting aggregate volume will represent what may practically be considered the total flood flow of the river. The third column of the table shows that the maximum average 48-hour discharge in the six severe floods has ranged from about 28,000 cubic feet per second to an estimated maximum average of 65,000 cubic feet per second for the flood of 1879. Finally, the greatest high-water elevation above low water during these floods is seen in the fourth column of the table to vary from about 25 feet to the estimated elevation of 36.65 feet for 1879. The preceding data are sufficient for the determination of complete reservoir control of the Chagres floods by a dam at Gamboa.

A reservoir created by the proposed dam may have two important functions—that of control only, in the case of a sea-level canal, and those of control and water supply in the case of a lock canal. It will be seen that if the reservoir is of sufficient capacity to control satisfactorily the floods of the Chagres, there will be abundant storage capacity for supplying the summit level of any lock plan.

In providing reservoir capacity for the control of the Chagres floods, it is to be borne in mind that two floods may follow each other with only a short intervening period, and that such a succession of floods may be both preceded and followed by comparatively high water in the river, although not sufficiently high to be considered a flood flow. It is obviously impracticable to estimate the severest combined effects of such conditions for the future, but the observed records of flow during the past twenty years are sufficient to make an entirely safe provision for any exigency of combined high water and flood flow, especially in view of the fact that two

severe floods, like either of those of November, 1885 or 1888, in close succession have never been observed in such a connection, not to cite the phenomenal flood of 1879.

If a dam be constructed at Gamboa with an elevation of its top at 180 feet above mean sea level, or 130 feet above the river bed, and if the highest flow line of that reservoir be taken at 170 feet, the area included within that flow line will be 29.47 square miles. With the minimum depth of water of 40 feet provided for the sea-level canal, the minimum wetted cross section would have an area of over 8,000 square feet, so that if 15,000 cubic feet of flood water per second from the Chagres be permitted to enter the canal prism at Gamboa, the resulting current, if the entire quantity admitted flows in one direction, will be but one and one-fourth miles per hour, a negligible quantity so far as its effects upon navigation are concerned; but the plans for a sea-level canal contemplate a provision which would permit the discharge through the canal prism and regulating sluices near the tidal lock on the Pacific side of approximately one-third of this Gamboa discharge, and to that extent, at least, dividing the flow between the two oceans and consequently reducing the current velocity. For the purposes of estimation in connection with this problem of flood control the Board has therefore assumed that the controlling sluices to be provided in the Gamboa dam may admit the flood waters of the Chagres to the canal prism at the uniform maximum rate of 15,000 cubic feet per second.

If a flood should occur with a discharge equal to that estimated for 1879, viz, 65,000 cubic feet per second at Gamboa for a period of forty-eight hours, and if a uniform outflow of 15,000 cubic feet per second be permitted during the same time, there would be accumulated in Gamboa Lake 8,640,000,000 cubic feet of water which is that portion of the volume of the lake included between water surfaces at elevations of 159 feet and 170 feet above sea level. Furthermore, a uniform outflow from the lake at the rate of 15,000 cubic feet per second would discharge the entire maximum average 48-hour flow of the 1879 flood in 8.7 days. It is seen, therefore, that there would be no practical difficulty in depressing the surface of the water in Gamboa Lake between two severe floods sufficiently to receive the entire maximum average 48-hour flow of such a phenomenal flood as that of 1879.

The capacity of flood control provided in such a lake as that under consideration is further illustrated by the fact that its volume between water surfaces at 108 and 170 feet above mean sea level is sufficient to take the aggregate discharge of three times the maximum average 48-hour flow of the 1879 flood without any water escaping through the regulating sluices of the dam; or the volume between elevations 128 feet and 170 feet will hold three times the flow of such a flood if a uniform discharge of 15,000 cubic feet per second be permitted concurrently through the regulating sluices.

These computations demonstrate conclusively that the controlling capacity of the Gamboa Lake as proposed by the Board is ample for all the exigencies of flood flow which can ever occur in the Chagres River without any other regulating or controlling aid, especially when it is observed that the highest mean monthly discharge for the rainy months of any year since 1890 (for 1892) is a little less than 5,300 cubic feet per second. There would only be required a simple grade of supervision, under which the water surface would always be depressed immediately after any flood low enough to receive any subsequent sudden flood flow which might possibly occur. This grade of supervision requires no special estimation or prevision of future events, but is quite within the ordinary administration of this feature of canal maintenance and operation.

The elevation of water surface assumed at 170 feet is sufficient to permit the use of an open channel between the Chagres watershed and the headwaters of the Gatun River for the discharge of surplus flood waters in that direction, should it ever be required. The controlling capacity of the Gamboa Lake, however, is so complete and satisfactory that the Board does not believe that it will ever become desirable to construct this open channel across the divide between the Chagres and Gatun watersheds.

The Gamboa Lake affords complete regulation and control of the Chagres River above Gamboa. It has already been stated that there are small streams now discharging into the Chagres River below Gamboa which must be taken care of during the construction of the canal. Ample provision has been made for the control of these smaller streams, either by utilizing the

diversion channels planned by the old French company and now partially constructed or by constructing dams across their courses high enough to compel them to reverse their flow and discharge through the divides at the heads of their watersheds. Among the latter class are the Caño Quebrado and the Gigantito, the reverse flow of which would be discharged into the headwaters of the Trinidad and the Gigante, whose reverse flow would be turned into the basin of the Peña Blanca marsh and pass on to the sea through the Chagres channel and its existing diversion. The Gatun River (sometimes called the Gatuncillo) would discharge its waters and those of the Mindi through the Gatun diversion, nearly completed by the old company, into that part of Manzanillo Bay known as Puerto Escondido. After the completion of the canal the aggregate observed flood discharge of all the streams entering it below Gamboa—the Caño Quebrado, Gigante, and Gigantito being diverted as hitherto observed—would amount to less than 4,000 cubic feet per second (see p. 240, Report of the Isthmian Canal Commission, 1901), a quantity that would exercise no material influence upon currents in the canal channel.

A similar observation will apply to the aggregate flood flow of the small streams between the Culebra cut and the Panama terminus, which may be taken into the canal prism at the completion of the work, but which would be controlled by diversion channels now largely excavated and by other temporary works of a simple and inexpensive character during construction.

The difference between the flood discharge of the Chagres at Bohio and at Gamboa, which discharge is partly observed and partly estimated, is stated by General Abbot to be 34,000 cubic feet per second, while the gauged flow of the contributing streams between Gamboa and Bohio is given by him as 26,335 second-feet.

Taking the flood flow of these streams at 32,000 second-feet, it is found that the maximum current velocity in the canal—which would be at Bohio due to the flow of said streams which are not diverted, together with 15,000 second-feet coming from the upper Chagres through the sluices contemplated—will be but 2.64 miles per hour, a velocity which will not interrupt navigation. As a part of the upper Chagres discharge will flow to the Pacific, and as the highest mean monthly discharge of this river in the rainy season at Gamboa is but 5,300 second-feet, as General Abbot points out, the currents in the canal will usually not exceed one mile per hour, and at extreme low water in the river there will scarcely be a perceptible current. At such times the water in the canal prism will be brackish, without currents save as influenced by the insignificant Caribbean tide.

The tributary streams, whose beds at point of junction with the canal are considerably above the prism of the latter, will be discharged over masonry-stepped aprons or through metallic discharge pipes, or these beds will be sloped and lowered so as to prevent objectionable currents at junction points. The means for the accomplishment of these results are such as are in common use on nearly all important canals.

During three-fourths of the time these streams discharge an insignificant amount of clear water. When they are in flood they will bring down some silt, and it is recognized that the maintenance of the navigable canal channel will require a small amount of dredging.

DAMS.

The consideration of the projects presented by Mr. Bates, Major Gillette, and others has raised certain questions regarding the types of dams, which the Board believes can better be treated as an independent subject than in connection with the plans presented by Mr. Bates or others, especially as some of these considerations bear also upon the design of the dam at Gamboa recommended for construction in the sea-level plan.

In these projects or plans it has been proposed to retain terminal or other lakes by earth dams resting upon the natural soil, consisting of sand, gravel, or sandy clay; or, as at La Boca, at the Panama end of the canal, upon mud and silt between San Juan Point and the easterly shore of the Rio Grande estuary near Sosa Hill, also between Sosa and Ancon hills. Under some of these dams or dikes the plans or proposals indicate that shallow sheet piling might be used in some cases, and in other cases that feature is absent. There are grave reasons for

doubting the stability of these types of structures under such circumstances. The earth dams which have already been built for the retention of large bodies of water, some of them exceeding 100 feet in height, show that this type of structure may give satisfactory results when properly designed and constructed, but the character of the foundation material on which such dams are built and the means for preventing dangerous seepage underneath or through such foundations must always be carefully considered. The earth dams which have been proposed for terminal lakes at the Caribbean and Panama ends of the canal are proposed to be placed directly upon the natural soil at Mindi or Gatun, near Colon, or on the silt, mud, and clayey material at La Boca, near Panama. It has not been proposed to dredge out the soft and yielding material at either place other than possibly a shallow strip of the natural surface, nor has it been proposed to sink a curtain either of masonry or of timber, such as deep sheet piling or of any other material, to cut off percolation or seepage underneath the structure.

These are disquieting considerations in the design of dams to retain water of depths varying from 30 to possibly 85 feet or more. The subsurface material at Mindi and at Gatun, extending down to the hard indurated sandy clay or soft rock, attaining a maximum depth of 258 feet, is in large part of a comparatively fine character, consisting of sand and clay in varying portions and in various degrees of admixture, but the borings have also shown coarse sand and gravel with water flowing through it and out of some of the pipes used in making the examinations. As a presumption or speculation it may be stated as probable that most of this material under the weight of an earth dam would be so nearly impervious that only a small or negligible quantity of water would find its way through, even with the increased head of the reservoir; but that is simply conjecture.

It is more than possible, it is highly probable if not certain, that at various points the material is sufficiently loose in texture to permit seepage or percolation in dangerous quantities. Nothing is more common in the sandy deposits of river valleys and in all sandy material than small passages or channels through which water moves, varying in size from thread-like openings to those sufficient to yield flowing wells of large discharge. Extended experience in dealing with the underground flow of subsurface waters in many places in the United States, and wherever investigations in that field of hydraulics have been made, shows this to be the case.

Vast volumes of water are daily taken from subsurface sands, and have been for years, for the public water supply of many cities in the United States, prominent among which is the borough of Brooklyn of the city of New York. All such experience indicates conclusively the danger of depending upon stopping, or even materially diminishing, such a flow by the weight alone of any superincumbent mass of earth.

The assumption of negligible seepage or percolation below these earth dams must necessarily be based upon the practically uniform quality or distribution of the material claimed to be essentially impervious. It is safe to state that this is never the natural condition over any considerable portion of a profile at the site of a great dam. The fine or coarse sandy or even gravelly material found in such locations has been deposited under radically varying conditions of floods and resulting currents separated by low-water intervals, so that it is physically impossible that even practical uniformity either as to kind of material or rate of deposition should result. The inevitable consequence is the great variation in strata, more widely different at some locations than others, but in all cases there is a wide departure from uniformity. It is one of the early and marked experiences in the construction of filter beds that the most scrupulous care must be taken in placing the sand or other filtering material so as to avoid variation in its character or its density of texture. If there is a lack of uniformity or a place at which a surface of separation between two portions of material of different character or variation in compactness exists, the water invariably finds such passages of decreased resistance to flow, and forms for itself small channels through which it escapes with readiness without being filtered. Indeed, the degree of care which is required to accomplish the uniformity of texture or compactness necessary for a proper flow without these small channels is shown by the fact that men are frequently forbidden to walk over the surface of a new sand filter, so as to avoid the

separating surfaces between the increased compactness under the foot and the looser material surrounding the footprint.

A careful consideration of these conditions of actual experience will show that any computations apparently indicating that the seepage or percolation taking place through a great geological profile like that at the sites of the proposed dams at Mindi, Gatun, Bohio, Gamboa, or at any similar location, are based upon assumptions without any warrant in engineering experience and involving the grave danger of excessive percolation under an earth dam.

The dam at La Boca between San Juan Point and Sosa Hill, unless carried down to bed rock at that location, would be placed upon a far worse foundation even than that proposed at Gatun or Mindi. The La Boca site is one covered by an ooze of mud and silt, with some sandy material overlying the rock. It is practicable to construct here an earth dam, with a heavy masonry core running down to bed rock, whose stability would be beyond question. Such a structure would be far more costly than a great mound of earth placed upon the mud and silt forming the natural bottom of the Rio Grande estuary. Unless some feature equivalent to that of a heavy masonry core characterizes the design of the dam at this point, or unless resort be made to dredging down to bed rock or near to it and refilling with suitable material, or an earth dam at this location be made very massive, it would be in grave danger of being pushed bodily out of place by the pressure due to the head of water in the reservoir.

The nearest approach to the earth dams which have been advocated in these localities is the great north dike or embankment of the Wachusett reservoir, a part of the new Boston water-supply system very recently constructed by Mr. F. P. Stearns, a member of the Board. In that case, deep and heavy sheet piling or deep excavation of the natural soil with refilling of suitable material was employed to prevent seepage or percolation wherever it was apprehended that the nature of the substrata was such as to permit it. It is the judgment of the Board that such safeguarding features as core walls, sheet piling, or the removal of unsuitable material should not be omitted in similar structures on this work of extraordinary magnitude and supreme importance.

The United States Government is proposing to expend many millions of dollars for the construction of this great waterway, which is to serve the commerce of the world for all time and the very existence of which would depend upon the permanent stability and unquestioned safety of its dams. The Board is therefore of opinion that the existence of such costly facilities for the world's commerce should not depend upon great reservoirs held by earth embankments resting literally upon mud foundations or those of even sand and gravel. The Board is unqualifiedly of opinion that no such vast and doubtful experiment should be indulged in, but on the contrary that every work of whatever nature should be so designed and built as to include only those features which experience has demonstrated to be positively safe and efficient.

The considerations of these and other reasons have prompted the Board to recommend at Gamboa either an earth dam with a heavy masonry core carried down to bed rock, or an all-masonry structure founded at the same depth and upon the same material.

THE SEA-LEVEL PLAN RECOMMENDED BY THE BOARD.

(a) ALIGNMENT AND DESCRIPTION.

The width of the Isthmus at Panama is less than at any other point where it is feasible to construct a canal open throughout between the oceans. The width, less than 36 miles in a straight line, is only five miles greater than at the narrowest place, San Blas, but an open cut is impracticable there. The summit on the Panama route, which was 333 feet above the sea originally, is lower than at any other known point between the Arctic Ocean and the Straits of Magellan, Nicaragua only excepted, while at the latter place, by reason of the greater distance between the oceans, the volume of material to be removed to form a lock canal is much greater than at Panama, and a sea-level canal is obviously impossible. At Panama alone is a sea-level canal in open cutting feasible, and the Board has no doubt of the practicability of such a canal.

The general direction of the Isthmus in this vicinity is nearly northeast and southwest and the general route for the canal nearly northwest and southeast. The summit at Culebra lies about nine miles from Panama Bay, and the distance between the point on the northern approach to this summit where the present elevation on the proposed canal axis is 100 feet above sea level to the point on the southern approach to Culebra at the same height is nearly nine miles. Within this distance will be found nearly one-half the total excavation required to make an open channel at the sea level adequate in dimensions and capacity to pass not only the largest existing commercial and naval vessels, but the largest which may be expected to require transfer between the Atlantic and Pacific oceans.

The line adopted by the Board for the sea-level canal which it recommends for construction is in general that which was adopted by both the old and the new Panama Canal companies for their projects. While the Board approves this alignment for the purposes of ultimate construction, it believes that further examination should be made for the reduction of curvature and for other improvements of the line in detail, particularly at the deepest portion of the Culebra cut. It is believed that a judicious relocation between Emperador and Cucaracha will reduce the excavation considerably with only a comparatively small change of alignment. In this manner, at this particular portion of the line, excessive excavation on the easterly side of the deep part of the Culebra cut may be avoided, at the same time utilizing the entire volume of existing excavation between Emperador and Cucaracha.

At the Colon and La Boca terminals, however, it is the judgment of the Board that material changes should be made both in the plans of these terminals and in the alignment to eliminate considerable curvature. The terminal plans recommended by the Board are described under the section of "Harbors."

The initial point of the axis of the canal is located in Limon Bay, about one mile northwest of Manzanillo light, at the beginning of the dredged entrance channel, where the depth of water is at least 40 feet at low tide. From that point the axis of the dredged approach channel runs straight to near the southern limit of Limon Bay, where, near Mindi, a curve unites it with the center line of the canal, as partially completed by the old company. From Mindi the proposed line follows the partially excavated canal through the low marshy ground nearly to Bohio, a distance of 12 miles. The canal line first cuts the course of the Chagres River at Gatun, seven miles from Colon, and then repeatedly cuts it from that point to Bohio. The excavation throughout this entire distance from the sea channel to Bohio can be made by the simple operation of dredging, but there is some hard clay to be removed.

After passing Bohio the ground rises gradually toward Panama and radically changes in character. A considerable quantity of rock must be removed at Bohio, and the same material is found in considerable quantities throughout almost the entire remaining distance to the shore of Panama Bay. The canal line from Bohio follows practically the general line of the Chagres River, cutting or coinciding with the bed of the river at many points, to Obispo, 14 miles from Bohio. The bed of the river at Bohio is practically at sea level, and about 50 feet above sea level at Gamboa near Obispo. While the surface of the ground is varied and broken, the ascent is gradual and nearly uniform to Obispo. The material to be excavated is clayey and sandy in large part, although rock in substantial quantities is found projecting above sea level at some points, mostly in the lower part of the proposed excavation. The excavations made by the old company along this portion of the route were generally shallow, although deeper at some points where hills exist, but constituting a nearly continuous surface cutting. That company excavated very little rock in this vicinity.

The general course of the canal from Colon to Obispo is southeast, and in part due south. Although there are several curves they are all of large radii, the shortest arc being one and four-tenths miles in length.

The vicinity of Obispo, about three-fourths of a mile only from Gamboa on the Chagres River, is a marked one in the alignment of the canal. At this point the valley of the Chagres, passing upstream, trends sharply to the northeast nearly at right angles to its course below

Gamboa, but the canal line continues toward the southeast, i. e., toward Panama. The great reservoir for controlling the floods of the Chagres, to be created by a dam at Gamboa, is described in another section of this report. The waters escaping from that reservoir through regulating sluices will enter the canal prism about three-fourths of a mile north of, or below, Obispo.

Continuing toward Panama the ground rises at a more rapid rate. At Obispo the great summit cut may be said to begin, as there is at that point a more abrupt rise in the surface of the ground and a correspondingly rapid increase in the depth of excavation. There is much rock to be removed from the canal prism at Obispo, and that material continues to form by far the greater part of the excavation through the divide to a point beyond Pedro Miguel, on the Pacific slope of the Cordillera. The deepest part of the summit cut at Culebra is about five and one-half miles from Obispo. The maximum depth of excavation required for a sea-level canal will be about 373 feet below the original surface where the axis cuts the saddle. The deepest part of the present cut, however, is about 160 feet below the original surface, or about 213 feet above the bottom of the excavated channel required by the sea-level plan. The length of the main part of the great summit cut is about nine miles, from Obispo to Pedro Miguel. The material to be removed is partly of indurated clay so hard as to be classed as soft rock, and partly of hard rock with a surface covering of clay.

The heaviest work of excavation done by the old and the new French companies is shown by this cut between Emperador and the southerly slope of Culebra Hill, where the canal line intersects the course of the Rio Grande River.

As has already been indicated in this report, it is believed that a slight relocation can be advantageously made along this portion of the line between Emperador and the little village of Cucaracha, on the Pacific slope of the divide. A careful study should be made to ascertain whether it may not be feasible to throw the center line of the canal a little to the westward of its present position in the deepest part of the Culebra excavation, so as to avoid further cutting of the high portion of the hill on the easterly side of the line. This would enable the further cutting to be made in the lower hill on the westerly side. It is possible also that improvement in the alignment at Emperador may be made, although at the expense of cutting more deeply into the hill at that point.

The canal line reaches low marshy ground nearly at sea level at a point about two miles below Pedro Miguel. From that point to deep water in Panama Bay the Board has adopted a different alignment from that of the French companies. The latter followed as closely as possible the course of the Rio Grande to its mouth at La Boca in order to avoid rock excavation, but that alignment included two curves which are avoided in the new location. The location recommended by the Board is practically a straight line from a point a short distance from Miraflores through the Rio Grande swamp; but opposite Corozal a low ridge or spur from the eastern highland is crossed, in which ridge the borings show rock. Advantage is to be taken of this conformation to locate on the rock foundation a wide spillway with regulating sluices primarily for discharging into the Rio Grande and so into the Pacific a part of the Chagres flow at Gamboa coming through the Culebra, but the sluices may also be used to regulate and reduce the currents in the canal while the tidal lock is open.

The canal continues in a straight line through the swamp to and through the saddle between Ancon and Sosa hills, where the tidal lock is to be placed, and thence to deep water off Isle Flamenco. From Miraflores to the lock the canal will be leveed, so as to prevent the tidal flow from entering it.

The French plan required a tidal lock at Miraflores some five miles from the bay shore, whereas in the new location it will be in the low Ancon-Sosa saddle, thus bringing it almost to the margin of the shore and avoiding the long approach channel wherein tidal currents would be generated if the locks for their control were at Miraflores, far inland.

Experience in the navigation of maritime canals shows that the area of the wet section of the prism must be at least four times that of the immersed section of the ship passing through it at a speed of six miles per hour. The smallest area of cross section of the canal prism, in rock

excavation, exceeds 8,000 square feet. The dimensions adopted by the Board, therefore, will permit a speed of six miles per hour for the largest existing vessels using it, and of not less than eight miles per hour for the average ship. For a ship of 90 feet beam and 38 feet draft a speed of four or five miles per hour might be considered sufficient.

These speeds will enable ships of the largest size to pass through the canal in seven hours if the gates of the tidal lock at Panama are open, as they will be for more than half the time, or in eight hours during high spring tides, when the tidal locks will be in use. The time of passage of the average ship will probably be between five and six hours with the gates of the tidal lock open, or one hour longer when the tidal lock is in use. For a ship of the exceptional size given the time of transit might reach ten hours.

After the completion of the canal the tracks of the Panama Railroad can judiciously be placed on one of the berms of the canal, at least between Bohio and Miraflores, as the railroad will then lose its present character and serve local and passenger traffic only, besides being a tender to the canal for its maintenance and for other similar purposes. Power for operating it would be developed at the Gamboa dam.

Some dredging will be required in the harbor channels as well as in the canal proper, but this will be nearly the same for either type of canal.

The entire length of the line between shore lines is a little over 40 miles, while the total distance including harbor channels is 49.35 miles.

The total length of curves is 19.17 miles, leaving 30.18 miles of tangents or straight portions.

Summarized, the sea-level canal as recommended by this Board is a channel commencing at the 41-foot contour in Limon Bay, about 5,000 feet northerly of a line between Toro and Manzanillo lights, protected by two diverging jetties with a width of opening of 1,000 feet; thence with a straight channel 500 feet in width at the bottom and a depth of 40 feet, protected by a parallel jetty on the west and by Manzanillo Island on the east, to Mindi, whence the land canal begins.

This canal is designed with a depth of 40 feet and a bottom width of 150 feet in earth, with side slopes adjusted to the nature of the ground so as to give a surface width of from 302 feet to 437 feet. In rock the section is to be altered so as to have a bottom width of 200 feet and a surface width of 208 feet. At the Pacific end the canal is to be protected by a tidal lock located between Ancon and Sosa hills. Beyond this tidal lock there is to be a straight channel projected into Panama Bay, with a bottom width of 300 feet and extending for a distance of three and three-fourths miles to the 45-foot contour.[a]

The width adopted for the canal will be sufficient to permit steamers to maintain a speed of six to eight knots per hour, and to allow two ordinary merchant steamers to pass each other on the line of the canal without stopping.

At Gamboa there is to be located a dam, either of masonry or of earth and masonry combined, for the control of the Chagres, and at Corozal, sluices by which, during half the tide period when the level in the Pacific is lower than that in the Atlantic, water can be discharged from the canal into Panama Bay.

The following tabulation gives the total excavation as very carefully computed from the data supplied by the Isthmian Canal Commission, supplemented by data collected at the instance of the Board:

Estimate of excavation of a sea-level canal 40 feet deep.

[December 22, 1905.]

Stations.	Classification.	Cubic yards.		Unit price.	Amount.	
41-foot contour to shore line of Limon Bay, 0 to mile 3.92.	Earth	2,781,668		$0.15	$417,250.00	
	Indurated clay	5,566		.70	3,896.20	
	Coral	135,500		1.50	203,250.00	
			2,922,734			$624,396.20
Shore line to Mindi, mile 3.92 to mile 5.49	Earth	7,695,885		.25	1,923,971.25	
	Indurated clay	2,351,588		.70	1,646,111.60	
			10,047,473			3,570,082.85

[a] Contours refer to mean sea level.

Estimate of excavation of a sea-level canal 40 feet deep—Continued.

Stations.	Classification.	Cubic yards.		Unit price.	Amount.	
Mindi to Bohio, mile 5.49 to mile 17.22	Earth	21,730,653		$0.25	$5,432,663.25	
	Rock above sea level	628,088		1.00	628,088.00	
	Rock below sea level	2,198,643		2.50	5,497,107.50	
			24,557,584			$11,557,858.75
Bohio to Obispo, mile 17.22 to mile 30.96	Earth	48,787,149		.40	19,514,859.60	
	Rock above sea level	4,490,926		1.15	5,164,564.90	
	Rock below sea level	7,396,362		2.50	18,491,905.00	
			60,674,437			43,171,329.50
Obispo to Pedro Miguel, mile 30.96 to mile 39.04	All material above +10	93,697,408		.80	74,957,926.40	
	All material below +10	16,194,302		1.25	20,242,877.50	
			109,891,710			95,200,803.90
Pedro Miguel to Miraflores, mile 39.04 to mile 40.77	Earth above sea level	2,136,125		.40	854,450.00	
	Earth below sea level	300,000		.25	75,000.00	
	Rock above sea level	518,881		1.15	596,713.15	
	Rock below sea level	2,474,138		2.50	6,185,345.00	
			5,429,144			7,711,508.15
Miraflores to south end of Sosa lock, mile 40.77 to mile 45.37	Earth	6,106,828		.40	2,444,731.20	
	Rock nearly all below sea level	5,223,700		2.50	12,659,250.00	
			11,330,528			15,103,981.10
South end Sosa lock to 45-foot contour in Pacific, mile 45.37 to mile 49.35	Earth	3,508,945		.15	536,341.75	
	Rock	2,663,922		2.50	5,659,805.00	
			6,172,867			6,196,146.75
	Total		231,026,477			183,136,107.30

Contours refer to mean sea level.

(B) HARBORS.

The harbor of Colon.—A first-class natural harbor is not found at either terminal of the canal, but good harbor accommodations can be created without unusual difficulty or extraordinary expense.

Limon Bay, on the easterly side of which is the city of Colon, must be the Caribbean terminal of the canal. It is a rectangular indentation of the low-lying coast, with a width of two and three-fourths miles and a length approximately in a north and south direction of a little more than four miles. It is shallow, freely open to the sea from the north, and but little less exposed to the northeast and northwest. The extreme range of tide seldom exceeds two feet six inches except under the influence of high winds. The mean range is about one foot six inches.

The depth of water at the entrance to the bay in its central portion is from 30 to 38 feet opposite the water front of Colon. The southern half of the bay is so shallow as to be of no value for harbor purposes. The depth of water varies from 28 feet opposite Cristobal Point, and gradually shoals to the gently sloping sandy beach at the extreme southerly end.

The currents in the bay have little velocity. One, called the Rio Magdalena current, comes from the east and is at times felt along the eastern and western shores, but chiefly along the latter. The discharge of a large portion of the Chagres River through the partially excavated canal prism between Gatun and Mindi, and through the latter into the head of the bay, produces a gentle outward current which opposes that described above. These currents are neither constant nor strong, and are often influenced by the wind. The tides are so small and the tidal section so large that they have little influence upon the currents.

The greater part of the bottom of Limon Bay is soft. A large number of observations have been made under the direction of the Isthmian Canal Commission by sounding with railroad rails, weighted where necessary by the hammer of a floating pile driver. The silt or other sediment forming the bottom is of such character that these railroad rails used as sounding rods usually sank from 10 or 15 feet to as much as 30 feet by their own weight. This material, therefore, is readily moved when the water is shallow by storm waves or by currents induced by the wind or other agencies.

There is undoubtedly a decided movement of the material of the soft bottom in the easterly portions of the bay south of Cristobal Point by storm waves, although the rarity of the storms prevents the aggregate of movement being very large. Since surveys were made by the old Panama Canal Company there a sensible advance of the shore line at the southeastern limit of the bay has been observed, particularly in the vicinity of the mouth of the Mindi River, where the

sediment carried by such of the flood waters of the Chagres as is here discharged is deposited. That portion of the harbor outside of the five-fathom line has been but little affected by the deposition of sediment, but there has apparently been some slight advance of this contour. With the diversion of the Mindi there should be no further decrease of depths in the bay. These physical characteristics have been carefully considered in the design of a terminal harbor at Colon.

In spite of this soft material and the depth of the bay, the anchorage is good enough for such conditions of weather as ordinarily prevail at Colon. The best anchorage is about one-half mile to a mile off the water front. Ships have no trouble in holding in this location except in the rare instances of very high winds. The swells that roll into the harbor at times from remote storms in the Caribbean do not give any serious trouble to vessels at anchor.

Limon Bay is open to the north, and northers blow directly into it. These northers are severe windstorms, usually accompanied by rain, generally from slightly west of north, but occasionally a little easterly of that point. They occur, on the average, not more than three or four days in the year and during some years not at all. During these storms the wind blows with high velocity, driving storm waves of great magnitude and force directly into the bay. At such times ships can not lie at anchor nor be berthed alongside the piers on the water front without grave danger. Indeed, vessels unable to get away in time to escape such storms have been wrecked on the water front of Colon as well as at other points in the bay. So many ships have lost their ground tackle while at anchor off Manzanillo Island that not infrequently anchors and chains are brought up by ships while raising their own anchors. During the very severe norther of November, 1879, a brig drawing 18 feet at anchor in five fathoms touched bottom in the trough of the sea and lost her sternpost and rudder. When northers begin to blow, all the steam vessels invariably get to sea as soon as possible. Many vessels then seek the naturally protected adjacent harbor of Porto Bello.

A prominent feature of Limon Bay is the artificial point or jetty head known as Cristobal Point. This was built by the old Panama Canal Company of material excavated from the canal or taken from other points, with its surface brought to about five feet above sea level. It is founded largely upon a coral bank which originally stood at about sea level. Its margin is protected by a rough revetment of fragments of the country rock of small size and concrete blocks a meter (3.28 ft.) cube. This artificial point projects about 1,300 feet into the bay from its easterly side. Recent surveys show that the bottom of all that part of the bay west and north of Cristobal Point is formed largely of mud from 15 or 20 to possibly 30 or more feet deep, the depth of water in the bay opposite being about 28 feet.

The fact that the old Panama Canal Company made the course of the approach channel a tortuous one, with curves of short radius to the entrance of the canal immediately south of and under the protection of the point, indicates the necessity of protecting the entrance of the canal from storm waves. The peculiar formation of the bed of the bay west and north of the jetty indicates that waves and sea currents may, unless checked, produce undesirable or even serious changes in the bottom at a depth of 30 feet and less.

As ships may wish to enter the canal at any time, the terminal harbor must offer safe entrance to it any day in the year and under all conditions of weather. In view of the experience with northers ever since the harbor of Colon has been frequented by shipping it is imperative that this terminal harbor should be so designed and constructed as to protect the dredged approach channel, both against the storm waves and the resulting currents which would otherwise tend to fill the channel. Without such ample protection it is practically certain that the dredged approach channel in the bay of Limon would be filled by sediment during one such norther as that of January, 1905, which was witnessed by three members of the Board. There should also be afforded ample anchorage ground within the protected harbor, with the requisite room for maneuvering.

To enable vessels to enter or leave the harbor at all times, even during severe northers, the channel should have the same direction as the winds during such storms, which are almost always from a point slightly west of north. A vessel entering or leaving this channel in a storm would therefore have the wind ahead or astern and without any wind abeam to complicate the navigation

of the channel. It is for this reason that the Board has proposed a straight entrance channel nearly parallel to the Colon shore and united at its southerly end by a curve of large radius with the axis of the canal near Mindi, as laid down by the French company.

If a line be drawn due west across Limon Bay from Cristobal Point, behind which is found the inner harbor leading to the canal near the mouth of the Mindi, the depth of 28 feet will be found on this line at mean low water throughout the greater part of its length, and it will be seen that the water loses depth at nearly a uniform rate from that point to the shallow mud beach at the southerly extremity of the bay. To the seaward of this line the depth increases quite uniformly to 40 feet about one mile north of Manzanillo Point light.

After much consideration of all the conditions bearing upon the construction of a safe and commodious harbor, the Board provisionally adopted two converging breakwaters, one extending from the beach to the easterly of the light-house in a northwesterly direction one mile, to a point where the low-water depth is at least 40 feet and a short distance westerly of a small reef; the other starting from a point about 3,750 feet west of Manzanillo light, running also one mile to a point where the depth at mean low water is at least 40 feet, so placed as to afford an entrance between the extremities of these breakwaters 1,000 feet in width, the southerly extremity of the latter breakwater to be connected with Great Reef, off Mindi Point, by a breakwater or stone dike two and one-half miles in length. The nearest point of this breakwater to Cristobal Point would also be about 3,750 feet. These breakwaters, therefore, would inclose a harbor area nearly 9,000 feet long from the entrance and nearly 4,000 feet wide for a distance of at least eight-tenths of a mile, within which the depth at low water would vary from 30 to 35 feet. Within the protected harbor a dredged entrance channel 500 feet wide on the bottom and 40 feet deep at low water would lead straight from the entrance between jetties to the canal entrance near the mouth of the Mindi.

At the same time, the inner harbor immediately south of Cristobal Point, and projected as the canal entrance by both the French companies, should be so completed as to afford on its easterly side the necessary coaling facilities, administration offices, and other buildings required by the canal traffic. Vessels entering the outer or main harbor will anchor, if they desire to do so, arrange for payment of dues and their passage through the canal, secure such supplies and make such other communications with the port as may be necessary, then pass to the coaling station, if desired, or proceed directly into the canal.

The breakwaters may be constructed as mounds composed of suitable fragments of hard rock for their superstructures, or blocks of concrete, as may be considered most economical or desirable, but resting upon rubble substructures, which may be of softer material taken from the excavations or from other sources, as the actual construction of the work may make most convenient or economical. The type and cross section of these breakwaters and the general character of the structures would be similar to others which have been constructed on the Atlantic, Pacific, and Gulf coasts of the United States, as at Delaware Bay, San Pedro, on the coast of southern California, and Galveston, Tex.

This harbor as designed, including the ports of Cristobal and Colon, will furnish sufficient accommodations for an indefinite period in the future for the greatest traffic which can now be anticipated for the canal. The Board does not set forth this plan as that which it would necessarily hold to in all details after a more prolonged study and consideration of all the circumstances affecting the construction of such a harbor, but it believes that the accommodations which it would afford will be ample for the purpose and that the amount estimated as its cost is sufficient to cover the construction of a suitable harbor for the Caribbean terminus of the canal should the plan herein described be modified or displaced by another.

The harbor of Ancon.—The harbor conditions at the Pacific terminus are radically different from those found at the Caribbean end, in that no storms ever occur of sufficient magnitude to disturb vessels anchored in the roadstead northerly of the islands of Perico and Naos, the usual anchorage, which is three miles by the present dredged channel to the entrance of the canal at La Boca. Owing to littoral currents from the west this channel requires the practically constant service of dredges in order to maintain a depth of 20 to 22 feet. At the present entrance of the

canal, which is also the mouth of the Rio Grande estuary, there has been built a wharf or pier of steel 1,000 feet long, carrying two railroad tracks and a platform for the exchange of cargo between ships lying alongside the pier and freight cars on the railroad tracks. The foundation structures of this pier, known as the La Boca pier, are steel cylinders sunk to bed rock by the pneumatic process and filled with concrete. Mud and rock have been dredged not only alongside the pier, but over an area in front of it to make a turning basin sufficient for the present needs. The depth of water alongside and in the basin varies from 22 to 25 feet at low water, but, like the entrance channel, must be frequently dredged to maintain this depth.

The bottom of the bay of Panama, at the anchorage off the islands of Perico and Naos, consists of mud mixed with sand, shells, and other materials, and forms excellent holding ground. There are no swells to disturb ships at anchor. There is, however, little depth of water near the shore, and the 30-foot contour lies to the westward and southward of those islands. Deep-water channels approach the islands or this anchorage from three directions, that immediately eastward of the island of Flamenco being probably the best adapted for the approach to the dredged channel leading into the canal.

The tides in Panama Bay are of far greater range than those at Colon, although mean sea level is the same in both harbors. They are very regular. During spring tides the water surface may oscillate between 10 feet above mean sea level to 10 below. During neap tides the range from high to low may not exceed 7.9 feet. Tidal observations have been made at the marigraph station on the island of Naos for many years and they supply data for the statement of the tidal range given above.

The flood tide passes between Naos and Guinea Point, in a direction north-northwest, with a maximum current exceeding two miles per hour. The tide ascends the Rio Grande to a point nearly four miles above La Boca pier and inundates, up to Miraflores, the manglares or low marshes through which the river flows. The period of inflow is short, and after it the water recedes from the swamp with an outgoing current increased by that in the river between two and four hours after high tide. This maximum current is estimated at a little over three miles per hour during the spring tides in that part of the rainy season in which high freshets occur. Under ordinary conditions the current in the Rio Grande during the dry season, or in those portions of the wet season when the rainfall is small, is too slight to have any effect upon the ebb flow of the tide. Between La Boca and the anchorage ground the ebb follows essentially the direction of the dredged channel, with gradually decreasing current, and then turns to the south and southeast beyond Flamenco.

The direction of the present dredged channel is about N. 60° W. It was originally intended by the old Panama Canal Company to give the channel a depth of 30½ feet at low water and a bottom width of about 170 feet, with side slopes of one vertical on three horizontal. The present channel was dredged to a depth of 30 feet below mean tide, and was opened to navigation in December, 1900, since which time it has been in constant service, but this depth has not been maintained. The material taken out in this dredging consisted of mud and silt, some material of vegetable origin, sand, gravel, and, in the vicinity of La Boca pier, a small quantity of rock.

It has already been observed that a littoral current moves from west to east across the dredged channel, causing considerable sediment to deposit. As a consequence of this condition nearly continuous dredging is required to maintain a depth in the channel of 21 to 22 feet at low water. The volume dredged in this manner is about 150,000 cubic yards annually, and sometimes rises to 20,000 or more cubic yards per month. This dredged material is not, except in comparatively small quantities, brought down by the Rio Grande River, but is moved into the channel by the littoral current. The course of that river is short and the volume of its flow far too small to bear a sensible quantity of sediment, nor does the latter appear to be of the character found along the banks of the Rio Grande or in its bed.

There are also other small currents existing in the bay in the vicinity of the entrance channel, and under certain conditions of tide and wind there may be even a little westerly current, but all other movements than that from the west are small and probably negligible in their effects upon the maintenance of the entrance, whether in its present location or on a new line between Ancon and Sosa hills.

If the present location of the Pacific end of the canal from Miraflores to La Boca should be retained it would be necessary to widen and deepen the channel sufficiently to meet the requirements of the ship canal now projected. Remembering that extremely low water may be as much as 10½ feet below mean tide it is obvious that a much deeper excavation will be required to afford the prescribed minimum depth of 40 feet in the harbor approach channel than will suffice at the Caribbean terminus of the canal. The location of the tidal lock will determine the distance inland to which this maximum depth of excavation must be carried. If, as in the former French plans, that lock should be located at Miraflores, a little over four miles from La Boca, the maximum depth of excavation would be carried to that point, but, on the other hand, should the new location for the tidal lock nearer the shore line be adopted the deep-channel excavation would be carried only to that lock.

The French location extending from Miraflores to the anchorage ground in deep water requires much more curvature than is desirable for a canal entrance, and the Board believes that a straight entrance possesses sufficient additional advantages over the old one to justify substantial increase in expenditure to obtain it. A new alignment, therefore, for the Pacific end of the canal and the dredged channel has been adopted, extending from a point between Corozal and Miraflores in a straight course to the new site of the tidal lock between Sosa and Ancon hills, thence with a slight change in direction near the lock directly to deep water off the island of Flamenco. Rock outcrops between Ancon and Sosa hills and that vicinity afford a perfectly satisfactory foundation for this structure. Although the tidal currents might be small in a sea-level section extending from the shore line to a tidal lock at Miraflores, and might only be a source of temporary inconvenience, yet they are undesirable for the navigation of large steamers, and would be entirely avoided by the location for the lock adopted by the Board.

This relocation of the terminal portion of the canal line necessitates the excavation of a materially increased amount of hard rock, which has been included in the estimate of total cost, although as much submarine rock excavation in the vicinity of the islands has been avoided as possible. While there may be a difference of opinion as to the justification for such additional cost in securing a better entrance, there can be no doubt that the alignment adopted by the Board will result in easier and safer navigation for vessels entering the canal from the Pacific, and in much less cost for dredging to maintain it.

The bottom width of the entrance channel leading from deep water off the island of Flamenco to the tidal lock near Sosa Hill will be 300 feet, but the side slopes will depend upon the character of the material to be excavated. Inasmuch as extreme low water of spring tides will occur but rarely, the depth of excavation in this dredged channel is recommended to be but 45 feet below mean sea level. This excavation is sufficient to give at least 40 feet at low water for all but those spring tides having a range of more than 10 feet. As the mean tidal range in Panama Bay does not exceed about 14 feet it is considered that the depth of excavated channel to be provided will never be a source of any inconvenience or any delay whatever for the great bulk of the traffic of the canal, the measure of the maximum inconvenience for ships of greatest draft seeking the canal, if they should be ready to enter it at extreme low water or at about that time, being a total of only two or three hours.

It is evident that the approach channel on this new location may be subject to shoaling by sand moved by the eastward littoral current, as is the present channel. The rock excavated from the new entrance should be deposited along its westerly side so as to form a low dike, completely isolating it from the Rio Grande estuary. This will in no way change the regimen of the latter or of the roadstead near the islands, but it will afford complete protection against the easterly drift of the sediment and thus prevent deposition in the channel. It is possible, though not anticipated, that it may be advisable to form a similar low dike on the easterly side of the channel, and there will be sufficient rock from the channel excavation for that purpose should it be desired. The precise character and amount of these measures of protection for the entrance channel can only be determined in the last instance by observations which may be made during the progress of its construction. It is important to observe that there is no reason whatever to believe that this proposed entrance work will change in any way the character of the anchorage ground north of the islands of Naos, Perico, and Flamenco, which has always been of

so much value to the harbor of Panama and which will in the future be of equal value to the Pacific terminal harbor of the canal.

The principal reason for the existence of the La Boca pier will vanish with the opening of the canal, but even with the new location of the Pacific terminal, uses of value will probably be found for that structure. No better location for shops, small shipways, and other similar and necessary plant can be found near the Pacific terminal than that now occupied at La Boca for those purposes. The requisite depth of water required for the service of these plants in their present positions can always be maintained at small cost, so that their usefulness will in no way be impaired.

The question of the necessity of a tidal lock at the Panama end of the canal has been raised by engineers of repute, but the limited time available to the Board has not permitted the full consideration of this question which is desirable. It is probable that in the absence of a tidal lock the tidal currents during extreme spring oscillations would reach five miles per hour. While it might be possible to devise facilities which would permit ships of large size to enter or leave the canal during the existence of such currents, the Board has considered it advisable to contemplate and estimate for twin tidal locks located near Sosa Hill, even though the period during which they would be needed would probably be confined to a part of each spring tide.

The highest recently recorded range of spring tides which the Board has seen (September, 1905), was 19 feet 9 inches between extreme low and extreme high water, while from 1882 to 1887 the highest amplitude reported was 20.93 feet. With such tides for a brief period at dead low water there would be a differential head of about 10 feet—that is to say, the water in the canal would be 10 feet above that in the bay, while at extreme high water for a correspondingly short period the level of the water in the bay would be 10 feet higher than that in the canal.

At the period of mean tide there would be no difference of level between the bay and the canal, so that during that period of the tide all the gates of the tidal lock could be open, leaving an unobstructed passage for vessels until the approach of the flood tide rendered it necessary for the gates to be closed until slack water would again be reached, and so on for each succeeding spring tide. During neap tides the range is so small that it will not be found necessary to bring the gates of the lock into use. Consequently, throughout the neap period of each tidal cycle a continuously open and unobstructed passage for traffic will be provided through the tidal locks.

If the matter be put into figures for the sake of comparison, it will appear (1) that in the project for the sea-level canal one lock may be required at times at the Panama end of the waterway. For one-half of each tidal cycle of fourteen days the gates may be operated to control a difference of head of an average height or depth of about eight feet for short periods on each tide, while for the remainder the difference of level between canal and ocean will be negligible. For the remaining half of each tidal cycle the gates will be out of operation and the locks will present an open and unobstructed channel, and (2) that in the project for the lock canal six locks or even more will be required for a canal with a summit level 80 to 90 feet above the mean level of the sea; that these locks will have differences of level ranging from about 27 to 35 feet; that their operation will be perennial, they will always be required, and consequently that the menace which they will present to the safe navigation of the canal by large steamers can not be avoided and will be cumulative, i. e., must be multiplied by the number of lockages to which such vessels will be subjected during their passage through the canal.

(c) CROSS SECTIONS OF THE CANAL PRISM.[a]

The cross sections of the prisms will vary with the character of the material excavated. Furthermore, the cross section of the deeply dredged channels at the terminal harbors must obviously be different from those in the canal proper between the shore lines of the Isthmus.

In the judgment of the Board the depth of water in the canal prism and in both of the approach channels of the terminal harbors should not be less than 40 feet, except in the case of the channel in the bay of Panama, where at intervals that depth would not be found during short periods at extremely low spring tides. The depth of 40 feet was therefore adopted by the Board as the standard minimum depth in the canal.

[a] See Plate III for diagram.

The standard bottom width in firm earth, including the dredged portions in soft material between the shore line of Limon Bay and Bohio, was fixed at 150 feet, the side slopes in the same material being taken at one vertical on two horizontal.

In rock the bottom width was taken at 200 feet with side slopes in the channel of ten vertical on one horizontal, i. e., practically vertical. The side slopes above water, as well as below, in firm earth between Bohio and Obispo and south of Paraiso were taken at the inclination of two vertical on three horizontal.

Some modifications of these standard sections were made by the Board in its estimates of quantities of material to be excavated in combined rock and earth sections between Bohio and Pedro Miguel, but not including the Culebra section. At many places throughout this distance the lower portions of those parts of the cuts above the water surface in the canal will be rock overlaid by earth or softer material. In the great summit cut the surface material overlying the rock for a considerable distance in the vicinity of Culebra Hill is clay, which, like all clay, slips easily when wet. When, however, this clay is drained, or otherwise protected from becoming saturated, it stands with satisfactory firmness and gives no trouble. Throughout these combined rock and earth slopes the rock is given a face slope in the estimates of ten vertical on one horizontal and the clay or other material above it one vertical on two horizontal. In the great Culebra cut, which really means the summit divide from Obispo to Pedro Miguel, a distance of seven and one-fourth miles, a special form of section has been taken, although it includes the same elements of slope adopted for other portions of the cuts taken out in the dry. The same rock section for the prism of 200 feet bottom width and with side slopes of ten vertical on one horizontal is carried up to an elevation of 10 feet above mean tide, at which elevation there is provided a horizontal berm 50 feet in width on each side of the canal prism. From the exterior limits of these berms benches are assumed for the purpose of estimate, each 30 feet high, with a face slope of four vertical on one horizontal, the width of the bench at top being 12½ feet. These benches are carried to the upper limit of the rock portion of the cut. This makes the average or mean slope of the rock three vertical on two horizontal. The clay or other soft material overlying the rock is given the same slope of one vertical on two horizontal already described.

It is believed by the Board that the estimated volume based upon these side slopes is ample. It is probable that large portions of this summit cut, composed of harder rock than the indurated clay which forms the material classified as soft rock, will permit of faces having a slope of four vertical on one horizontal to be taken out much higher than 30 feet. It is further believed that there will be little sliding of these benches, assumed in the computations of quantities, so that the volume taken out of the great summit cut is much more likely to be less than that estimated than in excess of it, especially as a contingent margin has been added to all items of cost.

The materials classified as soft and hard rock have been exposed with surfaces fully as steep as four vertical on one horizontal ever since the old company ceased work in 1889, a period of sixteen years. Furthermore, these slopes and others equally steep produced by the excavation made by the new French company have been under the personal observation of two members of the Board throughout the past six years, and under the daily observation of another member for over a year. During this time the effects of weathering have been small, soft rock as well as the hard having stood without sensible slipping or other deterioration. In fact, it is the result of extended experience with these steep faces both in Central America and on the Isthmus that the steeper the faces stand without crushing at their lower portions the less weathering and wash from the tropical rains will occur. It is therefore highly desirable to finish these slopes in as high benches and with face slopes as steep as practicable.

Very few slips of rock have occurred in the deepest portions of the Culebra cut since it was first opened. They are small and have been of such rare occurrence as not to affect the correctness of the preceding observations. The cross sections of the approach channels to be dredged in the harbors of Colon and Panama have been described under "Harbors."

It is believed by the Board that the cross sections of the prism for all parts of the canal from deep water to deep water are well adapted to meet the requirements of the law under which work

on the canal is now prosecuted, and that they are sufficient to accommodate ships of the deepest draft now afloat and which may be reasonably expected for the future. It is further believed that the conditions assumed, especially for the great divide cut, are such as to make the estimated total quantities larger than the quantities which will be actually excavated.

(d) ESTIMATE OF COST.

The unit prices to be applied to the various items of work entering the completion of a sea-level canal have been formulated by the Board after most careful deliberation upon all the conditions affecting the actual prosecution of the work, including climatic effects, inefficiency of available labor, the distance of centers of supplies, the present condition of the various incomplete excavations, the general experience of the Isthmian Canal Commission since its creation, and other influences peculiar to the circumstances which will surround the execution of work in the field to its completion. It has been the intention of the Board to make these prices liberal, so as to remove as far as possible any probability of the ultimate cost of the work being greater than that estimated, and it is believed that they are sufficiently liberal to accomplish that purpose.

It will be observed that they pertain to methods and material which have been well tried in engineering construction and do not rest upon anything of an experimental character, as it is the judgment of the Board that nothing should be included in the proposed plan other than that which has been justified by engineering experience with work as nearly similar to that contemplated in this project as possible. A complete schedule of these unit prices will be found in Appendix R.

The Board has taken account of and given due weight to the fact that vast improvements in mechanical excavating devices have, in the past few years, been made and their effectiveness demonstrated. The Board also believes that other improvements specially applicable at Panama will be developed and used as the work progresses, as was the case during the making of the Suez and the Chicago Drainage canals, and that these improvements will result in large economies and show that the unit prices are much too large; but in fixing these units account has been taken of nothing which has not been tested and justified in actual practice.

Applying the unit prices adopted to the quantities—a tabulation of the main items with a grouping of the smaller items—the following estimate of cost results:

Jetties in Limon Bay	$5,000,000
Excavation and dredging in earth, rock, etc., throughout the canal	183,136,000
Completion of river diversions, formation of dams across tributary streams, regulation of rivers which flow into the canal, etc	3,500,000
Dam across Chagres Valley at Gamboa, with flood sluices, etc	6,000,000
Spillway, with flood sluices, near La Boca	920,000
Twin tidal locks in the Ancon-Sosa saddle	6,000,000
Leading jetties above and below locks	795,000
Relaying track of Panama Railroad	500,000
	205,851,000
20 per cent for contingencies, administration, and engineering	41,170,200
Total	247,021,200

The Board is confident that the Panama Canal can be constructed and completed under the plans set forth and recommended in this report within the preceding total sum of $247,021,200.

There are certain items of cost, such as construction of military defenses, naval stations, government of the Canal Zone, sanitation, light-houses, buoying, lighting, and the provision of tugs, lighters, derricks, dredges, scows, etc., which have not been included. They are common to any type of canal. It was not understood to be the desire of the President that the Board should take into account anything that did not relate to the engineering features of the canal construction, but there is no doubt, in the opinion of the Board, that the expense of maintenance of a sea-level canal will be very much less than for a canal requiring lift locks.

Assuming that the total cost of the Panama Canal, including construction, payments to the French company for the property and franchise, to the Panama Republic for the rights conveyed,

the cost of the Zone government until the canal is open, and other collateral costs, the total possibly reaching $333,000,000, the interest charge on this sum at three per cent would reach $10,000,000. That such an investment would be a safe one from a commercial standpoint is indicated by the fact that the interest and dividends paid to the owners of the Suez Canal last year reached the total of $17,000,000, after paying all expenses of maintenance and operation, also the cost of the extensive enlargements and deepenings which are continually in progress.

(e) ESTIMATE OF TIME.

The time required for the construction of a ship canal across the Isthmus is one of the main elements of the whole subject. If the execution of the work in accordance with any one plan could be completed within a reasonable time while the execution of the work under another plan of equal merit could be realized within a less time, it is clear that the latter plan should be adopted. If, however, there are two plans, both feasible and each involving an amount of work which can be accomplished within a reasonable period, it is clear that the execution of that plan requiring the longer period may be justifiable if the advantages thereby gained are sufficient, or more than sufficient, to compensate for the delay. If the work required under the less desirable plan can be finished within ten or eleven years while that under the more desirable plan would require but two years longer, the small delay in the passage of the first vessel through the waterway might easily be neglected in comparison with the advantages secured under the better plan. It is necessary, therefore, to weigh carefully the significance of the time elements in reaching a conclusion as to the plan of canal to be adopted. In weighing these elements it is further necessary to consider that in the execution of the many locks and dams required for the lock canal, accidents during construction which would defer the opening of the waterway are more likely to take place than in the simpler works of the sea-level canal.

The time required to complete the construction of one or more of the main features of the plan controls the time required for the completion of the entire work, for the obvious reason that the various smaller features may be attacked and completed in detail in less time than would be required for the main or controlling ones. Under well-balanced administration of the work, therefore, the entire canal should be completed when the part requiring longest time is finished. As affecting the question of time for completion, and in marked degree that of cost also, there are two features of the sea-level plan which are of great moment: One is the excavation of the channel through the great divide, amounting to about 110,000,000 cubic yards in a length of about seven miles, and the other the construction of the tidal lock near Ancon-Sosa, having a usable length of 1,000 feet and width of 100 feet, with a maximum lift above mean sea level of 10 feet, this structure requiring over 600,000 cubic yards of concrete and other masonry. These two features have received an extended and careful study.

Inasmuch as hard rock outcrops in the immediate vicinity of the tidal lock site near Sosa Hill the amount of excavation required to secure a suitable foundation is not large and it can be expeditiously completed. The most serious part of this particular problem is to secure and assemble at the site the requisite cement, sand, gravel, or broken and other stone, and the plant required to mix and put in place the great mass of concrete and granite for the masonry portion of the lock. The gates as planned would be of steel, and each leaf would weigh about 275 tons. Their construction, shipment to the Isthmus, and erection in the locks would probably require a period of nearly two years. The Board has estimated that the time required for placement of the concrete and stonework would be four years after the excavation had been completed. It is therefore reasonable to estimate that the entire twin-lock construction, including excavation, concreting, erecting gates, and installing machinery, will require a period of not more than eight years. In estimating the time required it must be remembered that inasmuch as the change of level may be in both directions, up or down, to accommodate extreme high and low stages of tide, two sets of gates will be required in each of the twin locks. The total length of the structure will be not far from 1,300 feet exclusive of the approach works. While these locks are great structures the lifts are comparatively small.

It may be suggested that the Gamboa dam, built to the height of 180 feet above the rock in the deepest place, is also a great controlling factor as respects time, but the Board does not indorse such an opinion. If the dam be entirely of masonry, and allowing amply for interruptions by freshets or floods, the structure can easily be completed in less time than the tidal locks.

The excavation of 110,000,000 cubic yards probably can not be completed in the seven miles of summit cutting within the period of eight years which are estimated to be requisite for the construction of the tidal locks. The excavation at the summit may therefore be considered as the controlling element in the time required to build a sea-level canal. The work in this cut is unprecedented. Great excavations for similar purposes have been made in the Chicago Drainage Canal, at the Corinth Canal in Greece, and in the Manchester Ship Canal. The maximum annual excavations, however, in these works have been 12,500,000, 2,500,000, and 12,000,000 cubic yards, respectively, but in no case was it all steam-shovel work, as it probably will be in the divide cut at Panama. The maximum depth at the Culebra cut from the original surface to the bottom of the canal will be 373 feet and from the present surface 208 feet. The maximum depth of cut in the Corinth Canal was 286 feet, but no other excavation in recent years approaches in depth that proposed at Panama.

The time required to remove this great mass of material, by far the greater part being soft and hard rock, will depend greatly upon the efficiency of the method of operation and the organization of force and plant, all of which must be ultimately the result of most careful consideration of all the elements, including those of climate and character of labor available. It is clear that for the best results the greatest possible amount of work must be done by mechanical appliances and the least possible by manual labor. It is equally clear that the methods of conducting the work, including the control of the plant and force, must be such as will be subject to a minimum of climatic interference and effects of rainfall in the rainy seasons. All parts of the cut must be completely drained, so that the effects of rainfall and springs on the material to be moved may be reduced to the lowest limit.

In considering this part of the Board's work it has taken full evidence regarding this great excavation from not only the present and former chief engineers of the Isthmian Canal Commission, but also from the division and resident engineers who have had the direct charge of the work. The records and plans of the French engineers and committees have been diligently studied. It appears safe to estimate from this evidence that from 80 to 100 steam shovels of the most effective type now in use on the Isthmus can be efficiently employed continually on this work after complete organization. It will require from two to two and a half years to install and put in operation this excavating plant. The independent studies by the Board of the arrangement of railroad tracks and of complete systems of attack at both ends of this summit cut completely confirm the conservatism of the evidence given before it. It is as clearly demonstrable as any estimate of rate of progress and time for the completion of any great engineering work can be that after the full installation of plant not less than 100 steam shovels may be continuously engaged between Obispo and Pedro Miguel until the amount of work remaining to be done becomes too small to afford space for the operation of the whole plant.

The Board recognizes that the removal of the material in the summit cut is in reality a problem of transportation. It is a comparatively simple matter to excavate the material within a much shorter time than that allowed for the work, even on the supposition that all of it except the clay near the surface must be shattered by preliminary blasting. The whole difficulty attending this part of the construction of the canal is attached to the removal of the material from the shovels or other excavators to the spoil banks. This problem of transportation is in reality the substance of the problem of building the transisthmian canal and, in treating this part of the project, the Board realizes and has considered the large amount of railroad track and the extensive transportation organization required for the disposition of the waste material. It is probable, as has been estimated, that not less than three miles of standard track will be required for each shovel employed, making a total of 300 miles of trackage for 100 shovels.

If it be assumed that 100 shovels are available for continuous work, there being a sufficient surplus above that number undergoing repairs whenever necessary to maintain the working

complement, it can be demonstrated that as much as 20,000,000 cubic yards of material classed as rock may be annually removed from the summit cut. This estimate is based upon an average number of working days of not more than 20 per month throughout the year, which is an underestimate on the basis of the experience of the French companies and of that which has accrued since American occupation began, in May, 1904. In this estimate the capacity of one shovel is taken as materially less than would be justified by the actual operations of steam shovels in the Culebra cut during the past year, both in wet and dry seasons. Furthermore, it has been supposed that the working day is to be but eight hours long and that one shift only of laborers would be employed per day, whereas it is perfectly feasible to work two shifts in twenty-four hours during the greater part of the year and possibly during the entire year. Using these estimates for the period of what may be assumed to be the maximum annual output in the Culebra cut, and allowing at least two and a half years to attain this maximum rate at the beginning of the work and a period of not less than three years for a decreasing output in the more contracted space in the lower portions of the cut during the closing period of operations, it is found that the entire quantity of 110,000,000 cubic yards of material in the divide can be removed within ten years. (For time curve illustrating practicable excavation of Culebra cut, see Plate XXXI.)

Although the preceding estimate of time has been based upon ample allowances for the effect of the rainy seasons, for the low grade of labor available on the Isthmus, and for climatic conditions in general, the Board has added about 25 per cent to it for other contingent causes of delay, either similar to those already provided for or of any other character. It is therefore the judgment of the Board that a ship canal on the sea-level plan outlined in this report can be completed within a period of time not exceeding twelve or thirteen years.

(f) IMPORTANT CONSIDERATIONS.

A map of the world or, still better, an ordinary terrestrial globe presents at a glance the reason for the construction of the Panama Canal, such map or globe being of itself sufficient to indicate what the status of the waterway will be, and to show that the canal will provide the one great maritime highway of the West—not between seas, but between oceans; not for countries, but for continents.

The vastness of the interests to be served by the canal, many of which interests now wait for their development on the construction of the waterway, demands that the canal shall, when opened for traffic, be of the type which will most perfectly fulfill the purposes which the waterway is intended to accomplish.

First and foremost it is essential that the Panama Canal shall present not merely a means of interoceanic navigation—it may be said that any type of canal would enable vessels to pass from ocean to ocean—but a means of *safe* and *uninterrupted* navigation, on which no special hazards will be encountered by and no vexatious delays will be occasioned to the vessels which will traverse it. It is therefore evident that the canal ought to be formed in such manner that the course thereof shall be free from all unnecessary obstructions, and that no obstacles should be interposed in that course, whether temporary or permanent, which would by their very nature be an occasion of peril and of detention to passing vessels, and more particularly to vessels of the great size which the Panama Canal is (in accordance with the provisions of the law of Congress) designed to accommodate.

The Board is of opinion that this consideration should be of determinative force in respect to the type of canal to be adopted, and that it should lead to rejection of all proposed plans in which lift locks, whether few or many, form the principal or dominating features, and consequently to the acceptance of the sea-level plan as the only one giving reasonable assurance of safe and uninterrupted navigation.

It is not suggested that a maritime canal with locks forming the essential feature is an inherently unsafe system of navigation, for experience has not only demonstrated the contrary, but also that the matter is one of degree. A navigation with locks of small size capable of passing the ordinary commercial steamers may be made reasonably safe, while a maritime waterway with locks of the dimensions which the Board has considered to be necessary in order to

meet the requirements of the Spooner Act might be and is thought to be so unsafe for the passage of the great seagoing vessels contemplated by that act as to be altogether beyond the limit of prudent design for safe operation and administrative efficiency.

In the course of the proceedings of the Board it transpired that during the last nine years three accidents arising from collisions between steamers in transit and the lock gates, and resulting in each case in dangerous damage to these gates, occurred in the St. Marys Falls Canal; and also that three accidents arising from the same cause and having the same result occurred in the Manchester Ship Canal in England.

Several of these accidents were so serious that disastrous consequences were escaped by a narrow margin only. It is practically certain that if the locks upon which these accidents took place had been of the dimensions and had controlled the great differences of level contemplated for the locks of the Panama Canal, not merely serious accidents but disasters would have followed in perhaps all these cases, throwing the whole canal out of operation for a period which can not be estimated, and also wrecking the vessels in the path of the resulting flood, while the cost required to repair the damages is not within the limits of reasonable computation.

The three accidents at St. Marys Falls Canal occurred within a period of nine years, where there is only one lockage of about 20 feet. If six locks should be adopted in a plan for the Panama Canal, each having a lift of 30 feet or more, as has been proposed in several projects, it would not be unreasonable, with an equal number of vessels, to look for six times the number of accidents in the same period of time, which would be at the rate of two per year. If groups of locks should be arranged in flights, as has also been proposed in some projects, the imminence of disastrous accidents would be greatly enhanced, as would be the amount of damage to the structures and to the vessels involved. Indeed, it is highly probable that the grave disaster of a great ocean steamship breaking through the gates of the upper lock and plunging down through those below might be realized.

It is the unqualified judgment of the Board that the United States Government should not construct an interoceanic waterway to accommodate the commerce of the world exposed to hazards of this sort. These conditions become even more serious when it is contemplated that this canal is to be used for strategic purposes, and therefore for the interoceanic transit of vessels of war of the United States Navy.

Consideration of the growth in size and weight of battle ships during the last ten years—and of the fact that this growth is still progressing—leads to the inevitable conclusion that in the not distant future armor-clad vessels of a beam of 90 feet and with a displacement of 25,000 tons may be expected. The dimensions adopted by the Board for the canal prism and for the lock chambers would admit of the passage of these vessels.

Argument does not seem to be required to emphasize the necessity of avoiding the process of locking these ponderous and unwieldy ironclads up or down in the Panama Canal. The difficulty of handling them in the most favorable circumstances is notorious, while in the operations required for raising them in one series of locks and for dropping them down in another series the difficulty would come so perilously near impracticability that in the opinion of the Board no scheme involving it should be accepted.

As there is no maritime canal in the United States or about its borders it is natural to regard the navigation of the St. Marys Falls Canal as exhibiting conditions practically parallel to those which would exist in the Panama Canal, but inferences drawn upon such a basis may be greatly misleading. The lock in that canal has been so successfully operated and its administration has exhibited such gratifying results that there is danger of forgetting that it is located in an environment of a highly special character. It is now a marked feature of the navigation route of the Great Lakes. The masters of the vessels passing this canal and lock are therefore familiar not only with every detail of the short canal in which the lock is located and of the lock itself, but also of every circumstance of its operation. They pass to and fro with their ships every two or three weeks during the period of navigation, so that the vessels which the lock serves are almost fixed features of a daily routine from which there is little or no variation. Entrance to and exit from the lock becomes by constant familiarity a routine performance in which constant repeti-

tion leads to a degree of skill and safety which can never be attained in a maritime waterway like that of the Panama Canal, serving the commerce of the world, carried in vessels whose masters would come in contact with the physical conditions surrounding the locks and the regulations governing their operation at rare intervals only, and whose crews would be absolutely strange to every feature of this canal service. Under such circumstances any variation from the simplest and plainest conditions of navigation would necessarily be a source of grave danger and likely to lead to serious accident. Again, the canal navigation at Sault Ste. Marie is closed by ice for three or four months each year. Then the locks are or can be pumped out, the gates and all other mechanism examined and repaired or replaced; but there will be no such annual period of idleness for similar overhauling at Panama.

It has already been shown in this report how seriously the existence or nonexistence of locks may affect the safety of this canal navigation. Those considerations will not be repeated here, but it should be observed that the ease with which vicious enemies of all classes may destroy locks by small quantities of high explosives, or even ram lock gates with a passing ship in an apparently innocent manner, or produce other similar damage to locks, might actually put the control of a canal with lift locks in the hands of such an enemy at a juncture when its maintenance of operation for the passage of naval vessels or for other strategic purposes might be of the utmost necessity to the United States Government.

It is true that a sea-level canal or any restricted waterway may be closed by accident, as by a vessel stranding or sinking. Such an obstruction would be temporary only, as it could be removed in a few days, even if the wreck had to be blown up, as recently occurred in the Suez Canal, an incident mentioned elsewhere in this report. Such an accident is not to be compared with those greater and more far-reaching, resulting in the destruction of the lock gates, the drawing off of the water from the summit level, and the possible serious damage to the canal prism.

It may be argued that the objections to which we have referred as existing to the employment of lift locks apply also to the sea-level plan in which the construction of tidal locks at or near the Pacific terminus is a feature. In reply it may be conceded that the argument is at first sight a fair one and that due weight should be given to it; but while it is clear in any case that one obstruction in the course of a maritime highway would be preferable to six or eight, the difference between the functions of any lift lock in the lock-canal proposal and those of the tidal locks in the sea-level plan should be clear to any impartial critic.

The tidal lock is for regulating purposes only, and the reason for its introduction is due to the natural circumstances which exist, there being practically no tidal range in the bay of Limon, at the Atlantic end of the canal, while in the bay of Panama, at the Pacific terminus, the range at high spring tides is more than 20 feet.

Much has been said in the projects submitted to the Board about the advantages of lake navigation in the great reservoirs or lakes which it has been proposed to create by dams across the Chagres on the one side of the Isthmus and across the estuary of the Rio Grande on the other. Extended experience in the navigation of maritime canals on the continent of Europe and in Great Britain has shown that this advantage is largely imaginary, for it has been found in such canals, with prisms of much less dimensions than those recommended for this route, that steamers of the largest size which they can accommodate may steam through them at speeds of about six miles per hour without any real difficulty or danger. Such is the case in the Suez Canal and the Manchester Ship Canal. As a matter of fact, throughout the greater part of the Panama Canal traversing the proposed lakes the actual channels would have submerged banks, necessitating buoys, and within which the speed of vessels would not greatly exceed that possible in the sea-level canal.

It must also be observed in making a comparative consideration of the lock and sea-level types of canal that the locks in the former constitute a restriction or limit to the capacity for traffic of the waterway in which they are found, i. e., they are in a substantial measure obstructions to navigation. There is a limit to the number of lockages per day which may be made, perhaps not exceeding ten per lock or twenty per pair in any of the lock plans hitherto

considered. The maintenance and operation of locks is also costly. If of such great dimensions as those considered necessary by the Board under the Spooner Act, they require the installation, maintenance, and operation of an extensive power plant for the working of the gates. It is not easy to estimate what the annual cost of maintenance, including renewals and operation, of these would be, but, using the estimates of the Isthmian Canal Commission of 1899–1901, it is probable that the annual cost of operation of the six locks contemplated in the projects brought before the Board would be about $525,000. This annual charge capitalized at three per cent would make a sum of $17,500,000 to be added to the cost of the lock canal. The corresponding item in the sea-level plan would be the capitalized annual cost of operating the tidal locks near Panama.

The comparative ease and economy of enlarging the prism of the sea-level canal to accommodate any additional demands of the future must be given the weight which properly belongs to it. The operations which have already been conducted so extensively in enlarging the prisms of the Suez and Manchester Ship canals, and which are now about to be undertaken at the Kaiser Wilhelm Canal at Kiel, show that such operations may be required. The facility with which work of that character may be done in a sea-level waterway where there are no lock structures constitutes a material advantage.

It has already been stated as the opinion of the Board that the time required for the construction of the Panama Canal with a summit level at 60 feet above mean sea level will at best be only two years less than required for the construction of the sea-level canal. But as affecting this question of time, it should be observed that accidents during construction leading to an extension of the time required to complete the canal would be more likely to occur in the more numerous structures involved in the building of the lock canal than in the works for the sea-level canal. It has further been shown that the difference in cost between the two plans will not exceed about $71,000,000 in favor of the former, which must be reduced by the capitalized cost of the maintenance and operation of locks and by the cost of the overflowed lands, as before stated.

It is seen, therefore, that the lock design has inconsiderable advantage either in time of realization or ultimate cost over the one recommended by the Board for adoption by the United States Government, which possesses all the advantages of practically indefinite capacity for traffic, besides a degree of safety and uninterrupted operation which can not be approached by any lock plan.

Did a canal now exist of the widths proposed, but limited in depth to 35 feet, it would accommodate all existing shipping. By restricting the depths in the prisms (but not in the locks), as suggested but not recommended, the channel could probably be opened in a year or two less than if constructed at first to full depth, and the saving in cost would amount to about $17,000,000. When it should be decided to take out the other five feet in order to accommodate vessels of a greater depth, that could readily be done at some increase of cost over what would have been incurred if made originally at the full depth of 40 feet.

The Board desires to emphasize the fact that in its knowledge no great enterprise in connection with transportation, whether it be a canal, a railway, a harbor or docks, or similar work, has ever yet been completed of such size or proportions that subsequent enlargement did not become necessary. The Board is therefore of the opinion that in this particular case the United States Government should construct this great artificial waterway of such type and dimensions as to give it at the outset the maximum capacity that seems likely to be required, guaranteeing the greatest facility of operation, and leaving the canal as constructed with ample provision for a reasonable future increase of traffic and in condition for most speedy and economical enlargement in response to the future demands of commerce, without the undoing of any construction.

It is the belief of the Board that the essential and the indispensable features of a convenient and safe ship canal at the American Isthmus are now known; that such a canal can be constructed in twelve or thirteen years' time; that the cost will be less than $250,000,000; that it will endure for all time.

The Board does not believe that a provisional treatment of this great question would yield results which would be satisfactory to the American nation or advantageous to American commerce, or that such treatment would be in consonance with the increase of population, of trade, and of wealth which will surely take place during the next half century in the Western Hemisphere.

For all these reasons the Board recommends that the sea-level plan be adopted for the Panama Canal.

Mr. Quellennec's indorsement of this report is to be considered in connection with his statements qualifying his vote as recorded in the minutes of the nineteenth and twenty-fifth meetings.

Respectfully submitted.

GEO. W. DAVIS.
WM. BARCLAY PARSONS.
WM. H. BURR.
WM. HENRY HUNTER.
AD. GUÉRARD.
EUGEN TINCAUZER.
J. W. WELCKER.
E. QUELLENNEC.

MINORITY REPORT.

The undersigned, a minority of the Board, concurring with much of the preceding report, dissent from the preference expressed for a sea-level canal.

We believe a lock canal the better one for the United States to construct, for the following reasons:

1. Greater capacity for traffic than afforded by the narrow waterway proposed by the Board.
2. Greater safety for ships and less danger of interruption to traffic by reason of the wider and deeper channels which the lock canal makes possible at small cost.
3. Quicker passage across the Isthmus for large ships or a large traffic.
4. Materially less time required for construction.
5. Materially less cost.

The studies of a lock canal by the Board, and for the Board by its committees, embraced a number of projects with summit levels varying from 30 to 90 feet above mean tide (which will be hereinafter referred to as elevation 30, elevation 90, etc.), with duplicate locks having usable widths of 95 and 100 feet, and usable lengths of 900 and 1,000 feet, located at various places, and with the summit level maintained on the Atlantic side by dams at Mindi, Gatun, Bohio, or Obispo. The projects of Mr. Bates, with summit levels up to elevation 97, of Major Gillette, with summit level at elevation 100, and of Mr. Bunau-Varilla, with summit level at elevation 130, were also considered. The Board selected for comparison with the sea-level project a lock canal with summit level at elevation 60 and with locks having a width of 100 feet and usable length of 1,000 feet, which is described in the report of the Board.

The undersigned are of opinion that there are several variants for lock canals which should have preference over the sea-level project, consideration being given to facility and safety of transit, and time and cost of construction; and that, for reasons which follow, locks of the smaller dimensions noted above will adequately meet all probable demands for a long term of years. We present for comparison with the project preferred by the Board, to be considered later, a project with summit level at elevation 85 maintained by a dam and duplicate flights of three locks at Gatun. This is recommended for adoption, General Abbot preferring a lower dam with duplicate flights of two locks at Gatun, supplemented by a dam and duplicate single locks at Bohio, raising the summit level to elevation 85, as before.

THE LOCK-CANAL PROJECT RECOMMENDED.

This project is a modification of the one adopted by the Isthmian Canal Commission of 1899–1901, the modifications being due in part to the requirement for greater dimensions imposed by the act of Congress approved June 28, 1902, called the Spooner Act, and in part to data collected within the last two years, which make it feasible to design a much better canal without increased cost. The elevation of the summit level is practically the same as in the earlier project. Unfavorable developments at the site of the proposed Bohio dam and the existence of more favorable conditions at a site nearer the Atlantic, together with important incidental advantages, have led us to recommend the latter. On the Pacific side the terminal lock is placed at Sosa, instead of at Miraflores, for reasons which will appear further on.

(a) THE COLON ENTRANCE.

Commencing the description at the Atlantic end, the plan of the Board for a breakwater in Limon Bay is, with only a slight change, adopted for purposes of estimate. The change consists in swinging the long westerly line out from the shore at Mindi Point far enough to permit the

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channel (500 feet wide and 41 feet deep at mean tide) to be made through the easily dredged earth outside the point, instead of inside the point where there would be much expensive rock excavation. The breakwater and channel as modified will be extended to the head of the bay. It seems possible that the breakwater may be dispensed with wholly, or in part, and the channel widened to 1,000 feet or more, to the advantage of navigation and with a reduction of cost.

The Board's plan of harbor and canal entrance, however, is much superior to that of the French company, as it provides a safe and easy entrance at all times. The distance from the head of the breakwater to the shore line near the mouth of the river Mindi is 4.55 miles. From this point the 500-foot channel is to be continued 2.6 miles farther, to the locks at Gatun.

(b) THE GATUN DAM.

The controlling feature of the project with summit level at elevation 85 is the earth dam across the Chagres at Gatun. The object of this dam is to form a great reservoir, or inland lake, in which the floods of the Chagres will be received and from which the surplus water will be discharged through sluices and the height of water in the reservoir regulated. Lake Gatun will be about 110 square miles in area and will form the summit level of the canal. The lake will also serve to impound water for lockage and other purposes during the dry season and to give free, open navigation in a broad waterway all the way from Gatun to Obispo.

Every lock plan heretofore recommended for a Panama Canal has included a dam across the Chagres, thereby providing for lake navigation for a portion of the distance across the Isthmus. All of the official reports have recommended that the dam be placed at Bohio, where the valley is narrow, but Gatun has also been mentioned as a site which would be advantageous if the feasibility of building a dam and locks at this place at a reasonable cost were established.

Since the United States has taken charge at the Isthmus, the Isthmian Canal Commission has had many borings made at and near these two sites. Those at Bohio, which are especially complete, show a greater proportion of water-bearing porous material than had previously been found. The maximum depth to the rock on the most feasible line for a dam at this place is 165 feet below sea level.

The borings made prior to September, 1905, at and near Gatun showed nearly everywhere an admixture of sand with clay and impervious material, with a maximum depth to rock of 204 feet below sea level. Many of the borings, even those at considerable depths, encountered shells, wood, and vegetable matter, all tending to show that the material had been deposited in currents too sluggish to transport gravel and other coarse material.

The borings were "water jet" or "wash drill" borings, made by first driving, when necessary, an iron pipe (known as a casing) having an inside diameter of two or two and one-half inches, and then inserting a smaller pipe through which a jet of water was forced, washing the material in the larger pipe through the annular space between the two pipes to the surface of the ground. It was characteristic of these borings, and also significant, that in many cases it was not necessary to drive any casing; or, if one was driven, it was not necessary to drive it to the full depth, as the material contained enough clay to sustain the sides of the hole without the casing.

Of 27 borings made before September with reference to the location of a dam at or near Gatun, no casing was used in thirteen holes; in three other holes the length of casing did not exceed 20 feet, while in the remainder the length of casing ranged from 28 to 101 feet, but in no instance was the casing driven much more than halfway down to the bottom of the hole.

The depth to rock was shown to be so great, both at Bohio and at Gatun, that it would be costly and difficult in either case, if not impracticable, to excavate to the rock or to provide any efficient cut-off or stop-water extending from the surface of the ground to the rock; and if a dam were to be built without such cut-off the borings showed clearly that there would be less seepage beneath a dam built at Gatun than at Bohio.

In addition to the borings, the Commission had caused topographic surveys to be made at the site of the dam, which showed what was apparently an excellent site for locks on the high ground back of Gatun, and a suitable site for a diversion channel for conveying the water of the

Chagres during the construction of the earth dam and for regulating works to control the discharge of surplus water from the lake to be formed by the dam.

Few borings had been made at the exact site selected for the dam, and none had been made at the sites selected on the high lands for the locks and the regulating works. The Commission was therefore requested by the Board to have some additional borings made, both on the high lands and in the valleys, and also some additional topographic surveys.

The location of all borings is shown on the map of the Gatun dam site, Plate XI, and the borings on a line across the valley at the dam site are shown on Plate XII.

It will be noticed on Plate XII that there are two deep depressions or gorges in the rock, which have been filled with alluvial material. The deepest boring penetrated this material 258 feet before striking rock. The lower 50 to 60 feet of the material in the deepest gorge was found to be for the most part porous sand and gravel, which was undoubtedly deposited at a time when the currents through the gorge were swifter than existed when the upper 200 feet of the alluvial material was deposited. In the upper 200 feet some of the later borings show fine sand, while other borings near by show clay at the same depths, indicating, as do previous borings, that the upper 200 feet is practically impervious material. There was an outflow from several of the borings which penetrated the gravelly material in the bottom of the deep gorge, although the tops of the casings were above the surface of the river. This showed conclusively that there was no near connection with the bed of the river; in other words, that the material covering the sand and gravel was impervious for a long distance.

A sample of the material washed from the ground during the boring operations, which had been collected in a pail without allowing any of the fine material to escape, was shown to the Board during its visit to the Isthmus. This sample showed material of sizes varying from sand to the very fine particles of clay which settled last and formed an impervious film over the surface of the coarser material deposited in the bottom of the pail.

The samples of sand which had been obtained up to the time of the visit of the Board were fine, much more so than samples from borings at the Bohio site.

We believe as a result of the borings which have been made that if a large earth dam were to be built at Gatun, as indicated upon the drawings, there would be no appreciable seepage under the dam, owing to the practically impervious nature of the material on which it would rest and to the fact that the more pervious material found at the bottom of one of the gorges in the lower 50 feet is covered by a blanket of practically impervious material 200 feet thick.

The borings on the high ground, at the site of the locks, the regulating works, and elsewhere, showed generally soft clay to a depth of 20 to 30 feet below the surface, where indurated clay—a soft but compact rock—was found.

In making the design of an earth dam at Gatun, it was thought best to provide a dam which could not be destroyed by any of the forces of nature, and which could only be destroyed by making excavations which would require a large force working for a long time.

The cross section of the dam has been given the unprecedentedly large dimensions shown on Plate XIV. Its top is 50 feet above the water level in the lake and 100 feet wide; at the water level the distance through the dam is 374 feet, and at sea level the corresponding distance is 2,625 feet, or one-half mile.

It is intended that the downstream toe of the dam for about 200 feet shall be composed of rock obtained from excavation in the canal prism, so that if there should be any seepage of water through the dam there will be material at the toe which can not be washed away. The lower part of the dam, up to elevation 50, or even to elevation 80, is to be made from material dredged from the canal between the Gatun locks and Limon Bay, pumped by a suction dredge into the dam, the process being similar to the sluicing process employed in the construction of some important dams in the western part of the United States. By this process it is feasible when using a material like the alluvial material at Gatun, which contains both coarse and fine material, to separate the two and to deposit the coarser material toward the downstream slopes, forcing the finer material to the extent desired into the upstream portion of the dam. An embankment built in this way will be water-tight.

For the upstream slope, rock obtained from canal excavations will be dumped as riprap, care being taken to provide an ample thickness at and near the level where the dam will be exposed to wave action.

The portion of the dam above elevation 80 will be built of impervious material to a few feet above the water level, and at higher levels may be made of either earth or rock, as most convenient. It is expected that for the upper part of the dam, spoil from the Culebra cut will be used.

While earth dams are in common use, and in many cases support greater heads of water than would exist at the proposed Gatun dam, it will still be argued by many that in a great work like the Panama Canal nothing should be trusted but the most massive masonry dam on a solid rock foundation. At Gatun the rock lies at so great a depth that a masonry dam thus founded is impracticable, and without such foundation a masonry dam would be most unsuitable. It seems desirable, therefore, to enter to some extent into the discussion of the stability of the proposed earth dam.

STABILITY OF AN EARTH DAM.

It is obvious that if a dam of this kind is to fail, some part of its length must be pushed away bodily, or the earth of which it is composed must be carried away by currents of water. There are no other natural forces which can materially affect the stability of the dam.

The horizontal pressure of the water in the lake per linear foot of dam is less than one sixty-third of the weight of the dam per linear foot, a pressure so small that it is obvious that it can not move the whole mass, and there is left, therefore, as the only way in which a dam of this kind may fail, the carrying away of its parts by a current of water.

The currents of water requiring consideration are those resulting from the action of the waves, from the rainfall, or from seepage through the dam.

The feasibility of protecting the face of the dam from the action of waves will hardly be questioned. The effect of the rainfall can easily be provided for, particularly on the main downstream slope, which falls but one foot in twenty-five.

It is impossible for water to flow over the top of a dam that is raised 50 feet above the water level, and if the dam and the underlying material were strictly impervious there would be no water from the lake passing through it. On the other hand, if the material in or under the dam is somewhat pervious, there will be some water passing through which will appear at the surface, either immediately below the dam or toward the lower portion of the downstream slope.

The amount of water which will pass through somewhat pervious material in or under a dam depends upon the relation between the total head and the distance through the dam, and not, as is sometimes assumed, upon the total head against the dam.

If two dams are built under similar conditions, except that one has a thickness five times as great as the other, then there will be at the dam having the greater thickness only one-fifth as much seepage as at the other; that is to say, other things being equal, the seepage through a dam will be substantially in proportion to the depth of water against the dam, divided by the distance through the dam, giving what may be called the hydraulic gradient or slope of the line of saturation, which in this case does not exceed four per cent.

There have been many experiments on the vertical and horizontal filtration of water through various kinds of materials and with various hydraulic gradients. Some of these were made at the Lawrence Experiment Station of the Massachusetts Board of Health and others were made at the Wachusett reservoir of the Metropolitan Water Works, in Massachusetts, in connection with the construction of a dam similar to that proposed at Gatun. These experiments were made with materials of uniform character, through which more water would filter than through materials containing fine and coarse particles of the same average degree of coarseness, such as those found at the site of the Gatun dam, and they furnished results which confirm the statement already made that there would be no appreciable seepage under this dam.

If, however, a condition which *does not exist* be assumed, and all of the alluvial material beneath the embankment of the dam were considered to be a clean and reasonably uniform sand of

medium size, the total amount of filtration would then be for the whole length of the dam only about 10 cubic feet per second. Even this amount, which is much larger than would actually exist, is insignificant, and is less than one-half of one per cent of the water supply available in the driest season.

Few engineers who have been connected with the filtration of city water supplies would hesitate to provide works which would permit the amount of water above stated to rise to the surface without carrying with it any of the earth, because they have a much more difficult problem in connection with the downward filtration of water, where the works must be so built that the sand will not be carried down with the water.

The method followed in water filtration is to place coarse stones at the bottom of the filter and to cover these stones with finer and finer stones, and then with coarse sand, in order to retain the finer sand used for filtration. It is a simple operation to build the reverse of such a filter, which will permit the water to rise from the ground without carrying the earth with it.

It is not expected that there will be enough seepage through the Gatun dam to require any special treatment, but if there should be it could readily be taken care of by the method indicated, which has already been used with success in connection with a dam built of sand on a sand and mud foundation at Jeypore, India.

Upward filtration occurs frequently in nature, where water comes from springs near the base of hills, often in sandy or gravelly material, without carrying with it any appreciable quantity of earth.

Many small earth dams and levees have failed, owing to a passage being made through them by some burrowing animal, or by the water following some pipe or other structure built through the dam, but in the present case it is not proposed to lay any pipe or other structure through the dam, and a burrowing animal could not burrow through where the shortest distance at the water line is 374 feet.

It seems to be impossible that any of the particles of earth buried in the body of the dam could be moved by a slow seepage of water, except such particles as were soluble, which might, in the course of ages, be dissolved and carried off by the seepage water.

Some of the views held in respect to the movement of material in the body of earth dams are based upon observations of very small dams, and often of those negligently constructed or of a very narrow section, and have no place in connection with a properly constructed large earth dam.

A dam such as the one proposed is very heavy, the weight upon its foundation being about one ton per square foot for each 20 feet in height of embankment. Under the highest part of the embankment the pressure would be six and one-half tons per square foot. It is obviously impossible that with such a pressure upon the material any particles could be moved by the extremely gradual seepage of water through the interstices due to a difference of water level of less than four feet in 100.

Such a dam as is here proposed if not absolutely earthquake proof is probably more nearly so than any other type of dam.

A comparison between the section of the Gatun dam and that of a few existing earth dams is shown on Plate XIV. The San Leandro dam of the Contra Costa Water Company, 120 feet high, which supplies water to Oakland, Cal., is the highest earth dam in the world, and it was constructed in part by sluicing. The Pilarcitos dam, 95 feet high, built in 1866 by the Spring Valley Water Company, which supplies water to San Francisco, is also one of the larger dams, although there are several others of about the same size, which have been successful.

The Jeypore dam is introduced on the diagram because it was built of sand on a foundation of sand, mud, and soil, and at a place where the material is very pervious, so that considerable water filters under and through the dam. It has, however, proved to be stable under these conditions.

The United States Reclamation Service has recently planned an earth dam to sustain a head of 100 feet with a width at the water line less than one-fourth that proposed for the Gatun dam and with a proportionately narrow base.

It will be noted that these dams have a small section in proportion to the depth of water behind them when compared with the Gatun dam.

Earth dams are in such common use, are so generally indorsed by engineers, many of whom prefer them to other forms, that this extended discussion has been given only because the proposed use of earth dams has been unduly criticised in the report of the Board.

The nearest precedent in general design for the Gatun dam is the north dike of the Wachusett reservoir of the Metropolitan Water Works, of Massachusetts, which is two miles long and at the deepest place will have 65 feet of water against it. The highest portion of this dike was built on exactly the plan proposed for the Gatun dam, namely, the fine material of which the dike is composed was deposited on the fine underlying material without the use of either masonry or sheet piling to prevent the filtration of water. Under portions of this dike the depth to the rock is as great as at the Gatun dam.

PLAN OF THE DAM.

Plate XI shows a plan of the dam. Its total length from the locks to the westerly end is 7,700 feet. About midway in the length of the dam there is rising ground in which it is proposed to excavate, as already indicated, a diversion channel through which the Chagres will flow during the construction of the earth dam.

The regulating works, to be subsequently described, will be built mainly of concrete and will be located in part in the diversion channel and on each side of it. On each side of the rising ground referred to, and extending from it westerly to the high ground and easterly to the locks back of Gatun, there will be great earth embankments of the cross section already described, which will together contain 21,200,000 cubic yards of material. The westerly embankment will cross a French diversion channel. The easterly embankment will cross the French canal and the Chagres.

It will be feasible to begin at once the construction of one of the earth embankments, permitting the water to flow through the channel or channels at the site of the other embankment. It will also be feasible to begin at once the construction of the diversion channel, utilizing the material excavated in the embankments of the dam.

In the construction of the dam it is proposed to remove all trees, stumps, and roots from its site and to excavate the surface material to such an extent that the impervious material of the embankment will come in direct contact with the impervious clayey material which is found nearly everywhere in this region; also to do any other work required to cut off the flow through any pervious material which further investigations may disclose. For such work an allowance of $400,000 for all dams has been made in the estimate of cost.

The diversion channel is to have a minimum width of 150 feet and is to be excavated to sea level, or somewhat below it; although the lower part of the channel will be through indurated clay, it is proposed to place in it concrete where required for the protection of the channel or for the regulating works up to sea level, and to build in the channel to an elevation about four feet above sea level the foundations of certain piers and walls, which will remain for a time at this elevation, so that they will form only a slight obstruction to the discharge of flood waters.

After the earthwork of the dam reaches a sufficient height to be beyond all danger of overflow, the piers and walls, which will be above water at low stages of the river, and which will have in them grooves for stop planks, will be built to higher elevations to furnish a ready means of turning the river through half of the diversion channel while the other half is pumped dry to permit the placing of the concrete of the regulating works, and by turning the river alternately from one side to the other the regulating works may be built without special difficulty.

REGULATING WORKS.

The general design of the regulating works is shown on Plate XIII. The central 150 feet of their length, which will be built up from the bottom of the diversion channel, is to be a solid mass of concrete, having its crest at elevation 69. The crest is to be made wide with the downstream slope two horizontal to one vertical, making an unusually strong section.

On the top of the crest, piers eight feet in thickness, grooved for Stoney sluice gates, are to be built 38 feet from center to center, having clear openings of 30 feet. These gates, as proposed, are almost exact counterparts of the gates provided for controlling the flow from the lower end of the Chicago Drainage Canal, but the sills are to be placed 16 feet below the normal water level, instead of 15 feet, as at the Chicago Drainage Canal.

For the whole length of the regulating works the design is the same as the central portion, except that the concrete rests upon the surface of the rock or upon excavations made in the rock, as indicated by the two smaller sections on the plan. The water passing through the central sluices will flow directly out through the diversion channel to the Chagres; that passing through the sluices nearer the ends of the regulating works will be caught by intercepting channels sloping toward the central portion, and will follow the course indicated by the arrows on the plan, flowing toward the central portion and thence out through the diversion channel.

The regulating works are capable of discharging 140,000 cubic feet per second when the water in the lake is not more than one foot above the normal level.

It is thought that in connection with a great lake, such as here proposed, regulating works which can discharge a great quantity of water when the lake is at its normal level are preferable to an uncontrolled overflow spillway which will not begin to discharge water in any considerable quantity until a flood has raised the lake above its normal level.

With the uncontrolled spillway 2,000 feet long, recommended by the Isthmian Canal Commission of 1899–1901 in connection with the Bohio dam, it was estimated that the water in the lake might be raised five feet above its normal level by a maximum flood.

With the regulating works proposed in connection with the Gatun dam it is estimated that the surface of the lake will never be raised by a maximum flood more than two feet above the normal level, and with ordinary floods it would be feasible by beginning the discharge before the flood waters reached the lake to keep the surface from rising to any appreciable extent.

Such sluices as are here proposed would be very objectionable on a river or even at the outlet of a small lake, but in a great lake like that to be formed by the Gatun dam the currents toward the outlet will, under ordinary conditions, be inappreciable, so that the course of any floating substances will be determined by the wind instead of by the current and they will be stranded on the shores; moreover, if, during floods, trees and other drift should be washed into the lake from the tributary rivers, they would not have time, on account of the great size of the lake, to reach the Gatun dam before the flood subsides.

REDUCTION IN COST.

The great quantity of material to be placed in the Gatun dam may cause it to be inferred that a structure at this place adds to the cost of the canal; but it should be borne in mind that the adoption of this site eliminates large expenditures for the canal and diversion channels between Gatun and Bohio. A comparison shows that there is a saving of $11,894,621 in the estimated cost of works by the change in the location of the dam, made up as follows:

Works omitted.

Bohio dam	$6,369,640
Gigante spillway	1,209,419
Canal between Gatun and Bohio	7,643,067
Peña Blanca outlet	2,448,076
Chagres diversion	1,929,982
Gatun diversion	100,000
	19,700,184
Add 20 per cent for contingencies, etc	3,940,037
Total for works omitted	23,640,221

Additional works required.

Gatun dam	$7,788,000
Panama Railroad diversion from Mindi to Bohio	2,000,000
	9,788,000
Add 20 per cent for contingencies, etc	1,957,600
Total for additional works required	$11,745,600
Amount saved by change in location of dam	11,894,621

The estimates of the cost of the works omitted were made by the Isthmian Canal Commission of 1899–1901.

In the above table it will be noted that the locks have been omitted. The lock site at Bohio adopted by the Comité Technique of the New Panama Canal Company and by the Isthmian Canal Commission of 1899–1901 furnished a rock foundation for only two locks of the sizes then proposed. The requirement of the law under which the canal is being constructed makes it necessary to provide longer locks than can be accommodated with a rock foundation at the Bohio site. Moreover, it was thought desirable to make the lift to the 85-foot summit level with three locks rather than with two, and the Gatun site affords an opportunity for doing this. The three large locks will cost more than the two smaller locks proposed at Bohio.

The adoption of Gatun as a site for a dam not only provides for reduced cost and a better lock site, but, as compared with Bohio, it offers several important advantages. The first of these is a large addition to the drainage area tributary to the summit level and to the amount of water available for canal uses, which is of special value during the dry season; the second is the great increase in the reservoir area, Lake Gatun having almost three times the area of the lake formed by a dam at Bohio; this permits storing water for the dry season and the reception of floods with a maximum variation of lake level of only about one-half of that taken by the first Isthmian Canal Commission for Lake Bohio. A third advantage which will be described more fully farther on is the extension of lake navigation nine and one-half miles toward the Atlantic from Bohio; a fourth is that the Chagres and all its important tributaries will be received into the lake at points so distant from the canal route that no deposit of suspended material will occur along it, and a fifth is that the water discharged from the lake will enter the Chagres at the point where it finally diverges from the canal so that no diversion channels or heavy protecting embankments will be required along the canal line.

(c) WATER SUPPLY OF THE CANAL.

The general subject of water supply for the canal is treated in a paper by Gen. Henry L. Abbot, published as Appendix E of this report, and the present statement will deal only with the main features of the water supply for the project recommended.

It has been shown in the paper mentioned that the volume which would flow into Lake Gatun in the dry season is about two-thirds greater than that into a lake formed by a dam at Bohio, and that the minimum contribution to Lake Gatun, judging from the record of measurements of flow covering a period of fifteen years, is 1,250 feet per second during the driest three months. In order to provide for still drier periods it has been thought advisable to adopt 80 per cent of this volume, equal to 1,000 cubic feet per second, as an entirely safe quantity.

The lake can be safely raised toward the end of the wet season one foot above the normal level, and provision has been made in the design of the canal for drawing the lake three feet below the normal level, so that the contents of the upper four feet of the lake, equal to 12,270,000,000 cubic feet, will be available for water-supply purposes during the dry season.

This quantity will provide a steady flow of 1,577 cubic feet per second for ninety days, making the total quantity of water, after adding the inflow, 2,577 cubic feet per second.

Not all of this water, however, is available, as it is necessary to deduct losses by evaporation and leakage, and it is also convenient to use some of the water to furnish power for operating the gates, for lighting, and for other purposes.

The quantities required for these purposes are given in General Abbot's paper, and have been adopted with only a slight modification of the amount of leakage, due to the smaller size of gates provided by the plan recommended. The amounts are as follows:

	Cubic feet per second.
Evaporation	710
Leakage at gates	240
Infiltration, waste at locks, etc	77
Lighting, power, etc	200
Total	1,227

The item of 200 cubic feet per second for contingencies given in his table has been omitted, because this has been covered by using only 80 per cent of the estimated minimum flow; moreover, the allowance for evaporation is a very liberal one.

The net quantity of water available for lockage is, therefore, the difference between 2,577 and 1,227, equal to 1,350 cubic feet per second.

To determine the number of lockages which this quantity of water will provide for, the following provisions and assumptions have been made:

Intermediate gates are to be provided for the locks at Pedro Miguel and Sosa, so as to give a chamber length of 600 feet, and it is assumed that the intermediate gates will be used for eight-tenths of the lockages. At the Gatun locks intermediate gates would not furnish the same advantages for saving water, as there are three locks in a flight, and they are therefore omitted.

It is further assumed that all ships passing in one direction will use one set of locks, and all ships passing in the other direction another set. On this assumption, the same quantity of water is used whether a ship passes through a single lock or through two or three locks in a flight.

The lift to the normal summit level at Pedro Miguel is 30 feet and at Gatun 28¼ feet per lock. The quantity of water required per lockage at Pedro Miguel, on the assumption that intermediate gates will be used eight-tenths of the time, is 22.13 cubic feet per second, and the quantity per lockage at Gatun 29.77 cubic feet per second, making a total of 51.90 cubic feet per second.

The net available quantity of water is, as already stated, 1,350 cubic feet per second, and will therefore provide for 26 lockages per day at each lock during the driest three months.

In order to provide for more lockages per day it will only be necessary to store more of the freshet water. The Alhajuela dam, raised to the height proposed by the Comité Technique, would store enough water to provide for fully 27 additional lockages per day.

In order to determine the amount of tonnage provided for by the 26 lockages per day, for which the water supply is sufficient without the Alhajuela dam, it is necessary to take into account the amount of tonnage which will pass through the canal per lockage, and in this connection it should be noted that the full-sized locks will pass two ordinary ships at a time.

The size of the ships passing through the Suez Canal has been increasing from year to year; they averaged 3,163 tons per ship in 1904 and 2,398 tons per ship ten years earlier. The rules for measuring tonnage at this canal, however, give a measurement in excess of that given by Lloyd's net register of about one-sixth.

It seems probable that when the traffic at the Isthmus requires 26 lockages per day, in view of the growth in the size of ships and of the fact that two ships of ordinary size can pass through a lock at the same time, the amount of tonnage per lockage will be as much as 5,000.

The annual tonnage provided for by the water supply, both without and with the Alhajuela dam and on a basis of 3,000, 4,000, and 5,000 tons per lockage, is as follows:

Tons per lockage.	Annual tonnage without Alhajuela dam.	Annual tonnage with Alhajuela dam.
3,000	28,470,000	58,035,000
4,000	37,960,000	77,380,000
5,000	47,450,000	96,725,000

Should it be found necessary in the future to provide for the passage of a still larger tonnage, the Chagres and its tributaries will furnish additional water, which may be stored and subsequently utilized.

(D) THE SUMMIT LEVEL.

As already stated, the summit level will be reached from the level of the Atlantic by means of duplicate flights of three locks at Gatun. The flights being in duplicate give security against serious delays to ships in case one flight is out of use, as it must be occasionally to make the repairs and renewals necessary for efficient work. The facility afforded for repairs by duplicate locks meets any objection that there will be no period at the Panama Canal for repairing gates and other mechanism.

The total length of the lake will be 30 miles, of which 23 miles will be navigated by ships crossing the Isthmus. Its depth will be about 75 feet in the immediate vicinity of the dam, this being maintained with little reduction to Bohio and thence reducing gradually toward Obispo, where the depth of 45 feet will be obtained with but little excavation, the bed of the river being about 45 feet below the surface of the future lake.

For 15.69 miles above the Gatun locks the deep portion of the lake will have generally a width exceeding half a mile, and only a small amount of excavation will be required to provide a navigable channel nowhere less than 1,000 feet wide at the bottom and 45 feet deep. Farther up the lake, as the amount of excavation required to obtain a depth of 45 feet increases, the minimum width of the channel will be decreased, first to 800 feet for a distance of 3.86 miles from San Pablo to Juan Grande, then to 500 feet for 3.73 miles to Obispo, and to 300 feet for 1.55 miles from Obispo to Las Cascadas, where the channel will be further narrowed to 200 feet through the heaviest portion of the great central mass known as Culebra.

From Gatun to Obispo, a distance of 23.51 miles, the banks will be submerged except at a few points. Where excavation is required the side slopes will be one on one in earth and four on one in rock. From Obispo to Las Cascadas the banks will be a little above water for the greater part, and the borings indicate a good quality of rock which will permit nearly vertical sides. The sides should be made smooth for the greater safety of ships. This will give 25 miles of navigation from Gatun to the Culebra cut through channels nowhere less than 300 feet wide, and is about twice the distance for which a similar navigation was provided in the project of the first Isthmian Canal Commission, the improvement being due principally to the extension of the summit level from Bohio to Gatun, but also to some extent to enlarging the channel in the vicinity of Obispo, which can be done without great cost. The broad waterway from Gatun to Culebra really furnishes lake navigation and closely resembles the great navigable channels in many harbors and those through the succession of small connected lakes between Lakes Superior and Huron, called the St. Marys River, where the dredged channels in the shallower waters are 300 to 600 feet or more in width and are traversed by a tonnage of more than 3,300,000 net registered tons per month at a speed limited by regulation to nine miles per hour, a limit found necessary in the 300-foot channels on account of the dense traffic and frequent meetings.

Where changes of direction occur, the outer channel lines of adjacent courses are to be carried to an intersection, although very little excavation is required to accomplish this; the point of the inner angle will be dredged off so that a curve of 8,000 feet or more radius can be laid down wholly within the channel limits. This way of changing direction is illustrated in Plates XVIII to XXVIII, which show the turn below the Middle Neebish Rapids in the St. Marys River and the actual course of ships through it. With plenty of room on either side the ships make the turn more sharply than would be prudent in a narrow canal, and with entire safety. Observations taken to locate continuously ships passing this turn are plotted on the plates and show in many cases two turns of short radius instead of one of longer radius. The observations show that ships pass this turn at speeds up to 12 miles per hour. It will be noted that the width of the dredged channel is 600 feet above the turn and 300 feet below it. All the changes in direction in the Panama Canal, in the stretch above described, will be in a broader waterway, except at Obispo where the width will be practically the same. On the map prepared by the first Isthmian Canal Commission the canal line through Lake Bohio was indentical with the one

laid down by the French company, but it was not expected that ships would follow this line rigidly, and attention was called to the fact that Lake Bohio would be "a broad, deep body of water, affording room for anchorage as well as navigation." In the plan of canal advocated herein the lake is greatly extended, and lake navigation becomes a more important feature, so that it is deemed proper to present it more fully. The question is discussed with further detail in Appendix S.

For a distance of 4.7 miles through the deep portion of the Culebra cut the channel is to have a bottom width of 200 feet and to have nearly vertical sides below the water line, and then will become 300 feet wide for 1.88 miles to the Pedro Miguel locks, where the summit level will end. In the vicinity of the locks a low earth embankment without a spillway will be required on the west side.

The duplicate locks at Pedro Miguel will have one lift of 31 feet.

(e) LAKE SOSA.

Passing the locks, the channel will be 500 feet wide for 1.64 miles, then increasing to 1,000 feet or more for the further distance of 3.38 miles to the Sosa locks on the shore of Panama Bay. This broad navigation will be in an artificial lake created by three dams to be subsequently described. There are to be duplicate flights of locks on the west side of Sosa Hill near La Boca, with two lifts of about 31 feet each, from ordinary low tide to the level of Lake Sosa.

When the Board began its work, sufficient information for determining the feasibility of building dams to create a lake at the Pacific end of the canal was not available, and the Isthmian Canal Commission was requested to have additional surveys and borings made at dam and lock sites. As a result of investigations made in compliance with this request it was found to be entirely feasible to build three dams which would retain water to a height of 55 feet above mean tide, and create a lake having an area of about eight square miles, extending along the line of the canal to Pedro Miguel. It was also found that on the westerly side of Sosa Hill, near the La Boca pier, there is a suitable site for duplicate flights of two locks each.

The principal dam is the one at La Boca, which extends from the locks at Sosa Hill across the mouth of the Rio Grande to San Juan Hill. The other dams extend from Sosa Hill to Ancon Hill, and from Ancon Hill in the direction of Corozal to high land just across the Panama Railroad.

At the La Boca dam the greatest depth to rock shown by the borings is 64 feet below "spring low tide" and the material overlying the rock is impervious, consisting of mud and clay. At the other dams the borings showed rock but a short distance below the surface. The proposed cross sections of these dams are given on Plate XIV. They have very liberal dimensions, following in this respect the precedent established in the design of the Gatun dam.

The question having been raised as to the stability of the material at the site of the La Boca dam, the upstream side as well as the downstream side of the cross section of this dam was given a very wide base so as to insure the compression of the mud and clay rather than its displacement. During construction special provision will have to be made for shutting off the tidal flow in the Rio Grande, for which a sum has been allowed in the estimates.

In order to provide for the discharge of the Rio Grande and other rivers entering the lake during the construction of the earth dams, a diversion channel about 50 feet wide is to be cut through the slope of Sosa Hill, near the end of the Ancon-Sosa dam, and sluices or regulating works, similar to those proposed for the Gatun dam but of much less extent, are to be subsequently built in this channel.

The idea of building dams and forming lakes at or near the ends of the canal is not new, as it was suggested by Mr. Kleitz at the International Congress of Engineers, at Paris, in 1879. The Gatun dam was suggested in a discussion of interoceanic canal projects by Mr. Ashbel Welch, in March, 1880, before the American Society of Civil Engineers; both the Gatun and Pacific dams were again suggested by Mr. C. D. Ward in a paper read before that society on May 18, 1904, and both these sites are included in the projects recently presented to the Board by Mr. Lindon W. Bates. The official commissions, however, which have made reports on a lock canal, have favored carrying the tidal section of the canal up to Miraflores.

The advantages of the terminal lake are a reduction of about $8,000,000 in the cost of the canal and the greatly improved navigation, due to introducing 5.48 miles of channels not less than 500 and 1,000 feet wide and 45 feet deep.

In the project of the New Panama Canal Company, and also in that of the first Isthmian Canal Commission, tide water was to be reached at Miraflores, where the terminal lock was to be located.

The sea-level channel from Miraflores to La Boca is more objectionable than the one at the Atlantic end, on account of the great range of the tides at the former (20 feet at spring tides), which would produce tidal currents in the channel, and on account of the increased difficulty of maintaining the required depth by dredging. In excavating a channel to a depth of 40 feet below low tide from Miraflores to La Boca a considerable amount of rock would be encountered.

An objection may possibly be made, from a military point of view, to placing mechanical structures, such as locks, on the ocean shore exposed to the guns of hostile ships. Such an objection would apply also to the sea-level project with its terminal lock on the shore at the Ancon-Sosa saddle. The North Sea locks of the Amsterdam Canal are so placed. If the Panama Canal is to be neutralized, as the Suez Canal is, this objection has little force. A variant has been studied and estimated upon having the terminal lock at Miraflores, three and six-tenths miles inland, but it is not recommended because it costs much more and is less favorable for navigation.

(f) CHANNEL IN PANAMA BAY.

From the Sosa lock to the seven-fathom curve in Panama Bay, a distance of four miles, the channel is to be 300 feet wide at the bottom and 45 feet deep below mean tide. While this width and depth might be made greater with advantage to navigation, they are the dimensions adopted by the Board for the sea-level project with which the project here advocated is to be compared. Moreover, since it must be expected that considerable dredging will be required to maintain this channel, there is no doubt that it will be gradually enlarged by the dredges provided for maintenance.

Excepting near the locks the location of this channel is the same as that of the French company. It therefore renders available the excavation already made there by that company and, more recently, by the United States. With only a small amount of excavation access can be maintained for ships to the La Boca pier, built a few years ago at a cost of about $1,000,000. This pier will be of great service as a landing place during the construction of the canal, and very useful for a coaling station subsequently. The closing of the mouth of the Rio Grande by a dam, as previously described, will stop the existing tidal currents into and out of the estuary and entirely remove the most serious objection made by the Board to the French location.

(g) DIMENSIONS AND COST.

The waterway above described may be summarized with reference to channel widths as follows:

Width.	Length.	Per cent of route.
	Miles.	
1,000 feet	19.08	38.4
800 feet	3.86	7.8
500 feet	12.29	24.7
300 feet	7.21	14.5
200 feet	4.70	9.4
Locks and approaches	2.58	5.2
Total	49.72	100.0

It appears that only about one-seventh of the distance is in channels less than 300 feet wide, while for more than two-thirds of the distance the channels are 500 feet or more wide.

The estimated cost of the canal with summit level at elevation 85 as above outlined is, in round numbers, $140,000,000. If, for military or other reasons, the location of the terminal

locks on the Pacific at the shore line at Sosa should be deemed inadvisable and the location at Miraflores, three and six-tenths miles inland, be substituted, the cost of the canal would be increased about $8,000,000.

COMPARISON WITH THE BOARD'S LOCK-CANAL PROJECT.

The project for a canal with summit level at elevation 60 is fully described in the report of the Board. The principal differences between the two projects are:

The lower summit level in the project preferred by the Board.

In the Board's project the Gatun dam is to sustain a head of only 30 feet and the level above the dam is to be reached from the sea level by a single lift, duplicate locks being provided. Another dam and duplicate lock with equal lift will be located at Bohio, maintaining the summit level. There is to be a suitable wasteway in connection with each dam.

The low elevation of the summit level in the Board's project makes it necessary to regulate floods by building a dam on the upper Chagres, and the smaller size of the lake above the Bohio dam also requires the storage of additional water for lockage. The Board proposes to meet both of these requirements by a dam at Gamboa identical with that adopted for the sea-level canal.

In the Board's project the summit level is to be reached from the Pacific by two lifts instead of three, the locks being located at Pedro Miguel and Sosa, with the intermediate level at elevation 27.

The advantages of this project are:

1. The smaller head of water to be sustained by the dams at Gatun and Bohio than by the Gatun dam in the 85-foot project.

2. The smaller height of embankments required to maintain the intermediate level between Pedro Miguel and Sosa, the water surface being 28 feet lower.

3. The summit level would be lower and the locks reduced in number from six to four; there being no flights of two or more locks, but only a single lift at each locality, a transformation to a sea-level canal could be effected more readily.

4. The great lake to be formed by the Gamboa dam would afford control of the floods of the Chagres with less fluctuation of water in the canal.

5. The spillways would be smaller structures.

The disadvantages of the summit-level project preferred by the Board are:

1. The greater number of lock locations—at four points instead of three—which would require, until traffic becomes large, a little more expense for operation.

2. The greater number of dams and spillways on the Atlantic side, being three instead of one; one of the dams, that at Gamboa, far exceeding the Gatun dam for the 85-foot summit level in height and head of water sustained.

3. The great reduction of channel width, giving a canal less favorable for navigation.

4. The greater time required to build, estimated at two years.

5. The greater cost, estimated to be about $36,000,000.

The following table, classifying the channels of the two projects with regard to width and giving the proportion of each width, shows the great superiority for navigation of the canal with summit level at elevation 85.

Width of channel.	Proportion to entire length of route.	
	Summit elevation 60.	Summit elevation 85.
	Per cent.	*Per cent.*
1,000 feet	0.0	38.4
800 feet	0.0	7.8
500 feet	26.4	24.7
300 feet	52.1	14.5
200 feet	16.2	9.4
Locks and approaches	5.3	5.2
Total	100.0	100.0

The comparison of cost above given relates to the two projects as now planned. The provision for flood control and water supply for the project with summit level at elevation 60 is adequate for any traffic up to at least 100,000,000 tons annually, but if the project herein recommended with summit level at elevation 85 be adopted it will be necessary when the traffic reaches 40,000,000 or 50,000,000 tons annually to provide for storing water in the upper Chagres Valley. As Lake Gatun provides satisfactorily for flood control, storage will be required for lockage purposes only, and a much smaller dam than that proposed for the canal with summit level at elevation 60 will be ample until the tonnage reaches about 100,000,000 tons per year. Such a dam with the necessary wasteway would not cost more than $3,000,000, an expenditure which would not have to be made for many years, and would still leave a balance of cost of $33,000,000 in favor of the 85-foot level.

Most careful attention has been given to the question of transforming a lock canal into a sea-level canal, and the undersigned concur fully in the views expressed in the report of the Board that it is inadvisable to build a lock canal with a view to its transformation in the near future; and that, if not to be transformed soon, its construction should not be complicated with details which would increase first cost and detract from the efficiency of the lock canal. We believe, moreover, that a lock canal will have such advantages over a sea-level canal of the dimensions proposed by the Board that the transformation will not be called for in a very long time, if ever. The advantage offered by the canal with summit level at elevation 60 for transformation to sea level is therefore believed to be of little value.

Either of the two lock canals above compared would be convenient for shipping, although in a different degree, and would have a capacity for an immense traffic, larger than can be expected for a long time; but the better navigation afforded by the broad waterways of the canal with summit level at elevation 85, the simpler constructions, the shorter time required to build, and the great saving in cost are considerations too important to be neglected. The more costly canal would require more time to construct and would not serve navigation as well.

COMPARISON WITH THE BOARD'S SEA-LEVEL CANAL PROJECT.

The sea-level canal is fully described in the report of the Board. The most striking points of differences affecting navigation are with respect to number and dimensions of locks and dimensions of the waterway.

The Spooner Act provides that the canal "shall be of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use, and such as may be reasonably anticipated." Since the passage of this act the Cunard Company has projected two ships for the North Atlantic route of very much larger dimensions than any built heretofore. The new ships are to be 800 feet long, 88 feet beam, and to have a draft of 36 feet. They are specially designed for fast service between England and New York. They are subsidized by the British Government, are to be at its service in time of war, and are not likely in any conceivable circumstances to traverse the Panama Canal. But the language of the act makes it necessary to plan the canal for these ships and for larger ones if they "may be reasonably anticipated." What are the ship dimensions which may be reasonably anticipated is a question about which great difference of opinion may exist.

The table shows the number of commercial and war vessels now in use, of medium size or larger, classified with respect to beam:

Beam of large ocean steamers.

Beam.	Commercial ships in use.	War ships in use or projected.	Total.
40 to 45 feet	2,101	201	2,302
45 to 50 feet	1,993	139	2,132
50 to 55 feet	692	110	802
55 to 60 feet	177	83	260
60 to 65 feet	53	44	97
65 to 70 feet	26	123	149
70 to 75 feet	6	85	91
75 to 80 feet	3	81	84
80 to 85 feet	.....	8	8
Total	5,051	874	5,925

This table shows most clearly how insignificant in number are the commercial ships exceeding 70 or even 60 feet beam. The broadest commercial ships in use are less than 76 feet beam, and if we exclude the projected Cunarders, which of all seagoing ships are the least likely to pass through the Panama Canal, a length of 700 feet and a beam of 76 feet may be taken as the dimensions of the greatest commercial ships now in use or building which are at all likely to pass through the canal.

The table also shows eight war ships projected of more than 80 feet beam. The beam of these is definitely known only for the new Japanese battle ships of the *Satsuma* class, which are to be 83 feet 6 inches.

The steady advance in ship dimensions since the introduction of steamships is well known, and while at almost any period there have been a few ships too large for the current traffic and existing harbor facilities it can not be doubted that as traffic increases and harbor facilities are improved ships of larger dimensions will come into profitable use. While a limit may be near at hand, as some well-informed experts believe, it seems clear that the limit has not been reached, although in the class of cargo steamers by which the greater part of the sea-borne commerce of the world is served there has been little or no general advance for several years. From such somewhat conflicting data a judgment must be formed as to what further increase of ship dimensions "may be reasonably anticipated." In forming such judgment it is believed that the period for which such reasonable provision is to be made should also be a reasonable one; for example, probably no one would expect to provide in any commercial or military construction for needs at the end of the present century.

The Board adopted for lock dimensions a width of 100 feet and usable length of 1,000 feet, which are sufficient for a ship of more than double the tonnage of the great ships recently placed on the North Pacific route, the *Dakota* and the *Minnesota* (which are so much larger than any other on the Pacific that they must be considered experimental), and are ample for a ship of about 40 per cent greater tonnage than the projected Cunarders, which are much larger than any other ship built or projected for any route. We believe this allowance for reasonable anticipation excessive, and that locks 95 feet wide with a usable length of 900 feet will fully meet the requirements of the act for both commercial and war ships, and recommend the adoption of these dimensions. They provide for ships nearly double the tonnage of the *Dakota* and *Minnesota*, or 25 per cent larger tonnage than the projected Cunarders. The width will permit the passage of a battle ship of 13 or 14 feet greater beam than any ship now in use or building for the United States Navy.

If the locks are larger than necessary, they will not only cost more, but will require a larger water supply and will not be quite so convenient to operate. The gates must be larger, the locks can not be filled or emptied so quickly, and therefore a little longer time will be required to pass ships; in other words, if the locks are larger than necessary, they will not serve commerce as well as smaller ones.

We do not believe it is wise to attempt to meet the possible requirements of a distant future, which might be estimated erroneously and would burden the commerce of the present and near future with unfavorable conditions, but that it would be more judicious to build the canal with reasonable but not excessive allowances for further developments. If the locks should prove, after many years, to be too small, larger ones can be built when needed, and in the meantime the structures of more moderate size will have rendered better service to commerce.

The second striking difference between the two projects affecting navigation is in respect to width of channel. Wherever, in recent times, natural waterways have been improved or artificial channels made for purposes of navigation the original work has been speedily followed by demands for deeper, wider, and straighter channels. All these particulars have been notably exemplified in the entrance channels to New York Harbor, where the new channel will have a width of 1,000 feet and a depth of 40 feet, and in the waters connecting the Great Lakes, where the channels, first made 150 to 250 feet wide and 10 to 12 feet deep, have been enlarged from time to time to widths ranging from 300 to 1,500 feet and to a depth of 21 feet. In accordance with an act of Congress estimates of cost of increasing the depth to 25 feet have been prepared and are about to be submitted. As a result of experience in these channels with a heavy traffic, much exceeding that in any other waterway in the world, curved channels are avoided entirely. Wherever practicable changes of direction are made in deep water; where this is impracticable the inner angle at the intersection of the two courses is cut off so as to make a large widening at this point, and ships make the turn in safety and usually without reducing speed. Ships are guided through the straight courses by center-line ranges and by frequent buoys, many of them gas-lighted, defining the foot of each side slope.

In the plan for the Panama Canal herein recommended, all of the route except the locks and a short length in the deepest part of the Culebra cut will consist of broad channels 300 to 1,000 feet or more in width, with changes of direction effected as above described. In the sea-level plan, on the other hand, such channels are found only in Limon Bay and from the tidal lock to the terminus in Panama Bay. About half the distance from Mindi to Miraflores would be in curves, and no widening of the channel in curves is provided for. Ships of the largest size could traverse the lock canal day or night without difficulty, but night navigation in the narrow curves of the sea-level canal would be hazardous except for smaller craft. In the following table the two plans are contrasted with respect to channel widths:

Bottom width of channel.	Lock canal with summit level at elevation 85.		Sea-level canal.	
	Length.	Per cent of route.	Length.	Per cent of route.
	Miles.		*Miles.*	
1,000 feet	19.08	38.4	0.00	0.0
800 feet	3.86	7.8	0.00	0.0
500 feet	12.29	24.7	4.87	9.9
350 feet	0.00	0.0	0.77	1.6
300 feet	7.21	14.5	3.05	6.2
200 feet	4.70	9.4	19.47	39.6
150 feet	0.00	0.0	20.39	41.5
Locks and approaches	2.58	5.2	0.59	1.2
Total	49.72	100.0	49.14	100.0

The lock canal will be less than 300 feet wide for only one-seventh of its length and for more than two-thirds of its length will be 500 feet or more wide; it will be nowhere less than 200 feet wide. The sea-level canal for nearly half its length would be only 150 feet wide, and for nearly five-sixths of its length would not exceed 200 feet. Moreover, in the portion 200 feet in width there are stretches where the lower part of the canal is in rock which does not reach the surface of the water, a condition particularly unfavorable to safe navigation.

The lock canal is not only greatly superior to the sea-level canal in regard to width, but is also decidedly superior in regard to depth. The sea-level canal is planned to be 40 feet deep below the level of mean tide except in Limon Bay, where it would be 41 feet, and in Panama Bay, where it would be 45 feet below mean tide.

At low tide the depth of water in the canal for some distance inland from Limon Bay would be a little less than 40 feet. The plans for the sea-level canal contemplate the direct admission of the water of silt-bearing rivers of moderate size into the canal, and, in some instances, into the portions of the canal having a rock bottom. Under such conditions it will be difficult and expensive to maintain the full depth of 40 feet by dredging. In the lock canal, as planned, the sea-level section on the Atlantic side will have a depth of not less than 40 feet of water throughout at any stage of the tide. In the summit level the depth will be 42 feet or more at extreme low water in the driest season, and 45 feet or more under usual conditions. From Pedro Miguel to Sosa the depth will be 45 feet or more. The decided advantage to large ships of these increased depths will be recognized by all who are familiar with the difficulty of steering when there is but little water under the keel.

RELATIVE TIME FOR COMPLETION OF SEA-LEVEL AND 85-FOOT PROJECTS.

The Board estimates that the sea-level canal can be built, with favoring circumstances, in twelve or thirteen years, this being the estimated time required to excavate the central mass usually called the Culebra cut, including all the excavation between Obispo and Pedro Miguel. This section is 8.08 miles long, and for the sea-level canal requires 110,000,000 cubic yards of excavation, the heaviest mile requiring 22,000,000 cubic yards and the heaviest 3,136 feet (which is the length of the Gatun flight of three locks for the 85-foot level canal), 14,000,000 cubic yards.

This estimate of time is based on an estimated output of 800 cubic yards per day of ten hours for each steam shovel employed, the number of steam shovels to be increased to 100 as rapidly as they can be installed. Toward the end of the work the space would be restricted and the number of shovels would have to be reduced. It is recognized by the Board and by all others who have given attention to the subject that the real problem of excavation is to dispose of the excavated materials and to keep empty cars at the shovels for filling. Up to this time great difficulty has been found in the wet season in maintaining tracks and unloading cars, and the cost of experimental work done by the Isthmian Canal Commission was quickly and greatly increased when the rainy season came on.

The estimated average output above mentioned could easily be reached and even exceeded in a favorable climate, and in material suitable for steam-shovel work; but at Panama only three or four months each year can be called dry, and in the remaining months two or three times as much rainfall is concentrated as occurs in the entire year in the central and eastern parts of the United States. As to the material, the greater part of it will require blasting while much of it is hard rock. The average output estimated for shovels at the canal is nearly double that realized in mixed materials in several large operations in the United States.

We believe the time required to excavate the Culebra cut for the sea-level canal will be much greater than estimated by the Board and not less than fifteen years. This conclusion has been reached by considering the Culebra cut as a whole, studying the possible arrangements of tracks and distribution of plant, and also with special reference to the heaviest portion, about 4,300 feet in length. The lock canal with summit level at elevation 60 will require 72,800,000 cubic yards of excavation from the central mass, and assuming the time will be proportional to the amount to be excavated from this mass and that the sea-level canal would require fifteen years, the time required to complete the lock canal with summit level at elevation 60 would be ten years. On the same basis the time required for the lock canal with summit level at elevation 85, which requires the excavation of 53,800,000 cubic yards from the central mass, would be about seven and one-half years, a conclusion which is verified by a study of conditions in the heaviest portion; but before accepting this period as the time required to build the canal consideration must be given to the question of time required to build the locks.

For the 85-foot level the greatest amount of lock excavation and the greatest amount of lock masonry will be required at Gatun. The amount of excavation for this lock, embracing a distance of 3,136 linear feet, measured along the canal axis, will be 3,660,000 cubic yards, and the average width of the excavation will not differ greatly from the average width of the Culebra cut in the heaviest section. The excavation of the corresponding length of the heaviest section of the Culebra cut in fifteen years will require the removal of 933,000 cubic yards per year. If this rate can be maintained at the lock site at Gatun the excavation would require four years. It does not appear that the materials at Gatun are any less favorable to excavate than at Culebra, while the distance to a dumping ground would be less, and the excavating plant could be arranged for more effective use, and therefore a somewhat better rate should be reached at Gatun; but if no reduction be made on account of these better conditions the estimated time will be on a more conservative basis than the estimate of the time for the sea-level canal.

The amount of concrete masonry required for the Gatun locks will be about 1,300,000 cubic yards. This would be the greatest mass of masonry built in modern times. Like the excavation of the Culebra cut it will require special organization and the best plant. Plant and materials should be accumulated in advance while the excavation is being made. With such preparation a very rapid construction is practicable. In recent work in the United States an average of about 400 cubic yards per day was maintained for a considerable period with a single mixing plant, and a maximum was reached of more than 800 cubic yards in one day. At the Gatun locks, with their three main walls aggregating more than 9,000 linear feet, 20 mixing plants or even more could be set up and operated to advantage, and at the average rate of 400 cubic yards per plant per day the daily rate would be 8,000 cubic yards. But assuming a very large reduction from this—that only ten of these plants were operated simultaneously, with an average output of only 250 cubic yards per day for each—the daily rate would be 2,500 cubic yards, which is certainly easily attainable and may be much exceeded. At this rate the entire amount of concrete would be placed in 520 working days, or two and a quarter years. The materials for this daily output of concrete would amount to about 4,000 tons, or, say, 125 carloads. This is about one-fifteenth of the weight of the excavated materials to be moved daily from the Culebra cut, and it does not appear to offer any special difficulty.

The largest item of work remaining is the erection of the gates, of which 14 pairs will be required for the duplicate flight. At the Poe lock of the St. Marys Falls Canal five pairs of gates were erected with a small force and a single plant in sixteen and a half months, of which about six months were winter, and in that extremely cold climate little progress could then be made. Deducting half of this period, the period of effective work was not more than thirteen and a half months, giving less than three months as the time required for the erection of one pair of gates. Not less than five plants should be provided for the 14 pairs of gates at Gatun, and if we assume five months instead of three months as the period required for one pair on account of the greater size of the gates, the total time for all the gates at this lock would be fifteen months, or one and a quarter years. As the plants are not expensive, they might be further increased in number, and if seven were employed the time required would be only ten months, or, say, one year. As this work could be done under roof, little time need be lost on account of rain.

The periods above mentioned aggregate seven and one-fourth to seven and one-half years, which is less than required for the Culebra cut; but this aggregate results from assuming that excavation would be entirely completed before making concrete was commenced, and that the concrete would be entirely completed before the erection of the gates was taken up. These operations would, in fact, overlap and, to a considerable extent, be carried on together, effecting considerable reduction in total time.

The locks at Pedro Miguel and Sosa are of less magnitude than the Gatun locks and would require less time, and no other single work except the Culebra cut would require nearly as much. Nevertheless, where so many works of magnitude are to be built there is likely to be delay at some point, and the period of seven and one-half years for the construction of locks might be exceeded somewhat.

The period of seven and one-half years above given as required for the Culebra cut is based upon the same average number of steam shovels as required to complete the Culebra cut for the sea-level canal in fifteen years. Since the installation of the full number of steam shovels, tracks, etc., would require about the same time for either canal, and when the width of the cut becomes smaller toward the bottom there will not be room to operate so many, the average number in use for the lock canal will be less, and we therefore increase the estimated time required for the Culebra cut for the lock canal one year, making eight and one-half years. Until recently no one, so far as we are aware, has estimated a longer period than eight years for the construction of the locks in any project or, in fact, so long a period.

The French company allowed ten years for the various works at Bohio, including the dam, spillways, and locks, but this resulted from a plan of successively executing parts of these works; and the construction of the lock, including masonry, gates, and other appurtenances, was estimated to require only six years, of which two years were allowed for excavation. The first Isthmian Canal Commission based its estimate of time required for completion of the canal wholly upon the excavation of the Culebra cut, estimated to require eight years after the period of preparation.

Making due allowance, as before indicated, for possible delays in the concurrent execution of several works, and taking a total of nine years for the entire work, we arrive at a period which we believe to be far more conservative than the period of fifteen years for a sea-level canal. A saving of at least six years will result from the adoption of the plan herein recommended instead of a sea-level plan.

RELATIVE TIME OF TRANSIT.

In the sea-level canal it will be necessary for one of two ships of medium or large size about to meet to make fast to mooring piles or posts while the other passes at reduced speed. In the Suez Canal this is done in all cases, and at regular mooring places where facilities are supplied. At these mooring places, which are usually about four miles apart, the canal is widened for a distance of about 2,400 feet from the ordinary bottom width of about 108 feet to about 150 feet. The latter is the bottom width proposed for the greater part of the sea-level canal, but as the Panama Canal is intended to provide for larger ships than any now passing through the Suez Canal, it is assumed that passing places will be made in the 150-foot channels of the former, although the estimates of cost do not provide for them. In the Suez Canal no meetings are allowed where the canal passes through rock. It is here assumed that passing places will be made at Panama in all materials, unless the bottom width is as much as 200 feet with sides vertical and continuous for a considerable distance, as in the Culebra cut, or unless, if the sides are flat slopes, the bottom width is 300 feet or more. In the Culebra cut, where the sides are vertical, it can be arranged to make a ship fast anywhere. In channels 300 feet wide ships can pass each other at reduced speed without stopping. In widths of 500 feet or more it will not be necessary for either to reduce speed.

The broad channels afforded by the lock canal with summit level at elevation 85 will enable ships to pass through them at much greater speeds and with much greater safety than in the narrow channels of the sea-level canal, and as there will be only a small proportion of channel less than 300 feet wide in the lock canal, very little loss of time will occur at meeting points; but in the sea-level canal, with its narrow channel all the way across the Isthmus, the time lost at meeting points will be considerable, even with moderate traffic, and will increase with great rapidity as traffic increases. With ships of such size as those of the principal lines between western Europe and the Orient, the time lost by meetings and by the lower speeds through the narrow waterway of the sea-level canal would be greater than the time required for lockage through the several locks of the lock canal. With ships approaching in dimensions those contemplated by the act of Congress authorizing the building of an isthmian canal, the transit across the Isthmus, even with a small traffic, would require more time in the proposed sea-level canal than in the lock canal herein recommended, and with a heavy traffic the loss of time would be an important feature.

In order to test the relative time required for passage through these respective canals, a calculation has been made of the time required in each, following the methods described in detail

in the report of the Isthmian Canal Commission of 1899–1901. (See Appendix G of that report.) Since the time of transit will vary with the dimensions of the ships and the density of traffic, two type ships were selected, one called type C, 540 feet in length, 60 feet beam, and 32 feet draft, the other called type E, 700 feet in length, 75 feet beam, and 37 feet draft. The former is not quite as long or broad as the larger ships of the Union Castle Line, which run between England and the Far East via the Cape of Good Hope; the latter is a little larger than the largest ships now on the Pacific, but not so large by 30 to 40 per cent as the largest ships which could pass conveniently through a canal of the channel and lock dimensions proposed for the Panama Canal with summit level at elevation 85. The results of this calculation are summarized in the following table:

Type of ship.	Distance between passing places.	Type of canal.	Time required for transit across the Isthmus.				
			10 ships per day.	15 ships per day.	20 ships per day.	25 ships per day.	30 ships per day.
	Miles.		*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*
Type C, 540 feet by 60 feet by 32 feet	5.0	Sea level	8.9	9.6	10.5	11.5	12.9
	2.5	do	8.6	9.0	9.7	10.3	11.1
		Lock	9.5	9.6	9.7	9.8	10.0
Type E, 700 feet by 75 feet by 37 feet	5.0	Sea level	11.6	12.8	14.3	16.2	18.9
	2.5	do	11.1	11.6	12.6	13.6	14.7
		Lock	10.5	10.7	10.8	10.9	11.1

The saving of time by reducing the distance between passing places is apparent, but even for ships of the smaller type the lock canal will furnish quicker transit when the traffic becomes great, while for the larger ships the lock canal will afford quicker transit from the start. This would be still more marked for ships of the greater dimensions contemplated in the act of Congress. By increasing the width of the sea-level canal the time of transit would be reduced. If it were made 300 feet wide, except for 4.7 miles in the Culebra cut, the time would be less than in the lock canal with summit level at elevation 85 on account of the time lost at locks in the latter, but the cost of such a canal would be about $50,000,000 greater than that of the sea-level canal adopted by the Board.

In the narrow channels of the sea-level canal, with its large proportion of curves, night navigation will be more hazardous than by day, and ships will probably move at lower speed than assumed for the calculation of time of transit. Unless ships arrive very early in the day, they will not be able to pass through the canal by daylight on the day of arrival, but will have to submit to the delays of night navigation or tie up until the next day. While this may not appear to be an important matter, the loss from an average delay of twelve hours would amount to a large sum in a year. Taking, for example, a tonnage of 20,000,000, the annual loss on the basis of earnings of one-half mill per ton mile would not be less than $1,500,000, which, capitalized at three per cent, shows that an expenditure of $50,000,000 would be justified to avoid such a delay. It must be evident that even a small delay to the traffic is of much importance. By the adoption of the summit-level canal, instead of a sea-level canal, the time of transit is shortened, not only without additional cost but with a large saving.

CAPACITY FOR TRAFFIC OF THE TWO PROJECTS.

The best example of a ship canal with locks and modern equipment and a large traffic is the St. Marys Falls Canal, and it is therefore the best precedent in discussing the traffic capacity of a lock canal at Panama. The claim is made in the report of the Board that it is not a maritime canal, and that for this reason experience there is not a safe guide for the consideration of a canal for seagoing ships. This demands most careful attention. The other great ship canals with locks are the Manchester, the Amsterdam, and the Kaiser Wilhelm or Kiel, all of which connect with the sea at one or both ends.

The publication of the Department of Commerce and Labor entitled "Great Canals of the World" gives the traffic through the Manchester Canal for the years 1894 to 1900, inclusive, and through the Kaiser Wilhelm Canal for the years 1895 to 1904, inclusive, brought down to 1905 by later information from that Department. No data are given for the Amsterdam Canal nor are any readily obtainable for this report.

The traffic through the Manchester Canal in the last year reported, 1900, was 1,492,320 tons net register. The number of vessels was 5,362, giving an average tonnage of only 278. These figures include, however, a large proportion of small vessels not seagoing. Taking only the vessels going to Manchester, the number was 2,900, the registered tonnage 1,230,784, and the average tonnage per vessel 424. Exact figures as to the present tonnage are not available, but it is probably about one-third more. The largest ships traversing the canal up to this time are the twin-screw steamers of the *Somerset* class, 460 feet long between perpendiculars and 58.2 feet beam; single-screw steamers of the *Silverlip* class, 470 feet between perpendiculars and 55.2 feet beam, and the Manchester liners, single-screw cargo steamers, of which the larger are approximately 400 feet between perpendiculars and 50 feet beam.

The traffic through the Kaiser Wilhelm Canal during the year ending March 31, 1905, was 5,720,477 tons in 32,623 vessels having an average tonnage of 162. A large proportion of the larger ships were German war vessels, 648 of these having passed through the canal in that year.

There are two canals at the St. Marys Falls, the canal on the American side having two independent locks, one called the Weitzel lock, 515 feet long, 60 feet wide at the gates (80 feet in chamber), and 17 feet over the sills; the other, called the Poe lock, 800 feet long, 100 feet wide, and 22 feet over the sills. The canal on the Canadian side has a lock 900 feet long, 60 feet wide, with 22 feet over the sills. In 1905, 19 per cent of the tonnage passed through the Weitzel lock, 66 per cent through the Poe lock, and 15 per cent through the Canadian lock. The sailing route is a little shorter via the American canal, and the canal has nearly vertical sides; in the Canadian canal the sides have a slope of four on one, and floating fenders are in use to keep vessels from injury, but are not satisfactory; for these and other reasons the greater part of the traffic passes through the American canal. The depth of water on the sills of the Weitzel lock is not sufficient for the larger vessels when loaded, and it is used mostly by vessels of smaller size. The locks therefore effect a classification of vessels, the largest always passing the Poe or the Canadian lock when loaded, and usually when light. None of the locks is worked to its full capacity.

In 1905 the total net registered tonnage passing through the two canals was 36,617,699 tons, the number of vessel passages (excluding scows, etc., not registered) being 20,460, and the average tonnage 1,790. The net registered tonnage through the Poe lock was 24,176,472, the number of vessels 9,374, and the average tonnage 2,579.

These comparisons appear more clearly in the following table where the preceding figures are collected. The tonnage through the St. Marys Falls Canal is net register, and it is presumed the tonnage for the other canals is of the same measurement.

Canal.	Year.	Number of vessel passages.	Tonnage.	Average tonnage of vessels.	Remarks.
Manchester	1900	5,362	1,492,320	278	All vessels.
Manchester	1900	2,900	1,230,784	424	Manchester trade only.
Kaiser Wilhelm	1905	32,623	5,270,477	162	Year ending March 31.
St. Marys Falls	1905	20,346	36,617,699	1,790	All locks.
St. Marys Falls	1905	9,374	24,176,472	2,597	Poe lock only.

After an inspection of this table a claim that experience in regard to the navigation of lock canals is to be looked for at the Manchester or the Kaiser Wilhelm canals rather than the St. Marys Falls Canal would appear preposterous. It would require only 480 vessels of the average size passing the Poe lock during the present year to equal the tonnage of the 2,900 vessels

passing through the Manchester Canal in 1900, and only 2,044 to equal the tonnage of the 32,623 vessels passing the Kaiser Wilhelm Canal during the last year.

If, however, the dimensions of the largest class of ships passing the respective canals be compared, the result is more favorable to the foreign canals. The largest vessels passing the Manchester Canal are, as stated before, 460 feet by 58.2 feet, and their draft of 25 feet is practically the depth of the canal. Similar information as to the Kaiser Wilhelm Canal is not at hand, but it is probable that the largest vessels there are the war ships of the German navy. The largest vessels passing the St. Marys Falls Canal are 549 feet between perpendiculars, 56 feet beam and 20 feet draft, and are comparable with the largest vessels reaching Manchester. In model of hull, power of engines, and speed they are similar to ocean-going cargo steamers, although not as strong structurally. The principal differences are in the draft, which is four to five feet less, the location of engines, arrangement of deck, and other minor details which do not affect their adaptability for canal navigation.

Having in consideration all the foregoing facts, we believe not only that the experience gained at the St. Marys Falls Canal is applicable to the navigation of the Panama Canal, but that it is of vastly more value than any or all experience in the foreign lock canals. The amount and character of traffic through the foreign canals does not suffice to prove the capacity and suitability of a lock canal for a great traffic, because none of them carries such a traffic, but the St. Marys Falls Canal supplies the deficiency and makes the proof complete and, indeed, overwhelming.

Nevertheless, it is contended by the Board that the St. Marys Falls Canal is used by ships that frequently pass it, and that the pilots and crews are familiar with all the operations of passing locks, while the Panama Canal would be traversed by ships with crews ignorant of these matters, and therefore the record of safety and capacity so completely established in the American canal could not be paralleled at Panama, but, on the other hand, the most imminent risk and vexatious delays would be incurred at all times. We can not help believing that due consideration concerning the things required to be done to pass a canal lock would dispel these apprehensions.

The movement of a ship is controlled in both cases by signals transmitted from the pilot house to the engine room; the engineer must check, stop, start, etc., when ordered; he is accustomed to doing so quickly, whether at sea, in a canal, or in a harbor, whether approaching a landing or a lock. The engines are practically of the same type. As a ship nears a lock lines will be put out, carried by the lock tenders and placed on snubbing posts as required, the ship's sailors having only to haul in, to make fast, to slack off or pay out, which they ought to do more skillfully than the less trained deck hands on lake ships. All of these operations will be required at the passing places in a sea-level canal and under more difficult conditions than at locks. Furthermore, on each ship while in the canal there will be a pilot whose entire time will be given to the handling of ships in the canal and who will be not less skillful than the lake pilot who is in a lock canal for only an hour two or three times a month.

The estimate of the Board as to the possible number of lockages per day "perhaps not exceeding ten per lock or twenty per pair" is at variance with American experience. As many as 36 lockages have been made at the Poe lock in one day, passing 93 vessels. The estimate of lockage capacity given in Appendix L is based on actual performance, which the estimate of the Board ignores.

The want of data concerning the Amsterdam Canal is regretted, for there is some reason to believe that it might make a more favorable showing as a commercial ship canal than either the Manchester or the Kaiser Wilhelm canals, but the general results of the preceding discussion would not be affected.

The experience at the St. Marys Falls Canal is particularly important in establishing the capacity of a lock canal for traffic, because its nearest parallel in point of magnitude of traffic is a canal with no lock, viz, the Suez Canal. The tonnage through the Suez Canal in 1904 was 13,401,835 tons, Danube measurement, or about 11,500,000 tons net register, since the Danube measurement is 16 to 20 per cent greater. This is less than one-third the tonnage through the St. Marys Falls Canal in 1905 and less than half the tonnage through the Poe lock alone. Taking

into account the short navigation season at the St. Marys Falls Canal, the tonnage per month during the navigation period of 1905 was three times as much through the Poe lock alone as at Suez.

The Suez Canal is traversed almost exclusively by seagoing ships making long voyages, and therefore of large size. The average measurement of the 4,237 vessels passing in 1904, about 2,700 tons net register, is more than six times that of the vessels passing through the Manchester Canal to its terminus in 1900, and about sixteen times that of the vessels passing through the Kaiser Wilhelm Canal during the last year. It is about 50 per cent greater than the average tonnage of the vessels passing the St. Marys Falls Canal during 1905, but only 10.5 per cent greater than the average of those passing the Poe lock. The portion of the tonnage through the Poe lock which is carried in vessels equal to or exceeding the average measurement of the ships passing the Suez Canal is largely in excess of the total tonnage at Suez.

Finally, the aggregate tonnage passing all the four foreign canals above mentioned is much less than that passing the St. Marys Falls Canal, and is even less than that passing one only of the three locks in use there. The average tonnage of the vessels in these foreign canals is but little more than one-fourth the average of those passing the St. Marys Falls Canal and but little more than one-sixth the average of those passing the Poe lock. With these facts in mind there can be no need of further argument that this canal, although neither end touches salt water, furnishes abundant proof of the suitability of a canal with locks to serve a great commerce carried in ships of any size.

The duplicate locks of the Panama Canal will afford convenient passage for an annual net registered tonnage of 80,000,000, as shown in more detail in Appendix L.

SAFETY OF LOCKS AND OTHER STRUCTURES.

The most plausible arguments advanced by advocates of a sea-level canal to justify its greater cost and the greater time required to build it are the alleged danger of carrying away the lock gates at either end of the summit level if a ship moving at speed should strike them, and the possible damage to structures through malice or in time of war.

An accident to gates, if it occurs, is most likely to result from a mistake in the engine room, the engineer sending the vessel ahead when the pilot signals to back, and then the pilot, noticing that the ship's speed is not being reduced and not realizing that the previous signal is not being carried out, signals for full power or perhaps signals so rapidly that he can not be understood. One or the other of these successions of events has usually taken place when a ship has run into lock gates. The carrying away of a lock gate occurs but rarely, but it has occurred three times in the Manchester Canal. It has never occurred in the St. Marys Falls Canal.

In the Manchester Canal the gates at the lower end of the lock were struck, the upper gates being open, the ship moving downstream, but in all cases the operating force was able to get the gates at the head of the lock closed, or so nearly closed that they came together and held back the water in the canal. If such an event should occur at Panama, where the locks are in duplicate, traffic through the injured lock would be suspended until repairs could be made. With duplicate gates in stock the repairs could probably be made and traffic resumed through the injured lock without a prolonged delay. In the meantime, traffic would be continued through the duplicate lock, and although, if the traffic were great, it would be subject to some inconvenience, yet it would be maintained.

If, however, the gates supporting the summit level should be carried away and the current flow unobstructed through the locks with no means in readiness to stop it, such, for example, as a movable dam, the result would be very serious indeed. It would require many days to lower the level of Lake Gatun sufficiently to render the task of closing the opening through the lock easy, and in the meantime the channel and the works below the lock might be seriously damaged and navigation suspended for weeks or months. The chances for such a disaster are so small that if the Panama Canal were intended for commercial purposes only, the great additional expenditure required to make it a sea-level canal would have few advocates, but the possible need

of the canal for the passage of ships in time of war strengthens the argument for a sea-level canal and makes it necessary to consider with care the chances of such an event in ordinary canal operation, the facilities for handling and controlling the movement of ships which may be used, the precautions for safety which may be introduced in the operation of the locks, and the constructions which may be supplied to close off the current should it be set up.

We believe that in no ship canal in the world has such a disaster occurred as that imagined for the Panama Canal. If the accidents at the Manchester Canal show that gates may be struck and destroyed, they also show that disaster may be averted even without special safeguards. Of all the possible movements of a ship at canal locks the one that involves the most danger of opening a summit level is when a ship bound down in that level approaches a lock, but by proper safeguards this can be made very small. If a gate is struck by a ship upward bound the water pressure on the opposite side of the gate helps to resist the blow. By the use of two pairs of gates at each end of the summit lock all danger of opening the summit level by a blow on the downstream side of the lower gates is eliminated, as will be shown a little farther on.

The canal construction should provide long approach walls at each end of every lock or flight of locks so that lines can be put out quickly and handled readily and the ship held under perfect control. For this important purpose a long solid pier with suitable snubbing posts is vastly superior to mooring piles and floats, such as are used in some foreign canals. No canal in Europe is adequately provided in this respect, and the apprehensions of some members of the Board in regard to the hazards of navigation through lock canals may be due to the fact that their experience has been entirely with canals having this radical defect. With suitable approach piers and with rules duly enforced requiring ships to put out lines on arriving at the pier and to reduce speed to two miles per hour when moving along it, or to stop altogether several hundred feet from the lock, a great degree of security can be obtained. Such approach piers are provided in the lock plan herein recommended.

This plan also provides two pairs of gates at the head and two at the foot of each summit lock, so that a ship will always find two pairs of gates shut against it.

If the summit level is terminated by a single lock and the lower gate is struck by a ship upward bound, the gates at the upper end of the lock being open, the lower pair of gates at the foot of the lock having water pressure back of them will absorb the blow, and even if they are wrecked the second pair of gates, some 80 feet distant, will not be reached. The resistance offered by the first gates will almost surely stop the ship, and the rush of the mass of water, 80 feet in length between the two gates, will insure stoppage before it can reach the second pair. If the lower end of the lock is open and the upward-bound ship strikes the first pair of gates at the upper end of the lock its motion will be stopped by these gates, the miter wall, and the water, and the second pair of gates will be left intact. We believe, therefore, that, by the use of duplicate or safety gates at each end of the summit lock, all danger of opening the summit level by an upward-bound ship will be eliminated.

If a downward-bound ship is approaching the gates from the summit level it will find at least two pairs of gates closed against it, of which the first will be sustaining no water pressure to weaken the strength available to stop the ship. While this case does not afford the absolute security shown in the case of ships moving upstream, the possibility that the ship will so completely wreck the first pair of gates as to continue its course to the second and seriously harm it is extremely small. A large lock gate is a massive structure, not easily wrecked. The gates of the Poe lock have been struck three times and injured more or less, but they continued to support the summit level.

The provision of duplicate gates at each end of a lock herein adopted is an unusual precaution. It has been recently adopted in part at the St. Marys Falls Canal, where duplicate gates are now operated regularly at the lower end of the Poe lock, but the upper end is not similarly protected. In the additional lock now projected at that canal safety gates are to be provided at each end. The approach piers, the extent of which greatly affect the safety of a lock, are excellent at the St. Marys Falls Canal and far better than at any other ship canal, and doubtless have contributed to the remarkable record of immunity from serious accidents.

This canal has now been in operation a little more than fifty years and a traffic aggregating about 360,000,000 tons net register has passed through it, with no accidents seriously obstructing navigation. It is the best example existing not only of the capacity of a lock canal for a great traffic but of the safety with which this traffic can be handled with suitable equipment.

In view of these facts relating to the operation of canals not as well provided with safety appliances as proposed for the Panama Canal it appears fanciful to enlarge on the dangers of a lock system; but even the small risk which a lively imagination might still assign to a lock canal can be substantially diminished, since it is not impracticable to stop the flow from a summit level, if once set up. Several devices have been built to control the flow of water from the summit level in case lock gates should be carried away. More than forty years ago a pair of gates provided with powerful brakes to check their movement while closing in a current was placed about 3,000 feet above the locks in the St. Marys Falls Canal. The gates were removed about fifteen years later when the canal was deepened, before any occasion had arisen to use them for the purpose intended. When the channel was deepened a construction was adopted consisting of a series of wickets, each so small that its movement could be controlled by machinery of moderate power. The wickets were carried by a swing bridge, and when not in use the bridge was open and the wickets were then on land, where they could be inspected and repaired. The canal force was trained regularly in the handling of this device so that they might work efficiently in case of actual need. For such experimental practice the same procedure was followed as in a real emergency, viz, the bridge was swung across the canal and the wickets lowered one by one, their lower ends resting against a sill at the bottom of the canal, the upper ends supported by the bridge. After about eighteen years the canal was again deepened and the device removed before any accident requiring its use had occurred. A modified form of the device was built at the Canadian canal at the St. Marys Falls about ten years ago, but is yet untried, and another is about to be supplied for the American canal. The problem of working out a satisfactory device for this purpose in the deeper channel of the Panama Canal is a difficult one, but no doubt is entertained that a solution can be made. For such appliances the sum of $2,000,000 is included in the estimate of cost.

A lock may suffer other injuries, and will require repairs, during which navigation through it may be interrupted. For this reason, principally, duplicate locks are provided, so that if one is under repair navigation may continue uninterrupted through the other. It is seldom that a lock is put out of use, and the simultaneous disabling of two would be very unlikely. A brief summary of fifty years' experience at the St. Marys Falls Canal is given in Appendix S.

The canal structures most exposed to injury through malice or in time of war are the locks and wasteways. In the sea-level canal there would be three such points—the tide lock at Ancon, the sluices at the Gamboa dam, and those between Ancon and Pedro Miguel, the last named being of small importance. There will be five in the lock canal herein advocated—the locks at Gatun, Pedro Miguel, and Sosa, the sluices at the Gatun dam, and the sluices or wasteway in the Ancon-Sosa saddle. The latter is so small and may be so securely founded on rock but little below the level of the canal that no possible injury to the structure would interfere seriously with navigation. The Ancon lock of the sea-level canal and the Sosa locks of the summit-level canal are equally exposed to attack by a naval force.

While it is conceivable that a malicious person or a crank might carry enough concealed high explosive to injure a lock gate or a sluice, experience of many years of perfect immunity in all the ship canals shows that this is not a real danger. The only disaster to be seriously considered is one that might be inflicted by a hostile force in time of war. If the enemy had control of the coast, or occupied territory inland in the vicinity of the canal, enough high explosive could be carried through the tropical jungle by a small force to destroy any of the lock gates or sluiceways, or to sink a ship. In order to open the summit level effectively and cause a suspension of navigation for a long time it would not only be necessary to destroy two pairs of gates, but also the device already referred to for closing the channel in a current. So large a force and so much time would be required to do all this that it could be effected only by a force superior to the

strong guard which in time of war would certainly be stationed at every important canal structure.

It has been suggested that a vessel carrying a large quantity of concealed dynamite could be exploded in a lock and wreck not only the gates but the masonry. While the execution of such a plan is extremely improbable, there are three places where it might be attempted in a summit-level canal and one in a sea-level canal. In either case the duplicate system of locks would reduce the hazard very much.

But it must be remembered that it is easily possible to block a sea-level canal by the sinking of a vessel in its channel, either by design or by accident, such an accident, for instance, as that which caused the steamship *Chatham* to absolutely block the Suez Canal and suspend all traffic through it for a period of nine days, from September 27 to October 6, 1905.

This accident occurred in time of peace in a sea-level canal, thirty-six years after its completion. During the period of fifty years since it was built there has been no such protracted interruption to traffic in the lock canal connecting Lake Superior with the lower lakes, and the delays in the channels away from the locks have constituted the most serious interruption to traffic on that waterway.

It is therefore evident that the structures are not the only vulnerable points in a waterway across the Isthmus. The locks and wasteways could be much more readily guarded than the whole length of the canal. At almost any point on the sea-level canal the attempt might be made to explode dynamite under a passing ship, which, if successful, would close the narrow channel effectively. There are many places on the route where this could be done more safely to the hostile party than at the locks. To this danger ships would be much more liable in the narrow channel of the sea-level canal than in the broad waterway of which the lock canal mainly consists.

We believe that unless the canal were declared neutral by general agreement among civilized nations the maintenance of navigation through it in time of war and with an active hostile force in the vicinity would be difficult; but the danger under this condition does not differ greatly whether the canal be a sea-level or a lock canal.

Possible injury by earthquakes to a canal across the Isthmus has received much discussion and much has been made of it by opponents of any canal. It was treated fully and fairly by the first Isthmian Canal Commission, and the following opinion expressed, which is entirely applicable to the lock canal herein advocated, and in which we concur:

> The works of the canal will nearly all of them be underground. Even the dams are low compared with the general surface of the country, and, with their broad and massive foundations, may be said to form part of the ground itself, as they are intended to do. The locks will all be founded on rock. It does not seem probable that works of this kind are in any serious danger of destruction by earthquakes in a country where lofty churches of masonry have escaped with a few minor injuries.

A large number of engineers on both continents, including four members of this Board, have in previous years concurred in recommending lock canals as feasible and adequate waterways across the Isthmus. While the ships to be provided for in the present projects are larger, the increase is not so radical as to make the forms of construction which were feasible and adequate for the ships then contemplated "altogether beyond the limit of prudent design for safe operation" and without "reasonable assurance of safe and uninterrupted navigation" for the ships now under consideration, as asserted by the Board.

RELATIVE SAFETY OF SHIPS IN THE TWO TYPES OF CANAL.

The comparison between the two projects must relate principally to conditions at the locks in the summit-level canal and in the narrow channel of which the sea-level canal mainly consists. While there will be a short section of channel only 200 feet wide in the summit-level canal it will be so short that it will not affect in an important degree any conclusions that may be drawn if it be neglected; and similarly, while there is to be one lock in the sea-level canal there are six in the summit-level project, and the tidal lock of the former may be neglected in this connection.

A lock is a short section of canal, with vertical sides, in which ships are moved at a low speed and under perfect control. A ship is in much less danger of injury in a canal lock than

when landing at a pier in the most favorable conditions with no wind or current. Experience at the St. Marys Falls Canal, where no vessel has been seriously injured in a lock during fifty years of continuous use, should be conclusive on this point. Danger to ships in a canal is not at the locks, where they are moving slowly and under control, but in the excavated channels elsewhere through which they pass at speed, and where, if the width is insufficient, groundings are likely to happen, and if the sides are rocky and rough, serious injury to the ship will probably result.

What has been said above as to the relative danger to ships in locks and in narrow channels is equally true in regard to delays. From the records of the Suez Canal there was obtained for the first Isthmian Canal Commission a statement showing delays to traffic from ships grounding during a period of eight months, from January to August, 1899, inclusive. No delay of less than six hours was included. Groundings of more than six hours were 15 in number, the aggregate delays to the grounded ships being 292 hours 29 minutes. In 14 of the 15 cases the channel was blocked so that other ships could not pass, the total time during which the canal was blocked being 185 hours 46 minutes. In Appendix S is given a record of delays in the locks of the St. Marys Falls Canal. This is complete for the two locks now in operation in the United States canal since they were opened to navigation.

With duplicate locks, as proposed for the Panama Canal, navigation would seldom be delayed at the locks, as it would be extremely improbable that both of them would be out of use at the same time. In the same appendix information is also given respecting delays to navigation in the excavated channels of the St. Marys and St. Clair rivers. These channels are much wider than the sea-level canal would be, yet they have been blocked on several occasions. Only a small part of the loss to navigation was borne by the vessels causing the blockade. In one instance, when the blockade continued for five days, 332 vessels were delayed, and the loss to navigation amounted to a large sum, estimated to be $600,000. The loss in such a case increases very rapidly with the density of the traffic. In comparing the two projects it must be kept in mind that the broad channels and duplicate locks make a blockade almost impossible on the summit-level canal, while the narrow waterway of the sea-level canal is far more liable to interruption.

If the sea-level canal should be built as now planned it would serve only a temporary purpose; a strong demand would arise within a few years for a broader and safer channel. This demand, we believe, would be made much sooner than any demand for a material change in the summit-level canal built as herein recommended.

It is not intended in this discussion of the relative safety of and delays to ships in the two canals to give an impression that ships will be subjected to a high degree of hazard or delay in either, but to show that the summit-level canal is superior in both respects. The sea-level canal could be made equal to or better than the other by widening the channels a sufficient amount, but the cost of this would be very great.

LAND DAMAGES.

The extensive lakes proposed in the plans of both the lock and sea-level canals will flood large areas of land, a part of which is not owned by the United States. The total area of lakes in the lock-canal plan is 118 square miles, and in the sea-level canal plan 44.6 square miles. The United States owns large areas of land in the Canal Zone formerly owned as follows:

	Square miles.
By the Panama Canal Company	52.11
By the Panama Railroad	55.25
By the Republic of Panama	188.91
Total	296.27
Total area of the Canal Zone	435.50
Private ownership within the Canal Zone	139.23

In addition to the land owned by the United States in the Canal Zone there are, outside of the Zone, Panama Railroad lands having an area of 12.87 square miles.

Of the 118 square miles of lake surface in the lock-canal project 58 square miles within the Canal Zone are owned by the United States, leaving 32 square miles, or 20,480 acres, of private

ownership in the Zone, and 28 square miles, or 17,920 acres, of land belonging to the Republic of Panama or to private owners outside of the Zone.

There are statistics which show that the land purchased by the Panama Canal Company during the early part of the work and subsequently transferred to the United States, as above stated, cost the company an average price of $9.20 per acre in silver, equivalent at the time of purchase to $7.70 per acre in gold. In ascertaining this price per acre the Administration Building, situated in the central portion of the city of Panama, and the land on which it stands, were excluded, but all other lands and buildings were included.

The land which was purchased was located for the most part along the line of the canal and in the vicinity of the Panama Railroad, while the land to be flooded by the lakes and not now owned by the United States is located for the most part at a considerable distance from the railroad. Such land is accessible only on or near rivers which are navigable by canoes, because there are no roads on the Isthmus, and the inaccessible land is practically worthless jungle. Along the rivers there are in places banana lands which have been cleared and are estimated to have a value of at least $50 per acre.

We have not sufficient information for making a close estimate of the value of the lands to be flooded. The accessible lands are probably worth more at the present time than when the purchases were made by the canal company; but, on the other hand, most of the land required is inaccessible and nearly worthless, and it is probable that much of the land outside of the Canal Zone belongs to the Republic of Panama, which has by treaty granted to the United States the right to use it where needed for the purposes of the canal. An approximate estimate may therefore be based on the price per acre paid by the canal company for the whole area it acquired, and such an estimate would be 38,400 acres at $7.70 per acre, making the total cost $295,680, or, in round numbers, $300,000. While the actual cost is likely to exceed this somewhat, no better data for an estimate exist. It would be neither good judgment of values nor to the interests of the United States to submit an extravagant figure.

RELOCATION OF THE PANAMA RAILROAD.

Any plan for the canal requires the relocation of some portion of the Panama Railroad. The Isthmian Canal Commission of 1899–1901 made a plan and estimate for the relocation of the railroad from Bohio to Pedro Miguel, and these have been adopted for this report. In addition it is necessary in connection with the plan herein presented to provide for the relocation of the railroad from a point between Mindi and Gatun to Bohio, and from Pedro Miguel to Panama.

Between Mindi and Gatun recent surveys show that the work will not be particularly heavy or expensive. Between Gatun and Bohio no recent or complete surveys are available, but the information at hand is sufficient to show that a reasonably direct line crossing the lake and taking advantage of the support afforded by the high lands along the route is preferable to one going around the lake. There will be some heavy work along this line at the crossing of the Gatun and other valleys, the maximum height of embankment being about 80 feet, which is not unusual in railroad construction.

From Pedro Miguel toward Panama the railroad may be located without special difficulty around the margin of Sosa Lake until the northerly end of the Aneon-Corozal dam is reached, and it can then run along this dam, which furnishes a nearly direct route to Panama.

For the ten miles of relocation required between Mindi and Bohio, $2,000,000 have been included in the estimate, and for the six miles between Pedro Miguel and Panama, $400,000 have been so included. The estimate of the Isthmian Canal Commission of 1899–1901 for 24.5 miles from Bohio to Pedro Miguel is, in round numbers, $1,300,000, making the total estimated cost of the relocation of the railroad $3,700,000.

ESTIMATED COST FOR PROJECT RECOMMENDED.

An abstract of the estimated cost of the canal with summit level at elevation 85, using the unit prices adopted by the Board, is as follows, full details being presented in Appendix T:

	Miles.	Cost.
Breakwaters in Limon Bay	.....	$5,300,000
Channel in Limon Bay	4.55	1,245,000
Limon Bay to Gatun locks	2.60	3,921,000
Gatun locks, including excavation and back filling	.59	15,691,000
Approach walls to Gatun locks	.....	500,000
Gatun dam and spillway	.....	7,788,000
Gatun to Obispo	23.51	5,005,000
Obispo to Pedro Miguel	8.13	43,337,000
Pedro Miguel locks, including excavation and back filling	.23	6,988,000
Approach walls to Pedro Miguel locks	.....	300,000
Pedro Miguel to Sosa locks	5.47	420,000
Sosa locks, including excavation and back filling	.41	13,092,000
Approach walls to Sosa locks	.....	450,000
Sosa locks to deep water in Panama Bay	4.23	1,939,000
La Boca dam	.....	1,675,000
Ancon-Sosa and Ancon-Corozal dams	.....	1,645,000
Diversion channels between Obispo and Pedro Miguel	.....	850,000
Diversion channel and regulating works at Ancon	.....	275,000
Diversion of Panama Railroad	.....	3,700,000
Movable dams at ends of summit level	.....	2,000,000
Land damages	.....	300,000
	49.72	116,421,000
Administration, engineering, and contingencies, but not including interest during construction, sanitation, or expenses of Zone government	.....	23,284,200
Total estimated cost	.....	139,705,200

Neither the foregoing estimate nor that for the sea-level canal contains an allowance for the fortification of the route.

The total amount of excavation from the canal prism is 95,955,000 cubic yards, of which 53,765,000 cubic yards are from the Culebra cut. The cross sections of the canal used in computing excavation are shown on Plate X.

An allowance of 20 per cent for administration, engineering, and contingencies is provided, as in the Board's estimate for the sea-level canal. In the estimates of the Isthmian Canal Commission of 1899–1901 the same allowance was made, but this allowance was to cover somewhat different items. The allowance in the present estimates does not cover sanitation and Zone government, which were included in the allowance in the former estimate, but does include another item which may prove to be a large one, viz, revetments of the sides of the canal in the Culebra cut.

In the project of the Commission of 1899–1901 the concrete retaining wall was to extend the entire length of the narrow section through the Culebra cut, which, in the plans of that Commission, was 7.91 miles, and was estimated to cost, exclusive of the 20 per cent allowance, $9,619,304. It is now believed that for a large part of the distance through the Culebra cut the rock sides will be sound enough to stand vertical and remain smooth if properly formed by channeling machines, and where this is the case a revetment will not be required, while for the remaining distance some form of revetment will be necessary; it is also believed that the extent and best form of revetment can only be determined by a study of the materials actually seen in place as the excavation proceeds, and that items of this character are appropriately considered as contingencies. It should be pointed out that the cost of revetment on the sea-level canal would be greater than for the summit-level canal by the reason of the greater length of narrow section in the former. In the plan for a summit-level canal the length of the narrow section is reduced to 4.70 miles by widening to 300 feet at each end, while in the sea-level canal there would be 19.47 miles of channel 200 feet wide excavated partly or wholly in rock.

COST OF MAINTENANCE AND OPERATION.

In a comparison of the cost of maintenance and operation of a lock and of a sea-level canal there is in the case of the lock canal the additional cost of the force for operating the greater number of locks, and in the sea-level canal the extra cost of the force which must be kept at the meeting places where ships are moored, and of dredging the canal and diversion channels to maintain their depths.

The lock canal will have locks at three places, each of which will require a force of attendants, while the sea-level canal will have only one such place. On the other hand, there will be no specially prepared meeting places for ships on the lock canal except at the locks, while on the sea-level canal seven such places will be required, assuming them to be five miles apart, and the force required to attend to ships mooring at these places will to a considerable extent offset the extra force required at the locks of the lock canal. To maintain the depth and size of the 40 miles of sea-level canal between shore lines, and of the still greater length of diversion channels, will entail a greater annual expense, as the canal and channels are designed to receive directly the silt of all tributary streams on which dams are not to be built. The lock canal will cost very little for the maintenance of its channels between shore lines, because nearly all the streams empty into lakes where the silt will settle far from the canal. Any dredging required to maintain harbor channels will be common to both plans.

This brief analysis indicates that the sea-level canal will cost no less for maintenance and operation than the lock canal, and this view is supported by estimates given below in detail of cost of maintenance and operation of the two types of canals.

In connection with former projects two methods have been used for estimating the cost of maintenance and operation. The first in point of time was that developed by the French company, based on experience at the Suez Canal, but modified to meet the conditions at Panama; the second was that on which the estimate of the first Isthmian Canal Commission was based.

The estimate of the French company included allowances for (1) central administration in Paris, which it is here assumed would be the same for central administration in the United States; (2) general expenses for meetings, printing, etc.; (3) hospital expenses; (4) administration on the Isthmus, including salaries, office and traveling expenses, pilotage, and all other expenses of operation incurred on the Isthmus, and (5) maintenance, taken at seven-tenths of one per cent of cost of excavation, one per cent of cost of masonry, five per cent of cost of gates and other mechanical structures, and one per cent of cost of dam, diversion channels, etc. The foregoing items are carried into the present estimate without change.

The French estimate contained allowances for taxes, agency at Bogota, etc., not required with United States ownership and not included in the present estimate, but did not provide for maintenance of breakwaters, for which one-half of one per cent of cost is now taken; for maintenance of approach walls to locks, for which two per cent of cost is now taken, or for the government of the Canal Zone, for which the cost as estimated by the first Isthmian Canal Commission is now taken.

The estimate of the first Isthmian Canal Commission was arrived at by outlining an organization for the government of the Zone and the maintenance and operation of the canal, together with an allowance for general expenses in the United States. The details are given in Senate Document No. 253, part 2, Fifty-seventh Congress, first session, pages 693 to 698, inclusive. The allowances made in that estimate are accepted here except as changes are required on account of greater or less number of locks and passing places and greater or less magnitude of the work to be maintained. The allowances for maintenance of excavation, dams, breakwaters, and all constructions except masonry and metallic structures, were made from an estimate of the cost of maintaining and operating an adequate dredging plant and repair force, while other items were provided for by percentages on cost, as follows: Masonry, one-half of one per cent; lock gates, sluices, machinery, etc., seven and one-half per cent.

These two methods are the best thus far proposed, and the results of both will be compared. The amounts will first be given for the summit-level canal herein recommended.

Estimated annual cost of maintenance and operation of the canal with summit level at elevation 85.

I. By the method adopted by the French company:		
Central administration in the United States		$140,000
Government of the Canal Zone		348,480
General meetings, printing, etc		40,000
Hospitals		40,000
Administration on the Isthmus		543,000
Maintenance—		
$\frac{7}{10}$ per cent cost of excavation	$450,055	
1 per cent cost of masonry	325,845	
5 per cent cost of gates, etc	402,150	
1 per cent cost of dams, diversion channels, etc	121,212	
$\frac{1}{2}$ per cent cost of breakwater	31,800	
2 per cent cost of approach walls to locks	30,000	
		1,361,062
Total		2,472,542
II. By the method used by the Isthmian Canal Commission of 1899–1901:		
General expenses in the United States		100,000
Governor's department		39,300
Engineer department		1,053,697
Transit department		351,340
Medical department		104,860
Finance department		27,300
Law department		15,300
Police department		251,100
		1,942,897
Add 20 per cent		388,579
Total		2,331,476

Mean of the two estimates, $2,400,000.

For the sea-level canal there would be no change in the method of the French company except in maintenance, where the same rates would apply as in the preceding case. In applying the method of the first Isthmian Canal Commission no changes would be made excepting in the engineer and transit departments. It seems probable that in the narrow sea-level canal, with a depth nowhere exceeding 40 feet, the annual cost of dredging would be at least twice as much as in the lock canal, where only about 15 per cent of the length is less than 300 feet wide and more than 80 per cent is 45 feet or more in depth. In the transit department the cost will be changed by reducing the number of lock attendants; but there must be, as at the Suez Canal, attendants at each of the passing places. With these changes the following results are obtained:

Estimated annual cost of maintenance and operation of the sea-level canal.

I. By the method adopted by the French company:		
Central administration in the United States		$140,000
Government of the Canal Zone		348,480
General meetings, printing, etc		40,000
Hospitals		40,000
Administration on the Isthmus		543,000
Maintenance—		
$\frac{7}{10}$ per cent cost of excavation	$1,512,000	
1 per cent cost of masonry	72,869	
5 per cent cost of gates, etc	66,600	
1 per cent cost of dams, etc	63,358	
$\frac{1}{2}$ per cent cost of breakwaters	30,000	
2 per cent cost of approach walls to locks	19,080	
		1,763,907
Total		2,875,387

II. By the method used by the Isthmian Canal Commission of 1899–1901:

General expenses in the United States	$100,000
Governor's department	39,300
Engineer department	652,932
Transit department	343,060
Medical department	104,860
Finance department	27,300
Law department	15,300
Police department	251,100
	1,533,852
Add 20 per cent	306,770
Total	1,840,622

Mean of the two estimates, $2,360,000.

The large discrepancy between the two estimates is due principally to difference in the estimated cost of maintaining an excavated channel, the French estimate being based on experience at Suez and calculated to be proportional to the cost of excavating the canal. The estimate arrived at by following the method of the Isthmian Canal Commission is based on the cost of operating the dredging plant, and the number of dredges required may be underestimated. The correct amount probably lies between the two estimates, and if the mean be taken as above the estimated cost of maintenance and operation is practically the same for both projects.

SAFETY OF DAMS.

The Board in its discussion of types of dams has expressed many apprehensions of grave dangers to be feared on account of the character of the material on which it has been proposed to place dams at the Isthmus. A due consideration of each case by itself, giving proper weight to the character and location of the materials disclosed by the borings and to the adequacy of the design, would show that these apprehensions are unnecessary in regard to the dams herein proposed.

Reference is made in the Board's discussion to the subsurface material at Gatun, which is stated to be "in large part of a comparatively fine character, consisting of sand and clay in varying portions and in various degrees of admixture, but the borings have also shown coarse sand and gravel."

In order to make this statement express clearly the actual situation the addition should be made that the coarse sand and gravel are found in the bottom of the narrower of the two deep gorges in the rock, and overlying them are 200 feet in thickness of finer materials, the impervious character of which will prevent the waters in the lake from having access to this deep-lying sand and gravel in any appreciable quantity. In view of these conditions at the site of the Gatun dam, and the great width of one-half mile which has been given its base in the proposed design, we can not concur in the view expressed that "it is more than possible, it is highly probable if not certain, that at various points the material is sufficiently loose in texture to permit seepage or percolation in dangerous quantities." Actual experience with dams and experiments on the filtration of water through sand and finer materials show that the amount of water filtering under such circumstances will be too small to affect in any way the stability of the dam. Neither do we concur in the statement that "nothing is more common in the sandy deposits of river valleys and in all sandy material than small passages or channels through which water moves, varying in size from thread-like openings to those sufficient to yield flowing wells of large discharge," because there is nothing in our experience to support this view, nor does it seem that such passages or channels could possibly be formed or maintained in a saturated granular material.

The subsurface sands on the southerly slope of Long Island, from which a portion of the water supply of the borough of Brooklyn is taken, and to which the Board refers, are noted for their extent and for their porosity, due to the size and uniformity of their grains.

By far the larger part of this water supply is taken from the Ridgewood system of works,

which comprises both surface and subsurface sources. The quantity taken from the ground equals approximately 70 cubic feet per second, a volume which is small in comparison with the 1,477 cubic feet per second available for lockage in the canal plan recommended. This quantity, however, is collected in a length of 21.3 miles, so that the quantity per mile is only about three and one-half cubic feet per second, or, in a length equivalent to that of the Gatun dam, about five and one-half cubic feet per second. If instead of using the total length of the Gatun dam, only the parts of the length which cross the alluvial valleys were included, the proportionate quantity would be still smaller. If any inferences of value are to be drawn from a comparison of conditions at Long Island with those at the dam sites at the Isthmus, where clay is the predominating material, they are that even under conditions favorable to filtration the amount of water passing through a considerable length of ground is comparatively small, and that water may filter through and be taken from the ground without disturbing either the earth through which it filters or that from which it is taken.

The extent of the sand and gravel deposit in the lower part of one of the rock gorges at Gatun is limited, and if it be assumed that instead of being covered with an impervious blanket 200 feet thick the water above and below the dam has free access to the porous material, and if the further assumption be made that the material has as much filtering capacity as a coarse uniform sand or a coarse unscreened gravel or a typical Long Island sand, the quantity of water which would pass through it would be very much restricted by the long distance covered by the dam, and would not exceed two cubic feet per second.

The borings at the site of the La Boca dam indicate impervious mud and clayey material, and show no sandy material overlying the rock, as stated in the report of the Board, so that the introduction of a masonry core or other stop-water appears from present information to be unnecessary. The earth dam as proposed will be in no "danger of being pushed bodily out of place by the pressure due to the head of water in the reservoir," because it has been made very massive, conforming in this respect to the suggestions of the Board made since the dam was designed.

At the great north dike or embankment of the Wachusett reservoir, referred to by the Board, porous material was removed and replaced by fine and impervious material, and sheet piling was driven where seepage or percolation was apprehended, but at the other parts of the dike where there were no such apprehensions the impervious material of the embankment was placed directly on the impervious earth found at the site of the dike. Should any safeguards prove necessary to prevent seepage, when detailed investigations are made at the Isthmus, it is expected that they will be provided, and to cover any probable expenditure for this purpose an allowance of $400,000 for all dams has been included in the estimates.

The construction of earth dams to retain water 85 feet deep is not an untried experiment, as there are many earth dams of equal or greater height, nearly all of them made wholly of earth without a masonry core, and none of them having nearly the mass or the stability of those herein recommended.

CONCLUSIONS AND RECOMMENDATION.

The greater cost of the proposed sea-level canal—upward of $100,000,000 more than that of the lock canal herein advocated—is not a trifling sum, even for the resources of the United States. If such an outlay is incurred a greatly superior waterway should be obtained or the expenditure will be unwise and the result discreditable.

The question of relative safety of the two types of canal must be considered with reference both to the waterway and the traffic. Accidents to the waterway may stop traffic or may only retard it or may not affect it at all, depending on the nature of the accident.

There can be no doubt that the greater the number of locks the greater the risk of injury to some one of them. It has been shown that the risk of serious injury to a well-equipped canal lock has been found very small, and with the additional and unusual precautionary constructions

proposed for the lock canal at Panama it will be almost inappreciable, except in time of war. At such a time either form of canal would require efficient military protection, and such protection is as practicable for a lock canal with a broad waterway as for the narrow channel of the sea-level canal. In the former case military protection would be specially required at the locks and in the narrow portion of the Culebra cut; in the latter case, the advantage of a smaller number of locks to be guarded would be fully offset by the greater difficulty of guarding the entire length of narrow channel, which would extend from sea to sea.

It has been shown by ample experience that ships are far more liable to delay and injury while traversing artificial channels at considerable speed than when passing locks where they move slowly and are under perfect control. The narrower the channel the greater the danger of collisions, groundings, blockades, and injuries to ships.

The broad channels of which the lock canal will mainly consist will permit vessels to move at greater speed than would be safe in a narrow channel. Although the Board apparently questions this, its truth is self-evident and, moreover, is established beyond a doubt by abundant and long-continued experience. Ships meeting in these broad channels will pass in safety with little if any reduction of speed, while in the narrow sea-level canal one of two meeting ships, unless of small size, would have to stop and make fast to the bank at a regular meeting place and remain there until the other passed at reduced speed, involving both delay and appreciable risk to the ships.

In consequence of the lower speed and the delays of various kinds in the narrow sea-level canal, ships of large size would consume more time in passing through it than would be required in a lock canal, and with a heavy traffic this would be true for ships of even moderate size, for the reason that more time would be lost in the narrow channel of the former than at the locks of the latter. As the delays at meetings in the sea-level canal would increase rapidly with the traffic, they would become insupportable with a traffic much smaller than the lock canal would provide for. The sea-level canal may therefore be called "provisional" with far more propriety than the lock canal.

The difficulty apprehended by the Board in the passage through locks of large ships, especially of large war ships, would doubtless be realized if the locks were no better equipped than in some well-known ship canals. Long approach walls with vertical faces, where a ship can be checked and stopped at a safe distance from the lock, against which it can lie and along which it can move safely with lines out, are indispensable for the safe operation of a lock. When these are provided there are no special increasing risks as the ship dimensions increase. This is fully shown by experience where such approaches exist.

The summit level of the lock canal and the terminal lake on the Pacific side are to be held up by earth dams supporting less heads of water than many existing earth dams, but of unprecedented strength both in regard to width and to height above the water surface. Only the facility with which these dams can be built and the great importance of making them secure beyond a shadow of doubt justify dimensions so extraordinary in proportion to the height of water to be sustained.

We believe the locks and other structures of the lock canal can be built in less time than is required for the Culebra cut, but the margin is not great and the project is well balanced in this respect. If the summit level were made higher the Culebra cut could be completed sooner, but the locks would require more time and the canal would probably not be finished as soon; if the summit level were made lower the Culebra cut would obviously take longer. We believe, therefore, that the project we recommend will open navigation across the Isthmus in the least possible time. Since the Culebra cut will fix the time for completing either the lock canal or the sea-level canal, and the former requires only half as much excavation from the Culebra cut as the latter, it can be built in approximately half the time. A difference of six years in favor of the lock canal is a very conservative estimate.

In view of the unquestioned fact that the lock canal herein advocated will cost about $100,000,000 less than the proposed sea-level canal; believing that it can be built in much less time; that it will afford a better navigation; that it will be adequate for all its uses for a longer time, and can be enlarged, if need should arise, with greater facility and less cost, we recommend the lock canal at elevation 85 for adoption by the United States.

Respectfully submitted.

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HENRY L. ABBOT.
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JOSEPH RIPLEY.
ISHAM RANDOLPH.

O

59TH CONGRESS, 1st Session. } SENATE. { DOCUMENT No. 313.

REPORTS

OF THE

EFFICIENCY OF VARIOUS COALS,

1896 TO 1898.

EXPENSES OF EQUIPMENT ABROAD, 1902-1903,

AND

RECENT CHEMICAL ANALYSES OF COAL AT NAVY-YARD, WASHINGTON, D. C.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

[Concurrent Resolution.]

Resolved by the Senate (the House of Representatives concurring), That there be printed the following documents:

First. Reports of the efficiency of various coals used by the United States ships from 1896 to 1898, inclusive, made by the Bureau of Equipment of the Navy in 1899.

Second. Pages 47 to 71, inclusive, of the report of the Bureau of Equipment of the Navy for 1902, under the heading of "Equipment expenses abroad."

Third. Pages 55 to 67 of the report of said Bureau for 1903, under the same heading.

Fourth. Letter from the Secretary of the Navy to John T. Morgan, with the accompanying statements, dated March 6, 1906.

Said papers to be bound together in cloth, as one document, of which 2,000 copies shall be printed, 500 copies for the Senate, 1,000 copies for the House of Representatives, and 500 copies for the Navy Department.

Passed, April 9, 1906.

REPORTS

OF THE

EFFICIENCY OF VARIOUS COALS USED BY U. S. SHIPS, 1896-1898.

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LIST OF COALS TESTED.

BITUMINOUS COALS.

Trade name.	Page on which reference is made.			Where mined.	Reports from ships making steaming trials.	Chemical analyses.	Boiler tests.
	Chemical test.	Boiler test.	Ships' tests.				
Abecarn			16, 17	Wales	San Francisco, 1		
Acme			16, 17	Pennsylvania	Porter, 1		
Albion Cardiff	7, 16	10, 17	16 to 21	Wales	Adams, 3; Alert, 7; Baltimore, 1; Bancroft, 1; Bennington, 1; Concord, 2; Corwin, 1; Detroit, 1; Marietta, 6; Marion, 3; Mohican, 2; Monadnock, 3; Monterey, 1; Oregon, 4; Petrel, 2; Philadelphia, 1.	1	1
Alderson	7			Alderson, Indian Ter		1	
Altoona	9			Kittanning Point, Blair County, Pa		1	
Aurora	9			Summerhill, Cambria County, Pa		1	
Argyle	7, 9, 20	11, 21	20, 21	Pennsylvania	Dolphin, 1	3	1
Australian			20, 21	Australia	Alert, 1		
Battleship	7			Black Diamond Coal Co.'s Mines at Coal Creek, Tenn.		1	
Beynon's Newport Abercarse.			20, 21		Raleigh, 1		
Big Bend	7, 9			Twin Rocks, Cambria County, Pa		2	
Black Diamond	9, 22		22, 23	Black Diamond Coal Co.'s Mines at Coal Creek, Tenn.	Amphitrite, 1; Maine, 1; Newark, 1	1	
Bloomington	9			Pennsylvania		1	
Bonanza	7, 9			Bonanza, Sebastian County, Ark		2	
Bryant		11		Issaquah, Kings County, Wash			1
Bryn Blaen	7			Wales		1	
Cahaba	22		22, 23	Blocton, Bibb County, Ala	Texas, 1	2	
Cambrian Navigation			22, 23	Wales	Minneapolis, 1		
Cardiff			24, 25	do	Boston, 4; Miantonomoh, 1; Monocacy, 4; Terror, 1		
Castle Gate	7	11		Utah		1	1
Clearfield	24	11, 25	24 to 27	Pennsylvania	Alliance, 1; Amphitrite, 1; Iowa, 2; Maine, 1; Massachusetts, 3; New Orleans, 1; Newport, 1; New York, 1; Solace, 1; Texas, 1; Yankee, 1.	1	1
Coal Creek	7			Briceville, 36 miles northwest of Knoxville, Tenn.		1	
Coalbrooke Vale			26, 27	Wales	San Francisco, 1		
Comox	9, 26	10, 27	28, 29	British Columbia, Union, Vancouver Island.	Alert, 2; Concord, 3; Marietta, 1; Mohican, 2; Monterey, 2; Oregon, 2; Philadelphia, 1	1	1
Cory's Merthyr			30, 31	Wales	Alliance, 1; Bancroft, 1; Cincinnati, 2; Detroit, 1; Machias, 1; Minneapolis, 1; Raleigh, 6; San Francisco, 1.		
Cripple Creek	7			Briceville, Anderson County, Tenn		1	
Cumberland (Big Vein)	7, 9, 32		32, 33	Maryland, Allegany County	Castine, 1; Concord, 1; Detroit, 1; Hamilton, 1; Marietta, 2; Montgomery, 1; Terror, 1	3	
Derbyshire			32, 33	England	Marblehead, 1		
Dorchester	7			Virginia		1	
Dowlais Merthyr			32, 33	Wales	Castine, 1; Detroit, 1; Raleigh, 2		
Duckenfield	7, 34	11, 35	34, 35	Australia	Bennington, 1; Marietta, 1; Philadelphia, 1	1	1
Elk Garden	9, 34	10	34, 35	West Virginia Mineral Company	Marion, 3	1	2
Eureka	36	10, 37	36, 37	Pennsylvania, Clearfield County	Alliance, 1; Detroit, 1; Dolphin, 1; Massachusetts, 1; Texas, 1; New Orleans, 1	1	1
Fairhaven	7			Skagit County, Wash		1	
Ferndale Merthyr			36 to 39	Wales	Bancroft, 1; Boston, 1; Concord, 1; Detroit, 7; Machias, 10; Olympia, 11; Petrel, 4; Raleigh, 1; Yorktown, 1.		
Flat Top	7					1	
Fraterville	7			Tennessee		1	
Franklin	7	11		Near Seattle, Wash		1	1
Gamble	7			Alabama		1	
George's Creek	9, 40	10, 41	40 to 43	Maryland, Allegany County	Annapolis, 2; Bancroft, 2; Castine, 2; Catskill, 2; Hamilton, 3; Marblehead, 1; Nahant, 1; New York, 1; Solace, 2; Terror, 1; Yankee, 1.	4	1
Glen Neath	7			Wales		1	
Great Western Navigation			42, 43	do	Bancroft, 4; Boston, 1; Cincinnati, 1; Minneapolis, 5; San Francisco, 3		
Henrietta	7, 44	10, 45	44, 45		Annapolis, 1; Montgomery, 2; Newport, 1	1	1
Hetton	7	11		Bullock Island, opposite Newcastle, New South Wales, Australia.		1	1
Hoskins & Llewellyn's (No. 1 Colliery, screened; large steam).			44, 45	Wales	Alliance, 1		
Hood's Merthyr			44, 45	Wales	Minneapolis, 2; Raleigh, 1; San Francisco, 1		
Kemmerer	7			Kemmerer, Wyo		2	
Laurel County	7			Laurel County, Ky		1	
Lewis Merthyr			44, 45	Wales	Bancroft, 1		
Lloydell	7			Lloydell, near Dumlo, Cambria County, Pa.		2	
Lockitt's Merthyr			46, 47	Wales	Detroit, 1; Machias, 1		
Looney Creek	7			Looney Creek, Va		1	
Loyal Hanna	7, 9	10		Pennsylvania, Westmoreland County		3	1
Manchester	7			Altamont, Ky		1	
Marine Merthyr			46, 47	Wales	Bancroft, 2; Raleigh, 1; San Francisco, 1		
Midvale			46, 47	Pennsylvania	Marblehead, 1		
Milldale	46		46, 47	Milldale, Tuscaloosa County, Ala	Marblehead, 1; Montgomery, 2	1	
Monongahela	7			Willock Station, Wheeling Division, B. & O. R. R., Allegheny County, Pa.		1	
Monterallo	7			Aldrich, Ala		1	
Morrisdale	7, 9, 48	10, 49	48, 49	Pennsylvania, Clearfield County	Alliance, 1; Amphitrite, 1; Annapolis, 2; Detroit, 1; Indiana, 1; Marblehead, 1; Montgomery, 2; New York, 1; Terror, 2; Texas, 2; Wilmington, 1.	4	1
Moshannon Creek	50	10, 51	50, 51	Pennsylvania	New York, 1	1	1
Mt. Vernon	79			Houtzdale, Pa		2	
Nanaimo	7, 50	11, 51	50, 51	Nanaimo, Vancouver Island, B. C	Adams, 1; Baltimore, 1; Bennington, 1; Monterey, 2	1	1
Nantyglo			52, 53	Wales	Detroit, 1; Raleigh, 1		
National Merthyr			52, 53	do	Bancroft, 1; San Francisco, 1		
New Castle	7, 52	11, 53	52, 53	Near Seattle, Wash	Alert, 1; Bennington, 1	2	1
New Castle (Bowler)			52, 53	Wales	Raleigh, 1		
New River	54	10, 55	54 to 57	West Virginia, Fayette County	Alliance, 1; Annapolis, 1; Bancroft, 1; Castine, 1; Columbia, 1; Detroit, 1; Indiana, 3; Iowa, 2; Maine, 1; Marblehead, 1; Massachusetts, 1; Newport, 2; New York, 3; Raleigh, 1; Solace, 2; Texas, 2; Vesuvius, 3; Yankee, 1.	1	1
Nixon's Navigation			56, 57	Wales	Bancroft, 1; Essex, 1; Machias, 2; Raleigh, 2		
Ocean Merthyr			56 to 59	do	Castine, 6; Detroit, 1; Lancaster, 5; Machias, 3; Oregon, 3; Philadelphia, 4; Raleigh, 1; San Francisco, 1.		
Paint Rock	7			Oneida, Tenn		1	
Pardee	7, 9, 58	10, 59	60, 61	Pennsylvania, Cambria County	Amphitrite, 1; Annapolis, 1; Castine, 1; Columbia, 1; Iowa, 1; Texas, 1	2	1
Pardee Patton	9, 60		60, 61		Indiana, 1; Maine, 1; Massachusetts, 2; Montgomery, 1; Texas, 1	2	
Patent Fuel, Anchor Brand			62, 63	Wales	Raleigh, 1		
Patent Fuel (Prince brand briquettes).			62, 63		Bancroft, 1		
Penrikyber Navigation			62, 63	Wales	Marietta, 1; San Francisco, 1		
Penllyn Merthyr			62, 63	do	Castine, 3		
Philippi	7			Philippi, W. Va		1	

List of Coals Tested—Continued.

BITUMINOUS COALS—Continued.

Trade name.	Page on which reference is made.			Where mined.	Reports from ships making steaming trials.	Chemical analyses.	Boiler tests.
	Chemical test.	Boiler test.	Ships' tests.				
Pikesville	7			Kentucky		1	
Pinesville	7			do		1	
Pittsburg	7, 62		62, 63	Pennsylvania, Washington County	Maine, 1; Texas, 1	1	
Pocahontas	9, 64	10, 65	64 to 67	Virginia and West Virginia, Tazewell and McDowell counties.	Alert, 1; Amphitrite, 5; Annapolis, 1; Bancroft, 1; Castine, 3; Dolphin, 1; Hamilton, 2; Iowa, 2; Marblehead, 4; Massachusetts, 3; Michigan, 1; New Orleans, 2; New York, 2; Petrel, 1; Puritan, 2; Solace, 1; Terror, 12; Texas, 1.	4	1
Portage	9			Portage, Cambria County, Pa		1	
Powhattan	7, 68	10, 69	68, 69	Pennsylvania	Miantonomoh, 1	1	1
Powell Duffryn			68, 69	Wales	Detroit, 1		
Powelton	7			Pennsylvania		1	
Pratt	68		68, 69	Alabama, Jefferson County	Detroit, 1	1	
Providence	7			Providence, Ky		1	
Reserve Cape Breton			70, 71		Marblehead, 1		
Reynoldsville		10, 71	70, 71	Pennsylvania, Jefferson County	Montgomery, 2		1
Rockhill	7, 9	11		Robertsdale, Huntingdon County, Pa		2	1
Rock Springs	7			Wyoming		1	
Roslyn	7	11		Washington, Killitas County		1	1
Shawmut	7			Horton Township, Elk County, Pa		3	
Sonman	7			Pennsylvania		1	
Standard Eureka	9			Pennsylvania, Clearfield County		1	
Standard Merthyr			70, 71	Wales	Bancroft, 1		
Stonega	7			Virginia		1	
Thomas Steam Coal	9			West Virginia		1	
Toms Creek	9			Virginia, Wise County		1	
Thurber	7			Thurber, Tex		1	
Wallsend	7, 70	11, 71	72, 73	Newcastle, N. S. W., Australia	Adams, 1; Bennington, 1; Monadnock, 1; Monterey, 1	2	1
Webster	9			Pennsylvania, Cambria County		1	
Wellington	7, 9, 72	11, 73	72, 73	Wellington, British Columbia	Concord, 2; Mohican, 1; Montgomery, 1	3	1
West Hartley			74, 75	Wales	Marion, 1		
Westminster Brymbo			74, 75	do	Alert, 2		
Westport	7, 74	10, 75	74, 75	New Zealand	Alert, 1; Monadnock, 1; Monterey, 1; Wheeling, 1	1	1
Youghiogheny	7, 76		76, 77	Pennsylvania	Michigan, 1	2	

ANTHRACITE COALS.

Highland			76, 77	Pennsylvania	New York, 1		
Lehigh			76, 77	do	Marblehead, 1		
Morea	76		76, 77	Pennsylvania, Lehigh County	Montgomery, 1; Raleigh, 1	1	
Natalie	78	10, 79	78, 79	Pennsylvania, Schuylkill, Buck Mountain Vein.	Alliance, 1; Annapolis, 1; Detroit, 1; Montgomery, 2	1	1
Pardee Anthracite	9			Pennsylvania, Cambria County		1	
Scranton Egg			78, 79	Pennsylvania	Essex, 1		

CHEMICAL ANALYSES OF SAMPLES OF COAL AT THE NAVY YARD WASHINGTON, D. C.

[Arranged in order of per cent of fixed carbon.]

Coal	Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.
Powhattan	3.13	1.38	1.06	86.67	7.56	.331	1.11
Bryn Blaen	1.30	.65	7.40	84.60	6.05	.198	.409
Coal Creek	1.50	.83	2.53	82.14	13.00	.234	.133
Bonanza	.63	1.25	14.10	80.61	3.41	.365	----------
Lloydell	1.24	1.95	12.50	80.50	3.72	.108	.201
Lloydell	.925	.635	14.680	80.37	3.39	.098	.084
Rockhill	2.067	.86	13.38	80.28	3.42	.623	----------
Argyle	.899	1.811	11.408	79.977	5.068	.837	----------
Powelton	1.46	----------	12.56	79.82	6.16	.014	.118
Sonman	.721	1.849	12.619	79.497	5.089	.225	----------
Glen Neath	2.70	.69	14.25	78.74	3.62	.121	.889
Argyle	.697	.803	15.277	78.193	4.756	.274	----------
Sonman	.99	.27	16.54	77.60	4.60	.173	.203
Morrisdale	593	1.347	14.197	77.320	6.077	.466	.853
Henrietta	783	2.417	14.707	77.222	4.207	.664	----------
Big Bend	261	1.089	15.98	75.010	6.66	1.00	----------
Big Vein Cumberland	.995	.701	16.114	74.87	7.32	.14	.300
Mt. Vernon	.751	1.289	17.404	74.198	5.645	.713	----------
Flat Top	1.063	1.517	12.264	74.15	10.844	.162	----------
Pardee	.598	1.342	18.248	72.993	6.309	.509	----------
Thomas	1.059	.751	21.213	71.287	5.543	.147	----------
Glenwood	1.289	1.011	23.639	70.118	3.53	.413	----------
Albion Cardiff	1.62	1.17	14.91	69.92	12.38	.077	.463
Loyal Hanna	.6097	1.421	22.966	65.838	7.886	1.280	----------
Dorchester	1.32	1.04	28.52	65.66	3.46	.483	.416
Youghiogheny Ocean Mine, No. 2	1.51	.90	29.69	64.96	2.94	.024	.359
Stonega	1.37	.83	30.65	64.78	2.37	.119	.551
Philippi	1.06	1.48	26.12	64.76	6.58	.894	.650
Looney Creek	1.40	1.43	31.51	63.70	1.96	.225	.401
Cripple Creek	1.77	1.43	30.04	63.42	3.34	.427	.314
Pittsburg Mine, No. 1	2.59	1.55	30.12	63.01	2.75	.172	.300
Fraterville	1.08	1.29	31.47	62.72	3.44	.299	.790
Battleship Coal (Black Diamond Mines)	2.05	1.29	31.95	62.68	2.03	.248	.752
Shawmut Mine, No. 1	1.71	1.24	29.45	62.40	5.20	1.76	.534
Youghiogheny Ocean Mine, No. 1	1.58	1.20	26.76	62.26	8.20	.022	.318
Pinesville	1.94	1.31	33.59	62.07	1.09	.129	.603
Gamble	1.88	.90	24.67	61.96	10.59	.435	.423
Shawmut Mine, No. 2	1.14	1.40	27.00	61.92	8.54	1.96	.340
Westport	1.630	1.02	34.929	61.798	.199	.424	----------
Shawmut Mine, No. 8	1.68	1.00	32.06	61.67	3.59	.278	.702
Paint Rock	2.11	2.94	28.11	61.44	5.40	.185	1.12
Laurel County	2.05	2.59	31.50	61.00	2.86	1.12	1.07
Wallsend	2.54	2.16	28.731	60.393	6.001	.175	----------
Hetton	1.82	1.35	32.99	60.04	3.80	.167	1.23
Fairhaven	2.98	2.00	33.03	59.98	2.01	.202	.867
Cape Breton	2.781	2.139	30.132	59.52	4.262	1.166	----------
Duckenfield	2.71	1.34	29.22	58.68	8.05	.274	.504
Manchester (Altamont)	2.61	1.47	35.50	58.16	2.26	.461	1.05
Franklin	3.26	1.50	33.86	57.58	3.80	.097	1.61
Monongahela Gas Coal	1.06	.89	32.88	57.50	7.67	2.88	.406
Alderson	2.30	.98	32.38	57.34	7.00	.201	1.502
Providence	4.04	1.86	30.60	56.74	6.76	.807	1.17
Wallsend	3.392	3.768	23.281	56.014	13.161	.384	----------
Roslyn	2.05	1.51	32.04	54.55	6.85	.106	.402
Kemmerer Mine, No. 4	3.58	2.34	34.73	54.21	5.14	.414	.703
Kemmerer Mine, No. 1	3.00	2.43	37.17	53.61	3.19	.414	.825
Rock Springs	6.65	2.00	33.79	53.27	4.29	.399	.502
Roslyn	2.718	3.642	30.633	50.109	12.753	.145	----------
Thurber	3.35	2.22	32.93	49.43	12.07	.639	.491
Monterallo	.66	1.33	34.85	48.99	14.27	.672	.344
Castle Gate	2.30	1.05	38.66	48.63	9.36	.200	.433
New Castle Vein, No. 4	13.59	3.32	28.99	48.32	5.78	.164	3.78
Franklin	4.559	3.191	30.31	46.668	15.08	.192	----------
Bryant	13.38	4.00	27.33	46.274	8.349	.217	----------
Wellington	2.09	2.05	36.85	46.16	12.85	.563	1.22
Nanaimo	3.352	1.998	33.762	46.001	14.322	.565	----------
Pikesville	.64	1.18	42.11	36.53	19.54	2.58	.438

SPECIAL ANALYSES OF VARIOUS COALS TO DETERMINE THEIR LIABILITY TO SPONTANEOUS IGNITION.

The Bureau early in the year 1898 sent to many dealers requesting them to furnish samples of the different kinds of coal handled by them for the purpose of making tests to determine their liability to spontaneous ignition. These tests were made at the Washington Navy-Yard. The chemist, in submitting the results of these tests, says: "A series of investigations led Lewis, Richter, and others to the conclusion that the principal cause of a coal's liability to spontaneous ignition is its power of absorbing oxygen from the atmosphere, a characteristic closely connected with, and under certain conditions indicated by, the coal's power of absorbing moisture. A secondary cause of self-ignition, though only in wet coal, is the presence of pyrites, indicated by the amount of sulphur determined. An accessory, though by no means a cause, is the combustible volatile matter, which, when a coal, through primary causes, has reached its ignition point, naturally will furnish fuel for a lively combustion.

"The determinations of sulphur and combustible volatile matter were made in the customary way. Not knowing, however, the history and treatment of the coals submitted before they reached me, I had to subject them to a preliminary air-drying of two weeks' duration before determining the moisture and the oxygen absorption, taking care, of course, to protect them against rain."

The following are the results:

Name of coal.	Moisture.	Combustible volatile matter.	Increase in weight at 250° F.	Sulphur.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
"Argyle," from Argyle Coal Company, Cambria County, Pa	.901	17.00	.410	.399
"Aurora," from Aurora Coal Company, mines at Summerhill, near South Fork, Cambria County, Pa	.78	18.81	.36	.748
"Portage," from the Hopper Company, mines at Portage, Cambria County, Pa	.86	19.27	.475	.414
"Altoona," from Altoona Coal and Coke Company, mines at Kittanning Point, Blair County, Pa	.955	23.42	.372	1.062
"Tom's Creek," from Tom's Creek Coal and Coke Company	1.100	29.16	.765	.103
"Mt. Vernon, No. 6," Houtzdale, Pa., from the United Collieries Company	1.25	18.85	.715	.080
"Loyal Hanna," Burnside mine, from Loyal Hanna Coal and Coke Company	1.03	22.69	.863	1.73
"Loyal Hanna," from Loyal Hanna Coal and Coke Company, Mine No. 1	.81	29.00	.501	1.45
"Pocahontas," from Castner, Curran & Bullitt	.970	17.32	.464	.697
"Pocahontas," from F. H. Chappel & Co., New London, Conn	.630	15.49	.358	.787
"Standard Eureka," from Berwind-White Coal Mining Company	1.15	12.20	.792	1.93
"Morrisdale," from Morrisdale Coal Mining Company, Morrisdale, Pa	1.25	20.78	.853	.243
"Bed 'B,' Shaft 2," from Morrisdale Coal Mining Company, Morrisdale, Pa	1.36	20.58	.778	.487
"Morrisdale," Six Mile Run, from Morrisdale Coal Mining Company, Cunard Mine	.836	14.30	.336	.185
"Pardee Anthracite," from Pardee Colliery, Patton, Pa., from David Duncan & Son	1.38	1.38	.644	.569
"Pardee Bituminous," from David Duncan & Son	1.17	20.46	.756	.361
"Old Pardee, No. 2," from Peale, Peacock & Kerr	1.47	28.25	.483	.119
"Old Pardee, No. 9," from Peale, Peacock & Kerr	1.38	27.12	.543	1.23
"George's Creek," from Black, Sheridan, Wilson & Co.'s mines, furnished by Interstate Coal and Coke Company, Baltimore, Md	.763	26.85	.414	.981
"George's Creek," Big Vein, from L. M. Hamilton & Co., Baltimore, Md	1.34	20.42	.470	.253
"George's Creek," Small Vein, from L. M. Hamilton & Co., Baltimore, Md	1.00	21.30	.661	.265
"George's Creek," from E. B. Townsend, Boston, Mass	1.27	17.82	.506	.379
"Wellington," from Dunsmuir & Sons, San Francisco, Cal	.908	16.44	.460	.196
"Black Diamond," from Black Diamond Coal and Coke Company, Knoxville, Tenn	.984	22.59	.400	.230
"Elk Garden," from Davis Coal and Coke Company, Baltimore, Md	.868	17.24	.277	.253
"Webster Bituminous," New Central Coal Company, Cumberland, furnished by E. B. Townsend, Boston, Mass	1.16	25.60	.556	.975
"Comox," from Dunsmuir & Sons, San Francisco, Cal	.857	28.26	.830	.894
"Cumberland," furnished by F. H. Chappel & Co., New London, Conn	.636	19.11	.221	.229
"Big Vein Cumberland," from Merchants' Coal Company, Baltimore, Md	.747	19.47	.481	.064
"New River Kanawha," from Richmond, Va	1.36	18.95	.631	.074
"Thomas Steam Coal," from Davis Coal and Coke Company, Piedmont, W. Va	1.23	22.00	.421	.093
"Big Bend," from Twin Rocks, Cambria County, Pa., furnished by Van Dusen Bros. & Co., Philadelphia, Pa	1.15	18.68	.623	.465
"Bloomington," from Peale, Peacock & Kerr	1.47	22.66	.600	.988
"Bonanza," from Peale, Peacock & Kerr	1.36	14.10	.552	.365
"Rockhill," from Peale, Peacock & Kerr	1.03	13.38	.400	.623

BOILER TESTS OF COAL, MADE AT THE NEW YORK AND MARE ISLAND NAVY YARDS.

[Arranged in order of equivalent evaporation from and at 212° F.]

Name of coal.	Coal furnished by—	Place of test.	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal consumed per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° F. per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
			Hours.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Degrees*				
Albion Cardiff	Oregon Improvement Co.	Mare Isl'd.	13$\frac{58}{60}$	28,562.36	3,150	10	9.07	10.69	10	42.14	63	----------	Oct. 22, '97	----------	The refuse resulted almost wholly from hauling the fire, together with a small quantity of soot.
Henrietta	Allegheny Comp'y, Washington, D.C.	New York.	12	42,389	4,980	12.2	8.5	9.94	11.2	42	72.2	----------	July 14, '97	----------	Burns with long yellowish flame; smoke of light-brown color.
Westport	Oregon Improvement Co.	Mare Isl'd.	12$\frac{58}{60}$	26,691.878	3,250	11.25	8.212	9.76	4.27	42.7	64	----------	Oct. 27, '97	----------	This coal is remarkably free from ash and clinker. The refuse resulted from hauling the fire only, together with a small quantity of soot.
Pardee	David Duncan & Son.	New York.	12	44,281	5,400	11.25	8.2001	9.5797	11.296	40.75	72.625	Tin, lead, and zinc melted.	Aug. 10, '96	----------	Good coal for ordinary natural draft. No clinker. Antimony placed in front connection was intact.
Loyalhanna	Barroll & Azoy	New York.	12	46,494	5,670	11.8	8.2	9.5	14.7	41	66	----------	June 16, '97	----------	Suited for moderate forced draft.
Pocahontas	Navy Yard, Norfolk, Va.	New York.	24.66	89,729.75	11,280	12.034	7.9548	9.38	8.39	40.04	62	Tin partly fused.	May 15, '94	Practically all lump.	Burned freely. Short flame. Small coal fell through bars. Insignificant amount of clinker, and that of friable nature. Small amount of brown soot. Breaks readily. Irregular lustrous black fracture, somewhat slaty appearance.
New River	Chesapeake & Ohio R. R.	New York.	24.42	87,367	11,200	12.07	7.8006	9.179	6.288	39.88	64.88	Lead and tin melted.	Oct. 11, '93	----------	Burned freely. Long yellow flame. Cakes quickly. Small amount of coke fell through bars. Clinkers small and hard. Light-gray ash. Dark-colored smoke. Crumbles slightly in handling. Traces of slate.
Moshannon Creek.	Clearfield Bituminous Coal Corporation.	New York.	24	89,168	11,350	12.15	7.856	9.173	11.9	39.16	72.44	Zinc slightly fused.	July 28, '93	50 per cent	Burned freely. Long yellow flame. Cakes very slightly. Clinkers small in amount and size. White ash. Light lead-colored smoke.
Reynoldsville.	Geo. R. Dilker & Co.	New York.	12	47,036	6,180	12$\frac{38}{60}$	7.611	9.125	9.6278	41.7916	44	Tin and lead melted.	----------	About 60 per cent.	Coal suitable for ordinary forced draft. Used 1,380 pounds of wood to raise steam. Weather cloudy and rainy. Coal has bright fracture and burns very rapidly, with red-yellow flame; forms heavy black smoke when firing, and considerable all the time; requires to be frequently charged into furnaces. Slice bar not required. Steam pressure fluctuating and difficult to control. Soot formed mostly in tubes. Zinc and antimony placed in the front connection remained intact. Clinker, 83 pounds; soot, 88 pounds.
Comox	R. Dunsmuir, Sons & Co., San Francisco, Cal.	Mare Isl'd.	12.5	26,526.7	3,450	12.77	7.689	9.027	14.7	42	67.7	Tin and lead melted.	Aug. 27, '97	----------	
Elk Garden	Davis Coal and Coke Co.	New York.	24.5	86,909	11,280	12.116	7.7047	9.02	10.3258	39.96	70	583.2	Oct. 27, '94	33 per cent.	Burned freely. Short orange flame. Caked well and required very little labor. Clinker insignificant. Small quantity brown smoke. Soot, small amount and gray color. Breaks readily. Irregular fracture. Lustrous and dull black.
Elk Garden	Davis Coal and Coke Co.	New York.	24.75	87,243	11,400	12.122	7.653	8.938	11.36	37.11	72	Zinc fused	Aug. 7, '93	5 per cent.	Burned freely. Medium long bright-yellow flame. Cakes moderately. Clinkers small in size and amount. Lead-colored smoke. Soot moderate, light-gray color. Crumbles in handling. Shows signs of pyrites.
Powhattan	Madeira, Hill & Co.	New York.	12	40,335	5,400	11.25	7.47	8.896	10.4	40.1	44	----------	Feb. 15, '98	About 40 per cent.	Light-brown smoke. Moisture in coal, 2.38 per cent.
Morrisdale	W. C. Barber, 1 Broadway, N. Y.	New York.	12	41,509	5,470	11.4	7.58	8.87	13	40	70	566	Sept. 4, '97	Chiefly lump.	The sample furnished consisted chiefly of lump coal. Fire was started with wood, and steam was raised to 40 pounds. Then coal fire was started with wood embers.
Georges Creek	Davis Coal and Coke Co.	New York.	24.25	81,073	10,800	11.134	7.5	8.72	14.03	43.02	69.25	----------	Sept. 30, '95	----------	Coal burned freely with a long, white-yellowish flame, when first fired emitting a small quantity of dark-gray smoke; it did not coke, but caked slightly. The firing necessary with this coal was quite arduous by reason of the great quantity of fine coal falling through the bars, and the evaporative result undoubtedly was much higher than could be obtained on board ship by ordinary firing; also, the percentage of refuse was much lower than would result from ordinary firing.
Eureka	Berwind-White Coal Mining Co.	New York.	24.83	84,109	11,300	11.997	7.443	8.694	10.87	36.56	72	Zinc melted.	Aug. 4, '93	About 50 per cent.	Burned freely. Moderately long yellow flame. Clinkers small in size. Gray ash. Dark lead-colored smoke. First lot, 4½ tons. Crumbled in handling. Second lot, 1½ tons. Considerable force to fracture. Traces of slate and sulphur.
Natalie (anthracite).	Natalie Anthracite Coal Co.	New York.	12	40,379.5	5,652	11.7	7.14	8.58	20.5	41.66	41	----------	Jan. 30, '97	----------	Coal delivered contained 10 per cent moisture. Burns very freely with a short yellow flame and no smoke. Easily worked.

Hetton	Oregon Improvement Co.	Mare Isl'd	12.5	25,900.2	3,565	13.2	7.265	8.510	11.52	42.7	69.6		Sept. 10, '97		Dense gray smoke.
Wellington	R. Dunsmuir, Sons & Co.	Mare Isl'd	12.5	26,013	3,640	13.48	7.146	8.389	11.87	42	68	Tin and lead melted.	Aug. 25, '97		
Rockhill	Rockhill Iron and Coal Co., Philadelphia, Pa.	New York	24.75	76,133	10,700	11.38	7.115	8.276	14.09	37.2	70	Lead melted.	Sept. 11, '93	20 per cent	Coal broke easily, showing black lustrous surface at fracture. Where first coal was thrown on fire there was an immediate production of light smoke, which ceased completely soon after, so that, except at periods of firing the coal was practically smokeless; ignited readily; produced very little clinker, and is easily fired. An appreciable quantity of fine coal fell through the bars; though returned to the furnace repeatedly it was impossible to separate it all from the ashes.
Wallsend	J. C. Wilson & Co	Mare Isl'd	12	25,361.7	3,635	13.46	6.977	8.17	13.94	42.4	70.9	Tin and lead melted.	Sept. 15, '97		Moderate quantity of dense, dark, lead-colored smoke.
Castle Gate	Rio Grande Western Railway Co.	Mare Isl'd	12	22,025	3,320	12.296	6.934	8.123	12.049	42.83	69⅛	Lead and tin melted.	June 24, '98		Rather hard bituminous coal of good luster, the run of the mine, and a quantity worked over a riddle of ½-inch mesh passed about 28 per cent through. Ignites quickly and burns rapidly. Firing easy, clinkering and coking being slight. Can be burned easily with natural draft, but leaves considerable soot.
Argyle	Allegheny Coal Co., Washington, D. C.	New York	12	36,791	5,400	11.25	6.81	8.03	12.7	42.75	62.16		May 24, '97		This coal is good for blacksmithing purposes.
Franklin	Oregon Improvement Co.	Mare Isl'd	12.16	26,238.4	3,870	14.33	6.78	7.94	13.33	42	70.7	Lead and tin melted.	Sept. 13, '97		A friable bituminous coal. Of a quantity worked on a sieve with a ½-inch mesh about 21 per cent passed through. Grayish-black color with dull gloss. Structure laminated, with the dividing lines of the layers indistinctly marked. Cleavage very irregular. Vertical cleavage planes often contain a grayish-white film, while the more horizontal ones contain a reddish-brown powder. Burns freely with a moderately long, reddish-yellow flame and makes small amount of light, slate-colored smoke, which is easily dissipated. Swells in burning and cakes a little. Forms considerable clinker.
Nanaimo	Jno. Rosenfelds Sons	Mare Isl'd	12.33	25,217.5	3,875	14.35	6.5077	7.6315	15.45	42.75	69.3	Lead and tin melted.	Sept. 1, '97		
Clearfield	David Duncan & Son	New York	24.66	77,874	11,400	12.165	6.831	7.454	16.03			Lead fused.	Aug. 9, '93	5 per cent	Burned freely. Moderately long yellow flame. Cakes and breaks into small pieces. Clinkers large. Dark-gray ash and lead-colored smoke. Soot black and in large grains. Evidently large per cent of carbon. Lumps contained traces of iron pyrites and earthy matter.
Roslyn	R. D. Chandler, San Francisco, Cal.	Mare Isl'd	12.25	24,005	3,845	14.24	6.243	7.315	16.2	42.3	69.6	Lead and tin melted.	Aug. 20, '97		On first being thrown on the fire it burns with a long, reddish-yellow flame, which soon after becomes a shorter, bright-yellow flame. Swells slightly on surface of fire, but does not cake, and fire has a dirty appearance. Fire soon becomes dark underneath and needs frequent running under of slice bar to brighten it. Makes large amount of clinging clinker when forced draft is used. Moderate amount of gray smoke on adding fresh fuel, which was readily dissipated. Ash a mixture of gray and reddish particles.
New Castle	Oregon Improvement Co.	Mare Isl'd	12.11	24,456	4,100	15.14	5.965	6.996	10.5	43.6	69	Lead and tin melted.	Sept. 14, '97		Hard semibituminous coal, not easily broken, and of a grayish-black color with a dull lustre. Burns with long, reddish-yellow flame, but takes several minutes after throwing fresh coal on fire before it becomes thoroughly ignited. Moderate amount of brownish-gray smoke, easily dissipated. Swells but little and does not cake. Moderate amount of clinker.
Duckenfield	J. W. Holihan	Mare Isl'd	12	23,650	4,125	15.28	5.733	6.717	12.59	42.3	69.2		Aug. 8, '98		
Bryant	Central Coal Co., San Francisco, Cal.	Mare Isl'd	12.16	22,814.4	4,005	14.83	5.696	6.68	13.65	42	69	Lead and tin melted.	Sept. 7, '97		Lumps easily broken. Has a dull resinous appearance and its fracture has a dull black gloss. About 14 per cent passed through sieve of ½-inch mesh. Does not burn freely. Burns with comparatively short flame. Makes but little smoke, of a light-gray color, and easily dissipated. Does not cake. Forms considerable clinker.

DATA OF BOILERS IN WHICH THE ABOVE TESTS WERE MADE.

	New York.	Mare Island.		New York.	Mare Island.
Kind	Cylindrical return tubular	Cylindrical horizontal tubular brick furnace.*	Length of grates	6 feet	5 feet.
			Number and arrangement of combustion chambers	Two, side by side	One.
Diameter	10 feet	9 feet.	Depth of combustion chambers	32 inches	14 inches.
Length	9 feet 3 inches	15 feet.	Greatest width of combustion chambers	4 feet 1 inch	4 feet 9 inches.
External diameter of tubes	3¼ inches	3½ inches.	Greatest height of combustion chambers	4 feet	3 feet 8 inches.
Number of furnaces	Two	One.	Total heating surface	882 square feet	708.5 square feet.
Kind of furnaces	Cylindrical, not corrugated	External brick.	Total grate surface	38 square feet	22.5 square feet.
Greatest internal diameter of furnaces	40 inches	4 feet 9 inches.	Superheating surface		102 square feet.

* This boiler is so set in brickwork that the hot gases pass along the lower half of the shell (except the upper 5 inches of each side of this half); then to back of boiler; then through tubes to front of boiler; then over upper half of shell to back (except the lower 5 inches of each side of this half); then down back connection (except 4-inch partition between back connection and chimney flue) to passage leading to chimney. It will be seen that the entire surface is exposed to the hot gases, except a band of 10 inches along sides and 4 inches at back and where brickwork comes in contact with shell.

DATA FOR SHIPS' BOILERS.

[D. E. = double-ended return tubular; S. E. = single-ended return tubular; G. B. = gunboat boiler; M. L. = marine locomotive; a = auxiliary boiler; d = each furnace, separate combustion chamber; e = 2 adjoining furnaces, common combustion chamber; f = 3 furnaces having common combustion chamber; g = 2 opposite furnaces having common combustion chamber; m = main boiler.]

Name of vessel.	Number of main.	Number of auxiliary.	Kind of main.	Kind of auxiliary.	Diameter of main.	Diameter of auxiliary.	Length of main.	Length of auxiliary.	External diameter of tubes.		Total number of furnaces.		Greatest internal diameter of furnaces.		Length of grates.		Number and arrangement of combustion chambers.		Combustion chambers.				Total grate surface.	Total heating surface.
									Main.	Auxiliary.	Main.	Auxiliary.	Main.	Auxiliary.	Main.	Auxiliary.	Main.	Auxiliary.	Depth.		Greatest width.		Greatest height.			
					′ ″	′ ″	′ ″	′ ″	″	″			″	″	″	″			′ ″		′ ″		′ ″		*Sq. ft.*	*Sq. ft.*
Adams	6	----	S. E.	-------	9 0	-------	8 8	-------	$2\frac{1}{4}$	------	12	------	34	------	68	------	e6	------	1	$10\frac{3}{4}$	8	$1\frac{1}{2}$	5	2	192.6	4,940.4
Alert	2	----	S. E.	-------	12 0	-------	10 1	-------	3	------	6	------	36	------	84	------	d6	------	2	$3\frac{1}{4}$	3	6	7	5	126	3,375.2
Alliance	4	----	S. E.	-------	9 0	-------	9 0	-------	$2\frac{1}{8}$	------	8	------	34	------	68	------	e4	------	1	$10\frac{3}{4}$	8	0	5	2	128.4	3,135.6
Amphitrite	6	----	S. E.	-------	12 0	-------	10 $0\frac{3}{4}$	-------	3	------	18	------	36	------	84	------	d18	------	2	$3\frac{1}{4}$	3	$4\frac{1}{2}$	7	$4\frac{1}{2}$	378	8,800
Annapolis	2	----	B. & W.	-------	9 6	-------	11 7	-------	2 x 4	------	2	------	8′ 0″	------	6′ $1\frac{1}{2}$″	------	-------	------	-------		-------		-------		98	3,620
Baltimore	4	2	D. E.	S. E.	14 8	7 2	17 8	6 2	$2\frac{1}{4}$	$2\frac{1}{2}$	32	2	39	$35\frac{1}{8}$	82	45	e16	d2	2 / a1	$1\frac{3}{4}$ / $3\frac{3}{8}$	6 / a6	$5\frac{1}{4}$ / 2	8 / a3	7 / $10\frac{3}{4}$	676	17,175
Bancroft	2	----	G. B.	-------	8 $9\frac{1}{2}$	-------	17 0	-------	2	------	4	------	$41\frac{15}{16}$	------	72	------	d4	------	3	0	3	$7\frac{1}{2}$	4	$7\frac{1}{2}$	78	2,640.94
Bennington	4	----	G. B.	-------	9 9	-------	17 9	-------	$2\frac{1}{4}$	------	12	------	40	------	69	------	f4	------	3	9	8	10	5	11	220	8,092
Boston	8	----	S. E.	-------	11 8	-------	9 9	-------	$2\frac{3}{4}$	------	16	------	43	------	84	------	e8	------	1	11	10	4	6	$4\frac{1}{2}$	382	8,920
Castine	2	----	M. L.	-------	9 3	-------	18 6	-------	2	------	4	------	54	------	81	------	e2	------	3	$3\frac{1}{4}$	8	1	5	$1\frac{1}{2}$	120	4,590
Catskill	2	----	Martin water tube.	-------	10 0	-------	12 6	-------	2	------	6	------	2′ 9″	------	6′ 10″	------	d	------		18	4	4	2	9	-------	-------
Cincinnati	4	2	D. E.	S. E.	[5]14 4 / [5]13 4	11 6	20 $3\frac{1}{2}$	9 $10\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	12	4	$5\,46\frac{13}{16}$ / $5\,42\frac{7}{8}$	$44\frac{13}{16}$	76	76	d12	d4	2 / a2	$5\frac{1}{2}$ / 0	[5]4 / [5]3 / a4	6 / $10\frac{7}{8}$ / 9	[5]7 / [5]6 / a6	$4\frac{1}{4}$ / $8\frac{1}{2}$ / $7\frac{1}{2}$	617	20,179
Columbia	8	2	D. E.	S. E.	[6]15 9 / [5]15 3	10 0	18 0	8 6	$2\frac{1}{4}$	$2\frac{1}{2}$	[6]48 / 516	4	$41\frac{15}{16}$	$36\frac{1}{16}$	$78\frac{3}{4}$	70	[6]e24 / [5]b8	d4	2 / a2	$1\frac{3}{32}$ / $0\frac{3}{4}$	[6]6 / [5]6 / a4	10 / $7\frac{1}{2}$ / 1	9 / a5	9 / 10	1,408	45,221
Concord	4	----	G. B.	-------	9 9	-------	17 9	-------	$2\frac{1}{4}$	------	12	------	40	------	69	------	f4	------	3	9	8	10	5	11	220	8,092
Corwin	1	----	S. E.	-------	11 0	-------	12 4	-------	$3\frac{1}{2}$	------	3	------	32	------	6′ 9″	------	1	------		24	9	8	7	10	$58\frac{1}{2}$	1,755
Detroit	3	2	D. E.	S. E.	[5]18 $8\frac{1}{2}$ / [5]18 1	11 8 / 9 $0\frac{1}{2}$			$2\frac{1}{4}$	$2\frac{1}{4}$	14 / 58	4	44⅞	44⅞	$182\frac{9}{16}$ / 579	$75\frac{1}{4}$	[1]d4 / [5]d8	d4	2 / a2	$4\frac{3}{4}$ / 4	4 / a4	$10\frac{1}{2}$ / $10\frac{1}{2}$	7 / a7	$6\frac{1}{2}$ / $0\frac{1}{2}$	368	10,978
Dolphin	2	2	D. E.	S. E.	11 0	11 0	18 3	9 6	$2\frac{3}{4}$	$2\frac{3}{4}$	8	4	40	40	81	81	d8	d4	2 / a2	6 / 6	4 / a4	$8\frac{1}{2}$ / $8\frac{1}{2}$	6 / a6	$3\frac{3}{4}$ / $3\frac{3}{4}$	270	-------
Essex	4	----	S. E.	-------	9 0	-------	9 0	-------	$2\frac{1}{2}$	------	8	------	34	------	68	------	e4	------	1	$10\frac{3}{4}$	8	0	5	2	128.44	2,965.20
Hamilton	----	----	S. E.	-------	11 3	-------	14 1	-------	$3\frac{1}{2}$	------	3	------	2′ $10\frac{1}{2}$″	------	6′ 3″	------	f	------	2	0	7	$\frac{1}{2}$	7	9	54	1,904
Indiana	4	2	D. E.	S. E.	15 0	10 0	18 0	8 6	$2\frac{1}{2}$	$2\frac{1}{2}$	32	4	39	$36\frac{1}{16}$	69	70	e16	d4	m2	$6\frac{1}{8}$	m6	$5\frac{1}{2}$	m9	3	616	19,194.64
Iowa	3	2	D. E.	S. E.	16 9	16 9	21 0 / 19 0	9 $11\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	24	8	3′ $8\frac{7}{8}$″	3′ $8\frac{7}{8}$″	6′ 9″	6′ 9″	e	e	2	4	7	3	10	4	756	24,082
Lancaster	2	2	S. E. (Box.)	S. E.	11′ 3″ x 24′ 4″	6′6″x11′ (Oval.)	[5]11 3	9 7	3	3	14	2	36	48	84	72	d14	d2	m1 / a2	8 / 7	m3 / a5	0 / 1	m4 / a7	11 / $4\frac{1}{2}$	342	8,661
Machias	2	----	M. L.	-------	9 3	-------	18 6	-------	2	------	4	------	-------	------	81	------	e2	------	3	$3\frac{1}{2}$	8	1	5	1	120	4,590
Maine	8	----	S. E.	-------	14 8	-------	10 0	-------	$2\frac{1}{4}$	------	24	------	45	------	82	------	d24	------	2	$7\frac{5}{8}$	4	$3\frac{1}{2}$	9	$4\frac{1}{2}$	573.84	19,015.52
Marblehead	3	2	D. E.	S. E.	11 8	11 8	[5]18 $8\frac{1}{2}$ / [5]18 $1\frac{1}{2}$	9 $0\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	14 / 58	4	44⅞	44⅞	$192\frac{7}{8}$ / $5\,88\frac{5}{8}$	$84\frac{7}{8}$	[1]d4 / [5]d8	d4	2 / a2	$3\frac{3}{4}$ / $3\frac{3}{4}$	4 / a4	$9\frac{1}{2}$ / $9\frac{1}{2}$	7 / a7	0 / 0	414	11,057
Marietta	2	----	B. & W.	-------	9 6	-------	11 7	-------	4 / 2	------	2	------	8′ 0″	------	6′ $1\frac{1}{2}$″	------	-------	------	-------		-------		-------		98	3,620
Marion	8	----	S. E.	-------	9 0	-------	9 0	-------	$2\frac{3}{4}$	------	16	------	34	------	68	------	[7]e8	------	1	$10\frac{3}{4}$	8	0	5	1	256.88	6,587.2
Massachusetts	4	2	D. E.	S. E.	15 0	10 0	18 0	8 6	$2\frac{3}{4}$	$2\frac{1}{2}$	32	4	39	$36\frac{1}{16}$	69	70	e16	d4	m2	$6\frac{5}{8}$	m6	$5\frac{1}{2}$	m9	3	616	19,194.64
Miantonomoh	6	----	S. E.	-------	12 0	-------	10 $0\frac{3}{4}$	-------	3	------	18	------	36	------	84	------	d18	------	2	$3\frac{1}{4}$	3	$4\frac{1}{2}$	7	$4\frac{1}{2}$	378	8,800
Michigan	2	----	S. E.	-------	9 6	-------	15 $2\frac{3}{4}$	-------	4	------	4	------	42	------	78	------	e2	------	2	3	8	3	5	2	91	2,572
Minneapolis	8	2	D. E.	S. E.	[6]15 9 / [5]15 3	10 9	[6]20 0 / [5]18 0	8 6	$2\frac{1}{4}$	$2\frac{1}{2}$	[6]48 / 516	4	[6]$42\frac{7}{8}$ / $5\,41\frac{1}{16}$	$36\frac{1}{16}$	[6]84 / 578	70	[6]e24 / [5]e8	d4	[6]2 / a2	$2\frac{3}{8}$ / $0\frac{3}{4}$	[6]6 / a4	10 / 1	[6]9 / a5	$11\frac{1}{2}$ / 10	1,520	50,147
Mohican	8	----	S. E.	-------	9 0	-------	9 0	-------	$2\frac{3}{4}$	------	16	------	34	------	67	------	e8	------	2	$2\frac{3}{4}$	8	2	5	2	256	6,574.4
Monadnock	4	----	S. E.	-------	12 2	-------	10 1	-------	$2\frac{1}{4}$	------	8	------	$48\frac{3}{4}$	------	78	------	d8	------	2	$6\frac{1}{2}$	4	$11\frac{1}{2}$	7	4	200	6,241.76
Monocacy	2	2	S. E.	S. E.	-------	-------	-------	-------	-------	-------	14	2	-------	-------	-------	-------	-------	d2	-------		-------		-------		290.6	6,594
Monterey	2 / 4	----	S. E. / Ward.	-------	11 2 / 11 0	-------	10 7	-------	$2\frac{1}{4}$ / 1.9	------	4 / 4	------	$44\frac{13}{16}$ / 824	------	75⅛ / 122 / 363	------	-------	d4	2	$4\frac{1}{2}$	4	7	8	5	383.24	14,785.08
Montgomery	3	2	D. E.	S. E.	11 8	11 8	[5]18 $8\frac{1}{2}$ / [5]18 1	9 $0\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	14 / 58	4	44⅞	44⅞	$189\frac{1}{2}$ / 586	$82\frac{1}{4}$	[1]d4 / [5]d8	d4	2 / a2	$4\frac{3}{4}$ / 4	4 / a4	$10\frac{1}{2}$ / $10\frac{1}{2}$	7 / a7	$0\frac{1}{2}$ / $0\frac{1}{2}$	401	10,978
Nahant	2	----	Martin water tube.	-------	10 0	-------	12 6	-------	2	------	6	------	2′ 9″	------	6′ 10″	------	d	------		18	4	4	2	9	-------	-------
Newark	4	1	D. E.	S. E.	13 6	8 $10\frac{13}{32}$	19 $4\frac{7}{8}$	7 11	$2\frac{1}{2}$	3	24	2	$45\frac{27}{32}$	$35\frac{1}{8}$	72	46	g12	e1	4 / a1	6 / 10	4 / a7	4 / 6	7 / a5	$1\frac{1}{2}$ / 4	5,614	17,295.21
New Orleans	4	1	D. E.	Cyl. fire tube.	12 1	6 3	17 10	13 6	-------	-------	24	-------	3′ 0″	-------	6′ 8″	-------	f	-------	-------		-------		-------		480	-------
Newport	2	----	S. E.	-------	10 6	-------	10 6	-------	$2\frac{3}{4}$	------	4	------	3′ 3″	------	6′ 6″	------	d	------	2	$2\frac{1}{2}$	4	$6\frac{1}{2}$	6	$3\frac{1}{2}$	78	2,524
New York	6	2	D. E.	S. E.	15 9	10 0	18 0	8 6	$2\frac{1}{4}$	$2\frac{1}{2}$	48	4	$41\frac{15}{16}$	$36\frac{1}{16}$	76	70	e24	d4	2 / a2	$1\frac{5}{8}$ / $0\frac{3}{4}$	7 / a4	0 / 1	9 / a5	$5\frac{1}{2}$ / 10	1,052	32,958
Olympia	4	2	D. E.	S. E.	15 3	15 3	21 3	10 $11\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	32	8	$41\frac{15}{16}$	$41\frac{15}{16}$	76	76	e16	e4	2	6	6	7	9	5	824	28,298.84
Oregon	4	2	D. E.	S. E.	15 0	10 0	18 0	8 6	$2\frac{1}{4}$	$2\frac{1}{2}$	32	4	39	$36\frac{1}{16}$	69	70	e16	d4	m2	$6\frac{1}{8}$	m6	$5\frac{1}{2}$	m9	3	616	19,194.64
Petrel	2	----	G. B.	-------	8′ 8″ x 8′ 1″	-------	18 0	-------	$9\,2\frac{3}{4}$ / $10\,3$	------	4	------	$43\frac{1}{8}$	------	84	------	e2	------	3	0	7	8	3	$9\frac{1}{8}$	93	2,796
Philadelphia	4	1	D. E.	S. E.	14 0	8 6	20 0	8 3	$2\frac{1}{4}$	3	32	2	39	$35\frac{1}{8}$	72	46	g16	e1	m4	6	m3	6	m9	3	645.4	20,988.79
Porter	3	----	Herreshoff.	-------	10 9	-------	10 0	-------	$1\frac{1}{8}$	------	3	------	6′ 7″	------	8′ 0″	------	-------	------	-------		-------		-------		156	8,010
Puritan	8	----	S. E.	-------	13 0	-------	10 0	-------	3	------	24	------	3′ 4″	------	7′ 0″	------	d	------	2	2	3	8	8	2	560	12,707
Raleigh	4	2	D. E.	S. E.	[5]14 4 / [5]13 4	11 6	20 $3\frac{1}{2}$	9 $10\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	12	4	$5\,46\frac{13}{16}$ / $5\,42\frac{7}{8}$	$44\frac{13}{16}$	76	76	d12	d4	[5]2 / [5]2 / a2	$5\frac{1}{2}$ / $5\frac{1}{2}$ / 0	[5]4 / [5]3 / a4	6 / $10\frac{7}{8}$ / 9	[5]7 / [5]6 / a6	$4\frac{1}{2}$ / $8\frac{1}{2}$ / $7\frac{1}{2}$	617	20,179
San Francisco	4	----	D. E.	-------	14 8	-------	19 2	-------	$2\frac{1}{4}$	------	24	------	45	------	79	------	d24	------	2	$5\frac{1}{4}$	4	$2\frac{1}{2}$	9	4	553	19,657.56
Solace	3	No data available.																								
Terror	6	----	S. E.	-------	12 0	-------	10 $0\frac{3}{4}$	-------	3	------	18	------	36	------	84	------	d18	------	2	$3\frac{1}{4}$	3	$4\frac{1}{2}$	7	$4\frac{1}{2}$	378	8,800
Texas	4	----	D. E.	-------	14 0	-------	18 0	-------	$2\frac{1}{2}$	------	24	------	42	------	78	------	d24	------	1	8	4	2	8	6	531.6	16,912.4
Vesuvius	4	----	G. B.	-------	9 0	-------	19 $11\frac{3}{4}$	-------	2	------	12	------	37	------	69	------	f4	------	4	6	8	0	5	3	195	8,981.3
Wheeling	2	----	S. E.	-------	10 6	-------	10 6	-------	$2\frac{3}{4}$	------	4	------	3′ $3\frac{1}{2}$″	------	5′ 0″	------	d	------	2	2	4	5	6	3	60	2,508.46
Wilmington	6	----	S. E.	-------	7 11	-------	10 $4\frac{1}{8}$	-------	$2\frac{1}{4}$	------	6	------	3′ $8\frac{13}{16}$″	------	6′ 0″	------	-------	------	1	11	7	1	5	2	126	4,800
Yankee	3	1	D. E.	S. E.	-------	-------	-------	-------	-------	-------	18	2	-------	-------	-------	-------	-------	-------	-------		-------		-------		-------	-------
Yorktown	4	----	G. B.	-------	9 9	-------	17 9	-------	$2\frac{1}{4}$	------	12	------	40	------	69	------	f4	------	3	9	8	10	5	11	220	8,092

[1] One. [2] Four. [3] Three. [4] Externally fired. [5] Two. [6] Six. [7] Diaphram plate. [8] Height. [9] Stay. [10] Ordinary. [11] Vertical fire tube. [12] Internal. [13] Diameter. [14] Height of furnace, 22″.

SHIPS' TESTS.

ALPHABETICALLY ARRANGED.

S. Doc. 313, 59-1——2

ABECARN.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
San Francisco	*Tons.* 627	Smyrna	Oliver & Co	$4.08	Fair proportion of lumps.	Taken from steamer.	Under	10 hours	Clean	Assisted draft.	Good	*Sq. ft.* 276.5	*Knots.* 9.8	948	70	3,220

ACME.

Porter		Port Liberty, N.Y. Harbor.	G. S. K., New York.	2.00	Good	4 days	Not	2 hours	Excellent.	Easy forced draft.	Fair	52	17.5	No indicators.	No data.	2,200

ALBION CARDIFF.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.
1.62	1.17	14.91	69.92	12.38	0.077	0.463

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Adams	*Tons.* 150	San Francisco		$7.14		30 days	Not		Good			*Sq. ft.* 64.2	*Knots.* 7.98			
Adams		do	Oregon Imp. Co.	7.95	Large proportion of lump; free from slack, etc.	3 months	do	5 hours, 11 minutes.	do	Natural	Fair	64.2	6.6	362.39		930
Adams		San Diego, Cal.	Spreckles Bros. Com'l Co.	10.00	Fair	3 days	do	4 hours	do	do	do	64.2	5.1	216.1		735
Alert	190	Acapulco, Mex.	Fernandez & Co.	18.00	About 70 per cent slack.	1 month	Under	47 hours, 40 minutes.	Fair	do	do	126	7.97	320	None in use.	1,260
Alert		do	do	18.00	do	2 months	do	30 hours	Fairly clean.	do	Good	126	7.28	450	do	1,350
Alert		San Francisco	John L. Howard.	7.14	30 per cent lump.	From arriving vessel.	do	14 hours	Fair	do	do	63	5.5214	255.76	do	800
Alert		San Diego, Cal.	Spreckles Bros.	10.00	About 50 per cent lump.	4 months	Not	50 hours	do	do	do	110	6.62	371	do	1,150
Alert		Mare Island	G. S. K	7.95	About 60 per cent lump.	1 week	do	21 hours	Good	do	do	126	9.6	404	do	1,260
Alert		San Diego, Cal.	Spreckles Bros.	10.25	do	3 months	do	50 hours, 20 minutes.	do	do	do	126	10.54	420	do	1,330
Alert		Acapulco, Mex.	Fernandez & Co.	18.00	70 per cent lump.	4 months	Under	15 hours	do	do	do	126	10.15	490	do	1,470
Baltimore	1,143	Mare Island	G. S. K	7.95	Run of the mine.	Just ar'v'd	In a ship.	7 days, 22 hours.	Clean at beginning.	2 hours forced, 3½ hours natural, rest of time assisted.	Poor 3½ days.	492	10.7	1,727.5	120	5,299.7
Bancroft	203	Genoa, Italy	G. B. Penna & Co.	5.62	Good, clean, large proportion of lump.	2 weeks	Not	89.4 hours	Good	Natural	Good	87.75	9.34	300	35	938

ABECARN.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
6.71	60	*Lbs.* 3.15	16	Easily dissipated	Large in size and quantity.	Yes	No	Not swept	No	No	103 days	Fairly clean		

ACME.

17.5			2.7	Heavy smoke	Not large	No	No	Water-tube boilers	Yes	No	16 days	Poor	None	

ALBION CARDIFF.

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
Oregon Imp. Co	*Hrs.* $13\frac{55}{60}$	*Lbs.* 28,562.36	*Lbs.* 3,150	*Lbs.* 10	*Lbs.* 9.07	*Lbs.* 10.69	*Per cent.* 10	*Lbs.* 42.14	° 63		Oct. 22, '97		The refuse resulted almost wholly from hauling the fire, together with a small quantity of soot.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
21.8		*Lbs.* 2.71	About 20.	Small amount; dark brown.				Not necessary during trial run.			29 days	Clean		
15.8	44.4	2.56	12.15	Light brown	None formed	No	No	Not swept		No	222 days	Foul	Nil	
15.5	38	3.4	6.8	Light brown, easily dissipated.	Small in size and quantity.	No	No	do		No	277 days	do	do	
14.17	55.87	3.94	15	Grayish black, easily dissipated.	Small	No	No	2-day intervals	No trial.	No	166 days	do	None	
12.08	59.25	3	12	do	do	No	No	48-hour intervals	do	No	216 days	Very foul	Minus 1	
15.46	46.73	3.12	14	Light gray	do	No	No	4 days	Not tried.	No	3½ months	Somewhat foul.	None	
12.89	54.48	3.10	11	Grayish black, easily dissipated.	do	No	No	48-hour intervals	No trial.	No	232 days	Foul	1 knot retarded.	
17.06	65.60	3.12	11	do	do	No	No	72-hour intervals	do	No	22 days	Clean	None	
17.75	65.40	3.15	13	do	Large	Yes	No	do	do	No	28 days	do	1 knot per hour.	
15.46	66.05		10	do	Not large	No	No	60-hour intervals	Not tried.	No	45 days	do	None	
4.356	63.27	2.87	13.5	Light gray	do	No	No	Every other day	Yes	No	1 month	do		
22	141.07	2.77	13	Thin, easily dissipated.	do	No	No	Daily	Not tried.	No	2½ months	Fair	Nil.	

ALBION CARDIFF—CONTINUED.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—CONTINUED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Bennington	403	San Francisco	J. L. Howard, contractor.	No invoice received.	Moderately lumpy.	Unknown	Under	6 days, 8 hours, 44 minutes.	Clean	Natural	Fair	165	10.88	726.32	38.9	2,037
Concord	401	do	Jno. L. Howard	$8.65	Good, clean coal.	40 days	Not	6 hours	do	do	do	155	11.55	800.1	40	2,360
Concord		Mare Island	G. S. K.	7.95	Small per ct. of lump.	Unknown	Not known.	10 hours	do	do	Good	110	8.7	450	40	1,600
Corwin		Navy Y'd, Mare Island.	do	7.95	Principally slack.	Rec'd from schooner brought alongside.		55.24 hours	Good	do	do	63.3	9	206.95	1.5	730
Detroit	340	Funchal, Madeira.	Blandy Bros. & Co.	4.62	Large per cent lump.	Unknown	Under	73 hours	Clean	do	do	265.5	11.4	1,533.7	30	4,234
Marietta	236	Mare Island	John Howard, San Francisco, Cal.	7.95	Large per cent slack.	do	From open lighter.	48 hours	Good	do	do	94	10.2	S. 306.47 P. 307.42 = 613.89	18	1,418.5
Marietta		Navy Y'd, Mare Island.	J. L. Howard, San Francisco, Cal.	7.95	Good	do	do	47.97 hours	do	do	do	94	10.58	531.5	18	1,240
Marietta		do	do	7.95	do	do	do	63.75 hours	do	do	do	94	9.56	355.2	16	961
Marietta		do	do	7.95	do	do	do	47.63 hours	do	do	do	47	9.53	343	17	842
Marietta		do	do	7.95	do	do	do	35.55 hours	do	do	do	47	8.57	257	17	596
Marietta		Callao, Peru	W. R. Grace & Co.	15.00 Am. gold.	Fair	do	Not known.	95.57 hours	do	do	do	94	10.29	S. 359.55 P. 363.45 = 723	17	1,709.7
Marion	129	At Payta, from Callao, Peru.	do	19.00	Fair amount of lumps.	No information.	No information.	15 hours	Clean	do	Fair to good.	128	6.58	428		1,433
Marion		Callao, Peru	do	13.38	Two-thirds lump, clean.	No data	No data.	19.75 hours	Good	do	Good	128	7.16	478		1,313
Marion		do	do	12.16	Fair amount of lumps.	do	do	27 hours	do	do	do	128	7.2	511		1,500
Mohican	150	San Francisco and Mare Island.	J. Howard	7.90	Fairly lumpy, few or no impurities.			8 hours	Dirty and full of scale.	do	Poor	224	10.2	644	3	2,325
Mohican		Mare Island	G. S. K., Mare Island.	7.95	Fairly lumpy, and some slack.			3 hours	Interior of boilers clean, tubes dirty.	do	Fair	160	9.46	556.6	3	1,500
Monadnock	250	Navy Yard, Mare Island.	Oregon Imp. Co., contractors, G. S. K.	7.24	Fair	Just discharged.	From vessel.	2 hours	Good	do	Good	200	8.75			2,250
Monadnock		San Francisco	Oregon Imp. Co., contractors, G. S. K., Mare Island.	7.21	Very dusty, few lumps.	Taken from vessel discharging.	Under	6 hours	do	do	do	200	10.1			3,500
Monadnock		Mare Island Navy Yard.	Oregon Imp. Co.	7.95	About equal proportion of lump and slack.	Unknown	do	243 hours	Clean	All natural draft except 5 hours' forced draft.	Fair	200	8.81	778.58	80	2,725
Monterey	236	Sausalito, Cal.	do	7.14	Good	5 months ‡	do	9 hours	Good	Assisted $\frac{1}{8}$"	Good	238	9.8	1,220	90	3,726

‡ The coal was taken directly from the vessel in which it was shipped; in vessel 5 months, including passage.

ALBION CARDIFF—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
12	92.7	*Lbs.* 2.66	9.5	Light brown, easily dissipated.	Not large	No	No	Every two days	Yes	No	10 days	Clean	Inappreciable.	This coal burns freely with a good draft; adheres together on firing; very little smoke' light and soon dissipated. A very small amount of clinker forms, but does not adhere to the bars and is easily removed.
11	95.5	2.81	7.7	Easily dissipated	Medium	No	No	Not necessary	Probably wasteful.	No	3½ months	Fairly clean	None, sea smooth.	The coal was good and burned freely to a white ash with but little clinker. There seemed to be no impurities whatever, and there was no difficulty in keeping a steady pressure of steam.
13.18	76	3.26	6	Small in amount, easily dissipated.	Not large	No	No	Once in 48 hours	Yes	No	Less than a month.	Clean	Decreased ½ knot.	(*)
28	190,110	3.3	9	Light, easily dissipated.	Small, easily removed.	No	No	Have not swept them.	No	No	4 months	Good	1½ knots acceleration.	The coal was principally slack, and under forced draft would have been forced up the chimney.
6.02	107	2.47	8	Gray	Not large	No	No	Once in 60 hours	Yes	No	7 months, 3 days.	Foul		
16.1	S. 188 P. 188.1	2.2	13.2	Dark in color	Small in size, but cling to grate; percentage rather large.	Moderate.	No	Every 24 hours with steam, every 4 hours with air.	Not tried, probably fairly well suited.	No	2 months	Clean	Reduced about ½ to 1 knot by head wind and sea.	
19	181.1	2.26	11.7	do	Small in size, moderate in quantity.	No	No	Once every 4 hours with compressed air, once in 24 hours with steam.	Not tried, probably suitable.	No	About 5 months.	Probably good.	0 to ½ knot increase.	These four trials were made, the first and second with two boilers and the third and fourth with one boiler, at different speeds, and form part of one continuous run from San Francisco, Cal., to Acapulco, Mexico, with the same coal and under favorable circumstances.
22	160.5	2.59	11.7	do	do	No	No	do	do	No	do	do	do	
25	160	2.34	11.7	do	do	No	No	do	do	No	do	do	do	
32	140.3	2.18	11.7	do	do	No	No	do	do	No	do	do	do	
13.5	S. 188.51 P. 188.51 188.51	2.31	10.8	do	Moderate	No	No	Every 4 hours with air, every 12 hrs. with steam.	do	No	About 8 months.	Partly foul, barnacles and slime.	Reduced ¼ to ½ knot.	Ship steaming into moderate sea on long swell during trial.
11	41.7	3.34	10.5	Gray and easily dissipated.	Large	Considerable.	No	Once a day	Yes	No	10 months	Foul	None	
12.05	43.4	2.74	9	Light smoke only when firing.	Considerable clinker and clung to bars.	(†)	No	Once in about 48 hours.	Yes	No	12½ months	Clean	do	
10.75	44.8	2.93	10	Light only when firing, easily dissipated.	do	(†)	No	do	Yes	No	14 months	do	do	
9.7	49	3.6	8	Easily dissipated	Neither large in size or quantity.	No	No	Very rarely	Yes	No			do	
14	46.5	2.75	14	do	do	No	No	do	Yes	No			do	
8.7	S. 86.7 P. 88.7		16.66	do	Not large	No	No	Once in 12 hours	Yes	No	½ month	Clean		
6.46	105.9		16.4	do	do	No	No	do	Yes	No	2 months	do		
7.46	92.4	3.18	5.8	Light	Large and very thin.	No	No	Every 16 hours	Yes	No	2 weeks	do	None	This report covers a run from San Francisco, Cal., to Honolulu, H. I.
5.87	98	2.84	8	Light-brown	Not large	No	No	Each watch	Yes	No	3 months	Fair	do	

* This coal burned excellently. It is probable that with strong forced draft there would be heavy losses due to the escape unburned of the fine dust of which the main body of this coal is composed. There would be no undue heating of the uptakes and smoke pipe. The firing was done with regularity, and the required pressure of steam was easily maintained.

† Difficult to remove clinkers from bars.

ALBION CARDIFF—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Oregon	*Tons.* 1,594	Acapulco, Mex.	Alcorta & Co.	$18.00	Good	Unknown	Under	48 hours	Good	Natural	Poor to fair.	*Sq. ft.* 552	*Knots.* 9.1	2,153	175	6,691
Oregon		San Francisco	Oregon Imp. Co.	7.24	do	No appreciable time.	do	63 hours	do	do	Good	552	11.8	4,684	175	10,195
Oregon		do	do	7.14	do	do	do	168 hours	do	do	Fair	552	9.91	2,664	175	6,391
Oregon		do	do	Contract price; invoice not received.	Fair	About 3 months.	Not	15 days	do	do	Good to poor.	414	10.9	2,100.9	140	5,492
Petrel	200	Sausalito, Cal., in lighters from San Francisco.	do	7.25	65 per cent lump.	Taken direct from vessel in which it was imported from Cardiff, Wales.		87 hours	Clean	do	Good	97.2	10.36	381.42	10	1,188
Petrel		Sausalito, Cal.	do	7.14	Fair percentage lump, little impurities.	From hold of vessel in which it was imported.		8½ days	Good	do	Fair	93.2	9.6	354 68	8	1,110
Philadelphia	1,085	San Francisco	G. S. K., Navy Yard, Mare Island.	7.14	Lumps	Not long	Ship's hold.	365.84 hours	do	Both	Good	312	11.27	1,456	30	3,740

ARGYLE.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
1.400	2.930	10.678	80.493	4.078	0.421		Trace.
0.697	0.803	15.277	78.193	4.756	0.274		
0.901		17.00			0.399	0.410	

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Dolphin	*Tons.* 273	Washington, D. C.	G. S. K.	$2.34	50 per cent slack.	Brought from the mines in cars; time unknown.	Not	12 hours	Clean	Natural	Good	*Sq. ft.* 222	*Knots.* 13.25	1,060	30	2,892

AUSTRALIAN.

Alert	190	Acapulco, Mex.	P. M. S. S. Co.	20.05	90 per cent lump.	Unknown	Not	120½ hours	Fair	Natural	Fair	110	6.09	295	None in use.	1,286

BEYNON'S NEWPORT ABERCARSE.

Raleigh	460	Bizerta, Tunis	The Corporation Trading Co., Ltd.	4.46	30 per cent lump; clean coal.	About two months.	No; but white-wash'd outside	6 hours	Not very clean.	Natural	Fair	380	8.1	966	60	4,715

ALBION CARDIFF—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
3.05	73.5	2.8	8.5	Moderately dense, dark, easily dissipated.	Large	Yes	No	12 hours	Yes	No	9 months	Moderately foul.	None	
2.6	94.9	2.09	5.8	Not dense, dark brown, easily dissipated.	Not large	No	No	Once in 12 hours	Yes	No	11 months	do	do	
3:47	78.4	2.25	7.1	do	do	No	No	do	Yes	No	10 months	do	do	
4.24	75	2.4	10.8	do	do	No	No	Once in 24 hours	Yes	No	6 weeks	Clean	Nil	Coal of a remarkably good quality.
20.09	99.74	3.04	9.44	Moderately dense	Large in area and thin.	No	No	Once in 4 days	Yes	No	60 days	do	1 knot	
19.13	93.5	3.31	8.97	Dark, but easily dissipated.	Thin, but large in area.	No	No	Twice in 8 days	Yes	No	About 3 weeks.	do	Wind light, no effect.	
7.13	65.92	2.52	8	Light	Small	No	None	Once in 4 days	Yes	No	15 days	Fair	Not known	

ARGYLE.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	*Degrees*				
Allegheny Coal Co., 813 11th street, Washington, D. C.	12	36,791	5,400	11.25	6.81	8.03	12.7	42.75	62.16		May 24,'97		This coal is good for blacksmithing purposes.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
10.26	60.3	2.65	5	Dense	Not large	No	No	About every 3 days	Yes	No	11 months	Fair	None	This coal burned freely and gave no trouble in firing.

AUSTRALIAN.

10.61	51.68	4.36	14	Dark, dense, not easily dissipated.	None	No	Yes	8-hour intervals	Not tried.	Yes	142 days	Very foul	None	

BEYNON'S NEWPORT ABERCARSE.

3.84	60.8	4.6	Est. 11.	Not dark, and easily dissipated.	Not large	No	No	Not on run	Not tried.	No	About 6 months.	Foul		This coal was one of the cleanest and best which we have tried upon the station.

BLACK DIAMOND.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.572	2.138	30.409	63.036	3.618	0.227	----------	----------
0.984	----------	22.59	----------	----------	0.230	0.400	----------

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Amphitrite	250	Port Royal, S. C	G. R. Walker, agent.	$3.45	Mostly lump.	Just received.	Not	78.7 hours	Clean	Natural	Good	252	7.72	737	30	4,534
Maine	896	do	Charleston & Western Carolina Railway Co.	3.25	About 50 per cent lump.	Direct from mines.	do	3½ days	Clean and good.	do	do	430.38	11.8	2,678	400	7,500
Newark	809	do	R. R. Co. at Port Royal, S. C.	3.75	About 20 to 25 per cent lump.	No data	No data	10 hours	Not very clean.	do	Fair	270	9.8	914.6	100	3,100

CAHABA.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
1.030	3.130	24.940	67.430	3.268	0.192	----------	0.018
1.320	1.900	25.705	64.329	6.695	0.051	----------	0.003

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Texas	8 0	Galveston, Tex.	Fowler & McVitie, Galveston Coal Contractor.	$6.50	----------	No data	No data	24 hours	Good	----------	----------	531.6	10.1	----------	----------	----------

CAMBRIAN NAVIGATION.

Minneapolis	1,891	Genoa, Italy	Dufont & Bruzzo	$4.14	Good	6 days	Under	72 hours	Clean	Natural	Good	560.1	10.4	1,420	60	4,989

BLACK DIAMOND.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
4.03	48.7	5.91	8	Dense, dark-gray color, not easily dissipated.	Not large	No	Large quantity.	Once in 16 hours		No	3 months	Fairly clean		
3.54	83.57	2.3	8.5	Very dense, dark, not easily dissipated.	do	No	No	Not swept	Not well suited	No	6 months	Fair	None	This coal is very free burning, and gives off much flame. Even with natural draft more than 25 pounds per square foot of grate per hour was burned for a short time, when not on an allowance. With forced draft undue heating of smoke pipes, etc., would be expected.
7.01	60	3.0554	7.61	Dark and not very readily dissipated.	do	No	Not very.	Once in 48 hours	(*)	No	2 months	Fairly clean	do	The manner in which this coal burns and its general efficiency are very satisfactory.

*Not enough steaming data to judge, but probably is.

CAHABA.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
3.53		3.86	9	Dense				On arrival in port			2 months, 24 days.	Good		

CAMBRIAN NAVIGATION.

4.66	60.9	3.37	9	Light gray, easily dissipated.	Not large	No	No	Each 48 hours	I believe so.	No	Not 2 weeks	Clean	Trifling	

CARDIFF.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Boston	495	Nagasaki, Japan.	M. Gerisburg & Co.	$11.58	About 30 per cent lump.	1 week	Under	30 hours	Fair	Natural	Fair	286.50	10.73	939.2	90	4,113.3
Boston	------	Kobe, Japan	Geo. J. Perry & Co.	11.94	About 25 per cent lump.	Direct from steamer.	do	58 hours	do	do	do	286.50	9.06	749.62	90	4,040.8
Boston	------	Chemulpo, Korea.	M. Gerisburg & Co.	13.54	About 30 per cent lump.	About 6 months.	do	48 hours	do	do	Good	286.5	10.25	1,145.83	120	3,708.01
Boston	------	Nagasaki, Japan.	do	11.45	About 40 per cent lump.	About 5 months.	do	54 hours, 35 minutes.	do	do	do	286.5	10.44	1,149.60	120	3,954.5
Miantonomoh	260	Key West, Fla.	English steamer "Restormel."	3.87	Appeared to be weathered.	Not known.	From hold of vessel.	10 days, while on blockade.	Fair, tubes scaled.	do	Fair	From 246. to 266.5.	No record; on blockade.	No record; on blockade.	No record.	1,600
Monocacy	229	Shanghai, China	L. Chenler & Co.	9.55	Fair	do	Under	10 days, anchoring nights.	Clean	do	do	19 feet in each furnace.	Steaming up Yangtse	600	No auxiliaries.	2,398
Monocacy	------	do	do	9.06	do	do	do	do	do	do	do	do	do	600	do	2,398
Monocacy	------	do	do	11.08	do	3 weeks	do	6 days, anchoring nights.	Good	do	do	266	do	689	None	3,360
Monocacy	------	do	do	10.25	do	do	do	do	do	do	do	266	do	689	do	3,360
Terror	250	St. Thomas, D. W. I.	Paymaster	12.25	Good proportion of lump.	Unknown	Not	16 hours	do	do	do	315	7.3	------	------	3,217

CLEARFIELD.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.831	1.019	17.969	70.036	8.729	1.416	0.481	0.005

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alliance	159	Navy Y'd, New York.	*Clearfield Coal Co.	$2.00	Slack	Direct from mines.	Direct from mines.	12 hours	Good	Natural	Good	96.3	4.4	102.1	None	1,000
Amphitrite	250	Tompkinsville	*G. S. K., Navy Yard, New York.	2.00	65 per cent slack.	Unknown	Not	28 hours	Clean	do	Fair	378	8.7	658.2	35	3,316
Iowa	1,795	League Island, Pa.	G. S. K	1.63	Fair per cent lump.	Direct from mines.	do	24 hours	Good and clean.	do	Good	467	10.8	2,660.09	177	8,614

*From Empire Big Vein Mine.

CARDIFF.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
5.58	47.4	3.99	6.037	Easily dissipated	Not large	No	No	Every 60 hours	Yes	No	62 days	Slightly foul		
5.02	44.0	4.81	11.82	do	Small in size, large quantities.	Yes	No	Every 48 hours	No	No	76 days	do		
6.18	48.09	2.93	14.45	do	Not large	No	No	do	Yes	No	230 days	Foul	None	
6.514	47.8	3.19	9.993	do	do	No	No	Every 60 hours	Yes	No	6 days	Clean	do	
(*)	Variable			Dark, not easily dissipated.	Large	No	No	Every 3 days	Can not say.	No	21 months	Not clean		
Steaming against current.	14.2	3.9	24	Easily dissipated	Not large	No	No	Once in 24 hours	Yes	No	4 months, 3 days.	Clean		
do	14.2	3.9	24	do	do	No	No	do	Yes	No	5 months, 18 days.	do		
do	17	4.8	23	do	do	No	No	do	Yes	No	6 months	Fair		
do	17	4.8	23	do	do	No	No	do	Yes	No	6 months, 11 days.	do		
4.4	51.8		13.7	Dark	do	No	No	Once in 48 hours	Yes	No	201 days	Foul		

*Ship lying-to a large portion of the time, and speed variable.

CLEARFIELD.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°			*Per cent.*	
D. Duncan & Son	24.66	77,874	11,400	12.165	6.831	7.454	16.03			Lead fused	Aug. 9, '93	5	Burned freely. Moderately long yellow flame. Cakes and breaks into small pieces. Clinkers large. Dark-gray ash and lead-colored smoke. Soot black and in large grains, evidently large per cent of carbon. Lumps contained traces of iron pyrites and earthy matter.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
9.85	33.3	9.8	10	Dense, dark	Considerable and small.	Yes	Yes	Every 12 hours	Not determined.	No	4 days	Good	Little or none.	
5.38	52.6	4.88	8.5	Dark, easily dissipated.	Large	No	No	Once in 24 hours	No data.	No	5 months	Fairly foul		
2.87	67.2	3	Not hoisted out regularly.	Dark brown, easily dissipated.	Not excessive	No	No	Not during trial	No trial.	No	About 130 days.	Slightly foul	No effect	Steaming in squadron.

CLEARFIELD—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Iowa	1,795	Navy Y'd, New York.	*Morrisdale Coal Co., Mine No. 3.	$1.90	Fair per cent lump.	Fresh from mine.		24 hours	Good and clean.	Natural	Good	472.5	8.3	2,210.9	160	570.6
Maine	896	do	*Clearfield Coal Co.	2.00	About 30 per cent lump.	Not known	Not	20 hours	Clean	do	do	287	per log, 9.7	1,517	300	4,332
Massachusetts	1,597	do	*D. Duncan & Sons.	2.00	Little lump; dull.			29 hours	do	do	Fair	552	10.68	2,833.5	75	8,804.17
Massachusetts		Tompkinsville, N. Y.	*Clearfield Bit. Coal Corporation.	1.90	Slack and impure, large per cent.			15 hours	do	do	Fair and good.	414	9.84	1,662.2	60	6,133.33
Massachusetts		do	do	2.00	Little lump			26 hours	do	do	Fair	552	11.27	2,738	75	7,173.65
New Orleans	800	Navy Y'd, New York.		1.901	Fair, very little lump.	Rec'd from cars.	No	21 hours	Good	do	Good	480	13.2	1,491	135	4,507
Newport	238	New York	*Morrisdale Coal Co.	1.90	Large proportion of slack. No impurities observed.	24 hours	Under	36 hours, 8 minutes.	Excellent	do	do	78	10.27	267.51	7.49	1,154
New York	1,290	Tompkinsville, N. Y.	Clearfield Coal Co.	2.00	Small per cent of slack and impurities.	Direct from mines.	No	16 hours	Good	do	do	658.48	11.1	2,493	30	7,695
Solace	800	Navy Y'd, New York.	*G. S. K	Unknown.	About 50 per cent in lumps. No impurities.	Not known	From lighters.	93 hours	do	do	do	360	12.7	2,670	175	5,642
Texas	850	do	do	2.00	Ordinary, small lump.	No data	No data.	12 hours	Fair	do	Fair	531.6	9.3	1,494.23	33	7,705
Yankee	1,000	Tompkinsville, N. Y.	Clearfield Coal Co.	No invoice.	Poor, fine, a good deal of slack.	Not known	Not known.†	4 hours	Good	do	Good	450	13.4	Est. 3,300; no indicator.	275	6,720

*From Empire Big Vein Mine. † Received from partially discharged lighter.

COALBROOKE VALE.

San Francisco	627	Lisbon, Portugal.	Abecassir Bros.	22 shillings.	40 per cent lump.		From ship.	10 hours	Clean	Forced	Fair	553	12.9	Est. 2,366	75	8,311.7

COMOX.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.745	1.605	22.717	58.400	15.867	0.666	0.830	0.021

CLEARFIELD—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hours.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
2.96	58.9	2.4	-------	Dark brown, dense	Not excessive----	No --	No --	Not during trial---	No trial.	Heats smoke pipes.	7 months and 10 days.	Not clean----	Little or none.	
5.01	68	2.38	9	Not dense, dark, easily dissipated.	Moderate size and quantity.	No --	No --	Not swept -------	Yes--	No --	1 month---	Clean -------	None------	Making 68 revolutions with the expectation of giving 9.5 knots.
2.72	S. 115970 Ave. 90; P. 155769 Ave. 89.88	3.03	11	Dark, dense -----	Medium-------	No --	Considerable.	-------	------	No --	16 days----	----do -------	----------	A heavy dull-appearing coal, but fair steaming. This coal is very dirty, with a large percentage of waste.
3.54	S. 76.23 P. 76.24	2.86	13.42	Dark----------	Large, considerable.	Rather.	--do --	24 to 36 hours------	------	No --	2 months and 8 days.	----do -------	----------	
3.48	S. 86.94 P. 86.96	2.12	18.90	----do ----------	Large----------	Yes--	Yes--	----do ----------	------	No --	2 months and 19 days.	----do -------	----------	
6.59	94.17	2.77	15	Dark, easily dissipated.	Not large-------	No --	No --	Not necessary on the run.	Not tried.	No --	Not known	Clean; bottom sheathed.	Nil -------	Four boilers in use; three would have furnished the power.
19.9	99.8	4.2	13.4	Dark----------	----do ----------	No --	No --	Swept once during trial, reported on.	Yes--	No --	5 weeks ---	Clean -------	Speed increased 1.75 knots.	Coal is lusterless in appearance and contains much slack; coheres in coking, forms considerable ash, little clinker, and no glassy slag.
3.23	S. 69686 P. 69646	3.4	12.7	Dark, and easily dissipated.	Medium-------	No --	No --	Every 3 days------	Yes--	No --	About 9 months.	Foul -------	----------	
5.1	70.2	2.3	15	Easily dissipated-	Not large-------	No --	No --	At end of run------	Yes--	No --	4 months--	Fair--------	None------	
2.7	51,538	5.1	6	Very dark------	Rather large-----	Yes--	No --	On arrival port ----	Not tried.	No --	7½ months-	Foul -------	Variable --	Poor in quality, dirty, large percentage of ashes, does not supply steam sufficiently.
4.5	63.3	1.82	Est. 15. No means of weighing.	Easily dissipated-	Large----------	Yes--	Yes--	Every 24 hours ----	No --	Yes--	8 months--	----do -------	Favorable to draft, no sails, smooth sea.	

COALBROOKE VALE.

3.5	98	3.4	15	Dark----------	Large; considerable.	Yes--	Yes--	24 hours----------	No --	No --	6 months--	Moderately foul.	Nothing---	

COMOX.

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND, CAL.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
R. Dunsmuir, Sons & Co., 340 Stewart st., San Francisco, Cal.	12.5	26,526.7	3,450	12.77	7.689	9.027	14.7	42	67.7	Tin and lead melted; zinc did not.	Aug. 27, '97	----------	

COMOX—CONTINUED.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alert	190	Direct from mines.	Union Colliery Co.	$3.50	90 per cent lump.	Freshly mined.	Direct from mines	14 hours	Good; clean.	Natural	Good	126	10.136	505	None in use.	1,520
Alert		do	do	3.50	80 per cent lump.	do	Freshly mined.	16 hours	Fair	do	do	90	8.146	305	do	1,162
Concord	382	Port Angeles, Wash.	E. E. Caine	5.25	Fair amount of lump; no impurities.	Not known	Not known.	4 hours	Clean	do	Fair	165	Not taken.	900.5	43	2,871
Concord		Sitka, Alaska	Pacific Coast S. S. Co.	9.17	Fair average	do	Not	6 hours	do	do	Good	165	do	864.3	40	2,700
Concord		Comox, B. C	Union Coal Co.	3.50	Fair average; no impurities.	From mine	From mine.	12 hours	do	do	do	165	11	1,009	40	2,430
Marietta	236	Sitka, Alaska	Gov't coal pile	Not known.	Fair	Not known	Not	51.58 hours	Good	do	do	94	By patent log, 11.13	611.17	20	1,872
Mohican	150	Mare Island	G. S. K., Mare Island.	7.00	Large lumps and dirty.			8 hours	Clean inside, tubes dirty.	do	Fair	160	9.31	546.6	3	1,800
Mohican		Honolulu, H. I.	U. S. consul general.	11.90	Clean, fairly lumpy.		Under	do	Fair	do	do	4 boilers 128	7.2	444	3	1,440
Monterey	230	Port Angeles, Wash.	E. E. Caine & Co., Seattle.	5.50	Good	Fresh from mine.	Not	48 hours	Good	Assisted by blowers for short intervals.	Good	360	9.24	1,395	90	4,676
Monterey		Navy Y'd, Mare Island.	Navy Yard	7.00	do	Taken from collier.	Under	44 hours	Fair	Natural	do	292	8.16	697	90	2,568
Oregon	1,594	Port Angeles, Wash.	E. E. Caine & Co., Seattle.	5.25	do	Not known	Not known.	58 hours	Good	do	do	414	11.53	2,495	150	6,438
Oregon		Puget Sound Naval Sta.	do	5.50	Fair	Fresh from mine.	Fresh from mine.	64 hours	do	do	Fair	414	11.9	2,285.3	140	6,836
Philadelphia	1,020	Port Angeles, Wash.	Dunsmuir & Co	5.25	Lump	Not known	Not	64.82 hours	do	Both	Good	312	11.29	1,367	30	4,470

COMOX—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effec of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
14.94	65.63	3.01	12	Dark gray; not easily dissipated.	Medium	No	No	Intervals of 72 hours	Yes	No	65 days	Fairly clean	None	(*)
15.70	52.60	3.80	12	do	do	No	No	do	Yes	No	83 days	do	do	Convoying another vessel. Running at varying speeds. This coal has proved satisfactory in the "Alert's" boilers.
	102	3.04	6.1	Dark	do	No	No	About every 3 days	No	No	4 months	do	do	These data were secured while making the inside passage to Sitka, Alaska. The speed of the vessel was not recorded in the ship's log. The coal burned excellently, and the pressure of steam and revolutions of the engines were kept practically constant with little effort.
	102	2.98	7	Dense	Not large	Moderate.	No	Once in 12 hours	Yes	Not with natural draft.	6 months	Good		The only opportunity for testing this coal was during a run in the inland passages in Alaska, when the speed was not taken.
10.1	102	2.40	10	Dense; not easily dissipated.	do	No	No	do	Yes	No	do	do	None	The conditions under which this coal was used were excellent. The sea was smooth and draft good. It is probable that with strong forced draft there would be undue heating of the uptakes and smoke pipe.
13.3	S. 191.7 P. 191.7	2.9	20.5	Dark in color	Moderate	No	No	Once in 4 hours with compressed air; once in 24 hours with steam.	No	Yes	About 3 months.	do	¼ to ½ knot increase.	During 2 hours of period an average of 207.3 revolutions were maintained with natural draft, with an average speed by patent log of 11.85 knots, but the increased consumption of Comox coal necessary to maintain the number of revolutions was found to cause undue heating of uptakes.
11.5	46.5	3.6	16	Easily dissipated	Not large	No	No	Very rarely		No			None	Steam followed .36 of stroke high-pressure cylinder and .75 stroke low-pressure cylinder. Vacuum, 25 inches. High and low pressure cylinders developing about equally. Coal dull and dirty. No coal was used for any other purpose than steaming during the test.
11.2	44	3.22	16	do	do	No	No	do		No		Foul	do	Steam followed .3 of stroke high-pressure cylinder and .75 low-pressure cylinder. Vacuum by indicator cards, 18 inches.
4.44	102.5	3.15	14	Dense, dark	do	No	No	Every other watch	Yes	No	1 year	do	Retardation ½ knot per hour.	
7.1	80	3.26	15	do	Large	Yes	No	Every 12 hours	For moderate draft, yes.	No	10 days	Clean	Added ¼ knot per hour.	Blowers used at intervals with bulkhead doors open. Clinkers easily removed.
4.01	81.2	2.43	10.9	Dense, dark, not easily dissipated.	Average quantity	No	No	Once in 24 hours	Doubtful.	No	9 weeks	do	Estimate ¼ knot per hour.	Ship light, mean draft for above time 24′ 4″. Slip of propeller only 7.7 per cent. Strong following breeze and heavy following sea. Considerable pitch in ash-pits. The steam lighter brought the coal directly from the mine to the ship, hence it is supposed that it had just been taken from the mines.
3.89	80	2.8	12.5	Fairly dense, dark, easily dissipated.	Not large	No	No	Once in 12 hours	Yes	No	3 weeks	do	¼ knot plus	
5.45	64.47	3.13	18	Dense	Large	No	No	Not during run	No	Not this run.	5 months	Good	Unknown	

*The output of the Comox mines is generally screened, the slack and finer portions being retained for conversion into coke. This special lot was of most excellent appearance, while the results of its combustion compare favorably with those of Cardiff coals, burned by this vessel in the past. It was very easily fired, the formed clinker not adhering to bars.

CORY'S MERTHYR.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alliance	159	St. Thomas, D. W. I.	Bronsted & Co.	$7.00	Good proportion lump.	8 days	Not	8 hours	Good	Natural	Good	96.3	5.8	112	None	1,420
Bancroft	203	Hermopolis, island of Syra, Greece.	A. E. Mavrogordato.	4.37	Good, clean; moderate amount of lump.	1 month	Under	8 hours	do	do	do	87.75	7.78	275	35	890
Cincinnati	460	Smyrna, Turkey	Whithall & Co.	4.38	50 per cent lump.		do	24 hours	do	do	Fair	337	9.9	1,050	60	4,000
Cincinnati		Genoa, Italy	E. Jonershon	24.50 in gold.	40 per cent lump.	Not known	do	do	do	do	do	351	11.4	1,031	60	4,400
Detroit	340	Naples, Italy	Vincenzo Valpicelli.	4.46	Fair per cent lump.	Unknown	do	12 hours	Clean	do	Good	218.16	11.9	1,169.16	30	3,816
Machias	292	Aden, Arabia	Lerke Thomas Co.	7.50	Lumpy; little slack.	Direct from collier.		24 hours	do	do	Fair	120	10.2	529.18	25	1,380
Minneapolis	1,891	Venice, Italy	A. Millosevich	5.32	Fair proportion lump.	15 days	Not	22 hours	do	do	do	541.44	9.68	1,487.97	54.60	4,818
Raleigh	460	Algiers, Algeria	Lymsbre & Filis, jr.	4.13	About 30 per cent lump.	3 days	do	48 hours	Fairly clean.	do	2 blowers on after fire room	280	9.7	906	85	4,600
Raleigh		Smyrna, Asia Minor.	T. Bowler Rees & Co.	5.35	35 per cent lump.	6 weeks	Under	24 hours	Clean	do	Poor	342	9.3	850	60	4,541
Raleigh		Algiers	A. Legeinbre & Son.	4.31	do	Just ar'v'd from mines.	From st'm'r direct.	44 hours	Not very clean.	do	Fair	380	7.5	748	60	4,780
Raleigh		Messina	Bonanno & Fischer.	3.65	About 30 per cent lump.	About 20 days.	Under	22 hours	Good	do	do	342	8.5	935	60	5,100
Raleigh		Genoa, Italy	G. Joamshon & Co.	4.78	Good; about 30 per cent lump.	2 weeks	Not; in lighters.	48 hours	Clean and good.	do	do	280	8.1	580	85	3,700
Raleigh		Syra, Greece	A. E. Mavrogordato.	4.62	Good; 30 per cent lump.	1 month	Under	12 hours	Good; fairly clean.	do	do	254	8.35	595	76	3,440
San Francisco	627	Algiers, Algeria	Legeinbre et Cie	4.01	65 per cent lump.	Not known	Not	8 hours	Good	Natural and assisted.	Good	276.5	11.4	1,943.54	72	4,160

CORY'S MERTHYR.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
9.15	39	12.67	8.9	Easily dissipated	Not large	No	No	Not determined	Not determined	No	6 months	Fair	1 to 2	
19.3	137.2	2.87	12	Thin, easily dissipated.	Small in size and quantity.	No	No	Once in 24 hours	Not tried.	No	5 months	Dirty	½ knot adverse.	Coal of good quality, requiring little working.
5.5	70.3	4	14	Moderate, brown	Small	No	No	Not swept	No trial.	No	8 months	Slightly foul	None	Run of the mine coal.
5.8	78.1	3.8	14	Dark, not dense	do	No	No	Not swept during trial.	do	No	4 days	Clean	do	Run of the mine coal.
7.01	105	3.26	10.2	Light gray	Not large	No	No	Not swept during interval.	Yes	No	6 months, 15 days.	Partly foul		
16.12	132	2.6	15	Light and easily dissipated.	Large	No	No	Once in 24 hours	Yes	No	5 months, 26 days.	Foul	1 knot, approximately	
4.15	55.1	3.12	6.66	Quite black, quickly dissipated.	Not large	No	No	Not swept	Yes, but burns out rapidly.	Not with natural draft.	7 days	Clean	None	This coal is a soft variety and burns out very rapidly, giving a good flame and small amount of ash. Under forced draft an enormous quantity can be burned, and it would be advisable for forced draft to obtain a harder variety of bituminous coal.
4.7	69	4.6	13	Medium	do	No	No	Not during the time	Not tried.	No	About 4 months.	Not very foul		Except when the wind is strong ahead or on the beam, the draft is very poor. This necessitated running two of the forced-draft blowers in this case, which reduced the economy of the coal to a certain extent.
4.5	66	5	12	Not dense	do	No	No	Not during run	do	No	4 months	do		
3.5	56	5.9	11	Dense, dark	do	No	No	Every 48 hours	do	No	About 6 months.	Foul		
3.72	60.4	5.1	13	Not dense	do	No	No	Not on run	do	No	6 months	do		
4.9	56.9	5.6	11	Not dense, easily dissipated.	do	No	No	Not during run	do	No	Just out	Clean	None	
5.41	57	5	15	Light smoke, easily dissipated.	do	No	No	Once in 48 hours	do	No	About 3 months.	do		
5.95	71.4	2.1	12	Easily dissipated	do	No	Yes	Once	Yes	No	30 days	Clean, newly painted.		

CUMBERLAND (BIG VEIN).

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.
0.995	0.701	16.114	74.87	7.32	0.14	0.300
0.691	1.199	17.103	70.701	9.963	9.343	----------

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Castine	292	Port Antonio, Jamaica.	Boston Fruit Company.	$5.50	Nine-tenths slack.	10 days	Not	58 hours	Good	Natural	Good	120	9.25	452.56	40	1,576
Concord	401	Honolulu, H. I.	U. S. Consul General.	9.87	No impurities; very little lump.	Not known	Under	14 days	Clean	do	do	110	8.5	453	40	1,615
Detroit	340	Port Antonio, Jamaica.	Boston Fruit Company.	7.50	Rich-looking, 40 per cent lump.	1 month	Not	36 hours	do	do	Fair	181.5	8	619.25	75	2,500
Hamilton	-------	Key West, Fla.	Schr. "Nellie W. Howlett."	3.87	Slack and clean.	----------	Under	95 hours	do	do	Good	53.9	7.1	123	10	545.6
Marietta	236	Naval Base, Key West.	Naval Base, Key West.	3.87	Fair	Taken from steamer or schooner.	Open lighter.	72 hours, 25 minutes.	Fairly good.	do	Fair	94	9.04	460.5	20	1,467
Marietta	-------	Panama	Panama R. R. Co.	Not known.	Almost entirely slack	Not known	Not known.	96 hours, 11 minutes.	Good	do	do	94	10.07	624.74	17	1,542.52
Montgomery	340	Port Antonio, Jamaica.	Boston Fruit Company.	10.00	20 per cent lump.	do	Not	48 hours	Fair	do	do	256.88	12.7	1,230.5	60	4,261.2
Terror	250	Off Cardenas	Unknown	Unknown.	Good proportion of lump.	Unknown	Unknown.	8 hours	Good	do	good	315	8.6	----------	----------	3,450

DERBYSHIRE (ENGLISH).

Marblehead	340	Quebec, Canada.	W. H. Crawford & Co.	4.25	Good	4 days	Not	24 hours	Not clean	Natural	Good	273.15	10.42	1,256.72	40	3,960

DOWLAIS MERTHYR.

Castine	292	Para, Brazil	Booth & Co	8.89	Two-thirds lump.	Not known.	Under	136 hours	Good	Natural	Good	120	8.05	470.04	40	1,551
Detroit	340	Aden, Arabia	Lerke, Thomas Co., Ltd.	8.57	Fair per cent lump.	Unknown	do	135.16 hours	Clean	do	do	172	9.69	835.2	28	2,792
Raleigh	460	do	do	7.62	Good, about 40 per cent lump.	Discharged from steamer.	do	236 hours	(*)	do	Fair	(†)	9.14	1,005	70	3,905
Raleigh	-------	Colombo, Ceylon.	Krawehl Coal Co., Ltd.	6.56	About 35 per cent lump.	Taken from collier.	Yes, in collier.	168 hours	Good	do	do	407	10	1,013	76	4,790

*Good, except boiler F had two leaky tubes which caused its fires to be transferred to C and D. C had one leaky tube for 12 hours.
†145 hours, 280; 13 hours, 407; 70 hours, 394; 8 hours, 267.

CUMBERLAND (BIG VEIN).

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
13.1	443914	3.2	16	Dark, easily dissipated.	Not large	No	No	Not swept during trial.	Yes	No	19 days	Clean		Coal contained large amount of slack, made more than average amount of clinker. Work of firing hard, but not excessive.
11.57	74.5	3.47	12	Easily dissipated	do	No	No	Not necessary	Yes	No	1 month	do	Nil	
7.17	79	3.6	18.4	Light brown	do	No	No	Once in 72 hours	Yes	No	165 days	Moderately foul.	1 knot	
29.1	62.16	3.89	18.42	Dark	do	No	No	Not during trial	Not determinable.	No	3 months	Foul		
13.8	S. 708518 P. 708425 Ave. 163.	3.05	18.4	Dark in color	Large, but easily broken to pieces.	Yes	No	Every 12 hours by steam; every 4 hours by air.	Not tried.	No	About 12 months.	Probably fair	None	
14.64	183.13	2.47	20	Light in color	Large in size and quantity, but separate easily from grate.	Moderate.	No	Every watch with air; every 12 hours with steam.	Not tried, probably suited	No	About 7 months.	Probably foul, judging from speed relative to revs.	$\frac{1}{8}$ to $\frac{1}{4}$ knot reduction.	
6.83	109.6	3.30	9.7	Dense, dark, easily dissipated.	Not large	No	No	96 hours	Yes	No	169 days	Foul		
5.7	55.5		13	Dark	do	No	No	Once in 48 hours	Yes	No	111 days	Fair		

DERBYSHIRE (ENGLISH).

5.89	S. 110.4 P. 110.5	3.05	11.57	Dense, dark gray, not easily dissipated.	Not large, but were tough and tenacious.	No	Considerable soot.	Once in 2 days	(*)	No	15 months	Foul	Loss of $\frac{1}{4}$ knot.	Coal quite bulky, about 48 cubic feet to the ton.

*Not tried; thought not well suited.

DOWLAIS MERTHYR.

11.6	1011254	3	15.6	Light gray, easily dissipated.	Not large	No	No	Once in 72 hours	Yes	No	4 months, 23 days.	Foul		
7.77	87.5	2.8	11.5	Dark gray	do	No	No	Once in 48 hours	Yes	No	5 months, 13 days.	Partly foul		
5.24	69.7	3.64	12	Moderate in amount.	do	No	No	About once in 3 days.	Not tried.	No	About 3 months.	Clean		
4.68	75.6	4.4	14	Not dark, easily dissipated.	do	No	No	Once during run	do	No	4 months	Fair	Against ship, average $\frac{1}{2}$ knot per hour for the entire distance.	

DUCKENFIELD (AUSTRALIAN).

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.
2.71	1.34	29.22	58.68	8.05	0.274	0.504

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Bennington	403	Navy Y'd, Mare Island.	Navy Y'd, Mare Island.	$7.40	Good, moderate amount of slack.	Not known, a few weeks only.	Not	48 hours	Clean	Natural	Poor	165	9.34	824	40	2,909
Marietta	236	San Jose de Guatemala.	Pacific Mail S. S. Co.	*22.036	Fair	Not known	do	44 hours	Good	(†)	do	94	9.02	455.4	16	1,651.5
Philadelphia	1,085	Mare Island	Contractor	8.20	Small lump, clean, little slack.	do	do	6 days	do	Natural	Fair	468	12.7	2,592.2	110.5	6,918

* In American gold; including freight and lighterage.
† Natural, except use of blowers 10 minutes each watch to blow soot from tubes.

ELK GARDEN.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
1.062	0.978	15.115	78.145	4.406	0.294	0.277	0.015

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of ain engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Marion	129	Panama	Panama R. R. Co.	$9.85	No lumps	No information.	Not	18 hours	Good	Natural	Fair	128	6.9	392.8		1,317
Marion		do	do	9.85	Small per ct. lump.	3 months	do	71 hours	Clean	do	do	128	5.81	409		1,374
Marion		Jiquilisco Bay, San Salvador.	do	9.85	do	No data	No data.	59 hours, 34 minutes.	Good	do	Good	160	7.46	592.78		1,783

DUCKENFIELD (AUSTRALIAN).

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND, CAL.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
J. W. Holihan, P. A. Engineer, U. S. N.	12	23,650	4,125	15.28	5.733	6.717	12.59	42.3	69.2	----------	Aug. 8, '98	----------	

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
7.23	88.8	3.36	14.4	Dense, dark in color.	Burned to a heavy ash.	Yes	Yes	Once in 12 hours with steam.	No	Yes	2 months, 16 days.	Fairly clean; thin coating of barnacles.	.25 knot per hour.	This coal burned with a long flame, leaving a light coke that burned rapidly, and with a thick layer of ash.
12.23	S. 167.47 P. 167.53 167.5	3.29	15.7	Dense	Moderate	Yes	Yes, very.	Tubes cleaned every 12 hours with steam; every 4 hours with air jet and blowers.	Not suited for forced or natural.	Yes	7 months.	Probably foul, judging from speed relative to revolutions.	No effect	(‡)
4.12	77.1	2.55	16.8	Dark	Not large	No	No	Once a day	Yes	No	20 days	Good	----------	Last two days of run draft poor owing to wind being astern.

‡ The coal reported upon above was poor in quality and formed an excessive quantity of soot. The air jets were used every watch, the steam sweepers every 12 hours, and the blowers for about 10 minutes of each watch at a high speed to clean the tubes, but their combined use failed to keep the tubes clean and the draft from becoming choked.

ELK GARDEN.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Davis Coal and Coke Co.	24.5	86,909	11,280	12.116	7.7047	9.02	10.3258	39.96	70	583.2	Oct. 27, '94	33 per cent	Burned freely. Short orange flame. Caked well and required very little labor. Clinker insignificant. Small quantity brown smoke. Soot, small amount and gray color. Breaks readily. Irregular fracture. Lustrous and dull black.
Davis Coal and Coke Co.	24.75	87,243	11,400	12.122	7.653	8.938	11.36	37.11	72	Zinc fused	Aug. 7, '93	5 per cent	Burned freely. Medium long bright-yellow flame. Cakes moderately. Clinkers small in size and amount. Lead-colored smoke. Soot moderate, light-gray color. Crumbles in handling. Shows signs of pyrites.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock.	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
11.7	40.9	3.34	12	Not dense; easily dissipated.	Not large	No	No	Once per day	Light force.	No	15 months	Fairly clean	----------	
10.2	39.9	3.35	10.1	Dark	do	No	No	Every day	do	No	10½ months	Foul	None	
9.36	46.74	3.0	15	Not dense; easily dissipated.	do	No	No	96 hours	do	No	16 months	Somewhat foul.	do	

EUREKA.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.479	1.551	20.054	71.632	4.324	1.960	0.792	0.005

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alliance	159	St. Thomas, W. I.	Bronsted & Co	$5.80	Very slack	Not known.	Not	20 hours	Clean	Natural	Fair	64.2	4.2	201.85		935
Detroit	340	Key West, Fla	Schooner "Patterson."	3.00	Good looking, 60 per cent slack.	8 days	Under	55 hours	Fair	do	do	172.32	8.2	740.5	50	2,884
Dolphin	273	New York	G. S. K	2.63	One-half slack.	3 weeks	Not	3 hours	do	do	Good	133.6	13.3	781.6	36.6	2,700
Massachusetts	1,597	Tompkinsville, N. Y.		2.70	Good			27 days	Good	do	Fair	552	8.983	2,229.3	68.5	5,237.6
New Orleans	800	St. Thomas, D. W. I.	Bronsted & Co	12.15	do	About 3 weeks.	Not	41 hours	do	do	Good	360	13	1,338	155	4,900
Texas	850			2.70		No data	No data.		Clean			531.6	6.32			

FERNDALE MERTHYR.

Bancroft	203	Horta, Fayal, Azore Islands.	P. P. Bensaude & Co.	5.59	Good, clean; moderate amount of lump.	About 9 months.	Under	35.6 hours	Good	Natural	Good	87.75	10	310	35	942
Boston	495	Hongkong, China.	F. Blackhead & Co.	10.03	Good, about one-quarter lumps.	1 month	do	85 hours, 49 minutes.	do	do	Fair	286.5	12.51	1,218.71	120	3,998.51
Concord	401	Yokohama, Japan.	Carroll & Co	11.205	Good	Not known	do	4 hours	Clean	do	Good	165	11.2	962	40	2,750
Detroit	340			11.65	Good, clean, and of excellent quality.	Unknown	do		do			176	10.77			
Detroit		Shanghai, China	L. Charles & Co	9.37	Fair per cent lump.	do	do	35 hours	do	Natural	Good	218.16	12.65	1,354.71	30	4,000
Detroit		Nagasaki, Japan.	N. Ginsbury & Co.	11.36	do	do	do	73 hours	do	do	do	269.5	14.6	1,879.97	30	4,720
Detroit		Hongkong, China.	F. Blackhead & Co.	9.78	Good per cent lump.	do	do	117.2 hours	do	do	do	269.5	13.41	1,410.6	30	4,120
Detroit		Off Bangkok, Siam.	Paymaster W. L. Wilson, Machias.	11.84	do	do	Unknown.	64.4 hours	do	do	do	223.66	12.3	1,111.36	30	3,130
Detroit		Singapore, S. S.	McAllister & Co	8.62	Large per cent lump.	1 week	Under	127.7 hours	do	do	do	218.46	12.34	1,102.15	30	3,105.2
Detroit		Colombo, Ceylon.	Krawehl Coal Co.	7.42	Good per cent lump.	Unknown	do	196.8 hours	do	do	Fair	135.6	10.67	760.49	28	2,718.5
Machias	292	Chefoo, China	Ferguson & Co	10.80	Fair proportion of lump.	10 months	Under mats.	24 hours	Fair	do	do	120	7.5	320.15	22	1,230
Machias		Hongkong, China.	F. Blackhead & Co.	8.77	do	2 weeks	Under	do	do	do	do	120	11.3	625	30	2,340

EUREKA.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent*	*Lbs.*	°				
Berwind-White Coal Mining Co.	24.83	84,109	11,300	11.997	7.443	8.694	10.87	36.56	72	Zinc melted	Aug. 4,'93	About 50 per cent.	Burned freely. Moderately long yellow flame. Clinkers small in size. Gray ash. Dark lead-colored smoke. First lot, 4½ tons. Crumbled in handling. Second lot, 1½ tons. Considerable force to fracture. Traces of slate and sulphur.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
10	32.5	4	7	Dense	Large	Yes	Yes	Every watch	No	No	7 months	Fair	Diminished ½ knot by wind and sea.	
7.3	83.8	3.18	20.3	Dark	Not large	No	No	72 hours	Yes	No	209 days	Moderately foul.	½ knot	
11	56.6	3.3	6	Dark brown	Small	No	No	Once every 3d or 4th day when steaming.	Yes	No	7 months	Fair	Increased speed about 2 knots.	Speed was increased by strong wind aft with smooth sea.
3.13	S. 391910 P. 391759.2	2.28	7.47	Moderately dense, dark, and easily dissipated.	Not large	No	No	Once a day	Have not tried it.	No	14 months	No knowledge.		
5.94	90	3.28	13	Dense, black	do	No	No	Once	Not tried.	No	Unknown	Clean; bottom sheathed.	Nil	
		No data	8.75	Dense				On arrival at port			2 months, 19 days.	Good		

FERNDALE MERTHYR.

23.7	145	2.62	9.1	Light, easily dissipated.	Not large	No	No	Once in 24 hours	Not tried.	No	4 months	Clean; scoured by current in Tagus River.	¼ to ½ knot favorable.	
7.004	52.3	2.979	8.97	Easily dissipated	Moderate amount, some large, easily removed.	No	No	Every 60 hours	Yes	No	16 days	Clean	Nil	A sample of the above coal was tested before leaving port and the evaporative power found to be 9.33 pounds of water (from and at 212°) per pound of coal burnt.
9	103.7	2.74	7	do	Not large	No	No	Once in 48 hours	Yes	No	2 months	do	None	
10.47		2.72	10.5	Clean				Once in 72 hours			5 months, 6 days.	Fair		
7.05	107	2.9	11.4	Gray	Small per cent clinkers.	No	No	Not swept during run.	Yes	No	3 months, 7 days.	Clean	Smooth sea, no sail.	
6.93	122	2.5	10	do	do	No	No	Once in 60 hours	Yes	No	4 months	Slightly foul		
7.25	111.4	2.6	8.6	do	Not large	No	No	Once in 72 hours	Yes	No	4 months, 15 days.	Partly foul		Sea smooth and moderate; no sail.
8.58	103.2	2.41	13.2	do	do	No	No	Once in 60 hours	Yes	No	4 months, 17 days.	do		Sea smooth; no sail.
8.9	102.72	2.41	9.8	do	do	No	No	Once in 72 hours	Yes	No	4 months, 26 days.	do		Light winds; sea smooth; no sail.
8.79	92.7	2.9	9.7	Light gray	do	No	No	do	Yes	No	5 months, 3 days.	do		Winds light; sea smooth; no sail.
16.25	117	3.6	13.8	Dark in color, not easily dissipated.	Large	No	No	Once in 48 hours	No	Yes	4 months	Fair	None	
10.8	144	3.5	15.3	Easily dissipated	Not large	No	No	do	Yes	No	2 days	Good	Sails set, adding about ½ knot.	

FERNDALE MERTHYR—CONTINUED.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—CONTINUED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Machias	292	Bangkok, Siam	Borneo Co., Ltd.	$10.30	Fair proportion of lump.	1 week	Under	24 hours	Fair	Natural	Good	120	11.4	624	30	2,080
Machias		Saigon, Tonquin, China.	W. C. Hale & Co.	10.04	do	1 year	do	do	do	do	do	120	10	491	25	1,835
Machias		Hongkong, China.	F. Blackhead & Co.	9.78	Good	Direct from collier.	Direct from collier.	19 hours	do	do	do	120	11.7	800	40	1,938
Machias		Chefoo, China	Ferguson & Co.	12.87	Good, fair proportion of lump.	Direct from steamer.	Under	12 hours	do	do	do	120	12.98	1,010.6	40	2,000
Machias		Nagasaki, Japan.	Guisburg & Co.	10.94	Bright and lumpy.	1 month	do	96 hours	Good and clean.	do	do	120	11.2	522	30	1,500
Machias		Hongkong, China.	Blackhead & Co	7.81	Bright, fair proportion of lump.	1 month	do	24 hours	Good	do	do	120	11.6	735.1	30	1,430
Machias		Singapore, Straits Settlements.	McAllister & Co	7.79	All lump; impurities imperceptible.	1 month	do	do	do	do	do	120	10.4	631.89	25	1,450
Machias		Colombo, Ceylon.	Krawehl Coal Co.	7.30	Lumpy, very little slack.	2 weeks	do	do	do	do	do	120	11.2	695.54	25	1,495
Olympia	1,169			11.61		About 3 weeks.	do	24 hours, 40 minutes.	Clean			494	15.26			
Olympia				11.61		do	do	16 hours, 4 minutes.	do			494	15.84			
Olympia				11.61		do	do	52 hours, 15 minutes.	do			494 and 329.6	12.07			
Olympia		Nagasaki, Japan.	M. Guisburg & Co.	11.45 gold.	50 per cent slack.		do	17 hours	do	The blowers were running slowly on open fire rooms.	Good	577	17.12	6,000.1	285	14,894
Olympia		do	do	11.45 gold.	do		do	14 hours	do		do	577	15.34	4,050	255	11,880
Olympia		do	do	11.45 gold.	do		do	12 hours	do		do	494	16.29	5,140.8	270	11,878
Olympia		Hongkong, China.	F. Blackhead & Co.	9.78	Moderate amount of slack.	Just discharged.	do	82.9 hours	do			494.4	15.6			
Olympia		Hongkong, China.	Blackhead & Co.	9.78	Two-thirds lump.	Not known	do	82.9 hours	do	Natural	do	495	15.6	4,604	330	11,622
Olympia		Yokohama, Japan.	Langfeldt & Co.	11.11	About one-half slack.		do	3 hours	do	do	do	165	7.25	800	200	3,440
Olympia		do	do	11.11	do		do	4 hours	do	do	do	330	9.65	1,913	200	6,514
Olympia		do	do	11.11	do		do	10 hours	do	do	do	165	6.16	702	200	2,910
Petrel	200	do	do	11.11	40 per cent lump.	3 months	do	80 hours	do	do	Fair	92.2	9.5	339.12	10	1,136
Petrel		Nagasaki, Japan	The Metani Bassan Kaisha.	10.10	65 per cent lump.	Direct from vessel in which imported.	do	100.5 hours	do	do	do	93.2	7.5	204.71	10	809
Petrel		Shanghai, China	L. Charles & Co.	10.25	45 per cent clean.	6 weeks	do	108.75 hours	do	do	Good	93.2	10.27	352.45	10	1,165
Petrel		Hongkong, China.	Atteso Co., Compradores.	8.69	40 per cent	8 weeks	do	15 hours	do	do	do	93.2	Not obtained.	340.12	10	1,306
Raleigh	460	Ponta Delgada	Bensaude & Co.	5.47	A clean looking coal with a fair per cent of lump.	Direct from S. S. Algoina.	Direct from S. S. Algoina.	4 days	Good	do	Fair	368	10.7	1,075	75	5,100
Yorktown	380	Shanghai, China	L. Charles & Co.	9.55 U.S.gold	Normal for this type of coal.	About 4 months.	Under	86 hours	do	do	Good	220	11.2	834	50	2,420

FERNDALE MERTHYR—CONTINUED.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—CONTINUED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
15.5	148	*Lbs.* 3.1	12.2	Easily dissipated.	Not large	No	No	Once in 48 hours	Yes	No	1 month, 21 days.	Good	None	
12.3	134	3.5	14	do	do	No	No	do	Yes	No	2 months, 13 days.	do	do	
14.2	154	2.3	15.37	Dark, easily dissipated.	do	No	No	do	Yes	No	2 months, 23 days.	Fair	do	
14.6	168.9	1.9	4	Light, easily dissipated.	do	No	No	No sweeping on run	Yes	No	4 months	Clean	do	
16.7	139	2.9	15	Very little smoke, easily dissipated.	Large	No	No	Once in 96 hours	Very well suited	No	3 months, 6 days.	Good as far as can be seen.	Less than 5 knots.	
18.2	154	1.86	12	Thin and of a brown color, easily dissipated.	Not large	No	No	Once in 48 hours	do	No	5 months, 10 days.	do	1 knot	
16	140.5	2.2	14	Quite thick, of a brownish color, not easily dissipated.	Large	Moderate.	Moderate.	Once in 24 hours	Yes	No	5 months	do	About 3 knots off.	
16.53	148	2	13	Light brown and easily dissipated.	Large in size and quantity.	Yes	No	do	Yes	No	5 months, 11 days.	Getting foul	Increase of speed 8 knots.	
3.856		1.983	6.5	At first light gray, then none.				Every 48 hours			About 2 weeks.	Clean		
3.373		2.430	7.1	do				do			About 13 days.	do		
4.647		2.788	7.17	do				do			About 15 days.	do		
2.56	101.9	2.37	8.25	Very slight	Considerable, easily removed.	No	No	Not done	Yes	No	4 months	Good	None	
3.16	89.14	2.53	8.25	do	do	No	No	do	Yes	No	do	do	do	
3.08	96.13	2.19	8.25	do	do	No	No	do	Yes	No	do	do	do	
3.01		2.51	5.5	do				do	Yes		10 days	Clean		Burns very freely with moderate amount of slack, and is suitable for use under forced draft.
3	90.88	2.34	6.8	do	do	No	No	do	Yes	No	do	do	Speed reduced .2 knot.	This coal was very free burning.
4.72	58.47	3.44	7.25	Light brown	do	No	No	Once in 72 hours	Yes	No	2 months	do	None	One engine only was in use during the trials reported on.
3.32	78.1	3.10	7.25	do	do	No	No	do	Yes	No	do	do	do	
4.77	56.65	3.23	7.25	do	do	No	No	do	Yes	No	do	do	do	
18.74	95	3.25	11.26	Easily dissipated.	Thin, but considerable in quantity.	In a slight degree	No	Once in 4 days	Yes	No	3 months	do	do	(*)
19.72	78.4	3.7	10.38	do	Small, but considerable in quantity.	No	No	do	Yes	No	do	Slightly foul	do	
19.42	96.2	3.20	13.7	Dark and easily dissipated.	Small, but fair quantity.	Great, but not excessive.	No	do	Yes, apparently.	No	1 month	Clean		Burns freely and quickly. Cokes readily.
Not obtained.	94.5	3.8	12.2	Easily dissipated.	do	No	No	Once in 6 days	Yes	No	7 weeks	do		
4.7	76	4.7	13	Not dense	Not large	No	No	Not swept on run	Yes	No	1 month, 15 days.	Fair	Moderate to rough sea; moderate to stiff squalls on port bow and beam.	
10.2	S. 507690 (98.4) P. 505910 (98)	2.73	15	No smoke worth noting.	Scarcely any clinker.	No	No	Not necessary during the run.	Yes	No	Just docked	Clean	Dead calm, smooth sea.	The coal was "run of the mine." The per cent of slack coal was normal for this type but proved useless as fuel and unburnable. The coal separated from the slack was of about the average value.

* This coal was part of a cargo shipped from Cardiff, January 15, 1897, in steamer "Knight Templar," to Singapore and then transshipped in steamer "Saiwan Maru" to Yokohama.

GEORGES CREEK.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
1.077	0.843	16.467	75.954	5.407	0.252	----------	0.009

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Annapolis	225	Navy Yard, Portsmouth, N. H.	Consolidated Coal Co., Baltimore, Md.	$2.8352	½ lump; no impurities.	3 months	Not	4 hours	Clean	Natural	Fair	98	9	233	8	625
Annapolis	-------	Newport, R. I.	Pininger & Manchester.	4.73	Good	30 days	Under	4 hours	Good	do	do	98	9.02	368.8	8	900
Bancroft	203	Key West, Fla.	Bark "James A. Wright."	-------	Dull, very little luster; about 35 per cent lump.	1 month in bark.	-------	14 hours	Fair	do	do	87.75	9.5	330	25	1,093
Bancroft	-------	do	do	-------	do	do	-------	9 hours	do	Forced	One-half water pressure.	87.75	12.12	647	30	1,827
Castine	292	do	----------	-------	Nine-tenths slack.	Unloading from schooner.		80 hours	Good	Natural	Good	120	7.98	312.27	40	1,658
Castine	-------	do	----------	-------	do	do	----------	68 hours	do	(†)	do	120	8.79	360.84	40	1,882
Catskill	167	League Island, Philadelphia.	U. S. Navy Department.	-------	Fair amount of small lump.	----------	-------	4 hours	Good except water legs.	Natural	Fair	120	4	No indicator.	30	1,326
Catskill	-------	Gloucester, Mass.	James Fairfield, Salem.	3.25	Lumps rather small and fair amount of lumps.	----------	-------	3 hours	do	do	do	120	5	do	30	750
Hamilton	-------	Key West, Fla.	Schr. "King Philip."	-------	Lumpy and clean.	----------	Under	80 hours	Clean	do	Good	53.9	9	192	10	654.3
Hamilton	-------	do	do	-------	do	----------	do	53 hours	do	do	do	53.9	7.2	76.4	10	720
Hamilton	-------	do	Brig "Baltimore."	3.87	do	----------	do	132 hours	do	do	do	53.9	10.1	265.3	10	503.2
Marblehead	340	do	G. S. K	-------	Good, but not much lump.	Not long	do	48 hours	Not very clean.	do	Fair	268.76	10.02	782.92	40	3,339
Nahant	167	League Island, Pa.	Equipment officer.	-------	Good, free from slack, etc.	----------	-------	4 hours	Clean and good.	Slightly forced.	Equal to ¼" air pressure.	72	5	320	20	1,360
New York	1,290	Key West, Fla.	G. S. K	No invoice yet received.	Indifferent	Not known; lying at Key West on board schooner.	In hold of schr.	24 hours	Good	Natural	Good	823	12.35	4,018	117	10,048
Solace	800	do	Schr. "Wm. H. Swan," from Philadelphia.	Unknown.	About 40 per cent lump, very little impurities.	Unknown	In schooner's hold.	88 hours	do	do	do	360	14.2	2,476	175	6,030

† Natural draft $20\frac{35}{60}$ hours. Forced draft $47\frac{35}{60}$ hours.

GEORGES CREEK.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Davis Coal and Coke Co.	24.25	81,073	10.800	11.134	7.5	8.72	14.03	43.02	69.25	----------	Sept. 30, '95	----------	Coal burned freely with a long, white, yellowish flame, when first fired emitting a small quantity of dark-gray smoke; it did not coke, but caked slightly. The firing necessary with this coal was quite arduous by reason of the great quantity of fine coal falling through the bars, and the evaporative result undoubtedly was much higher than could be obtained on board ship by ordinary firing; also, the percentage of refuse was much lower than would result from ordinary firing.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
31.5	84.5	2.6	18	Easily dissipated.	Not large.	No.	No.	Once in 24 hours.	Yes.	No.	14 months.	Clean.	½ knot.	
22.3	96	2.38	13	do.	do.	No.	No.	do.	Yes.	No.	6 months.	do.	None.	
19.5	133.6	3.08	18.75	Dark.	Excessive; small in size.	Yes.	Yes.	Once in 8 hours.	No.	None noted.	1 month.	do.	None. Weather perfect. No sea. No sail set.	(*)
14.86	173	2.7	17.79	do.	do.	Yes.	Yes.	do.	No.	do.	do.	do.	do.	
10.8	108.9	4.7	21.5	Light brown; not easily dissipated.	Large.	Yes.	Yes.	Tubes choked with soot after 50 hours.	No.	No.	2 months, 3 days.	Fair.	None.	
10.5	119.1	4.69	14.8	do.	do.	Yes.	Yes.	do.	No.	No.	2 months, 6 days.	do.	do.	
6.7	37.0	4.5	15	Not very dense, nor easily dissipated.	Not very large.	No.	No.	Once in 4 days.	------	No.	----------	Clean.	----------	
13.2	38.0	4.33	12	do.	Not large or numerous.	No.	No.	do.	------	No.	----------	do.	----------	
30.7	71.3	3.24	18.75	Dark.	Not large.	No.	No.	Not during trial.	Not determinable.	No.	4 weeks.	do.	None.	
22.4	55	8.3	20.1	do.	do.	No.	No.	do.	do.	No.	5 weeks.	do.	do.	Vessel blockading.
42.3	72.05	1.83	16.21	do.	do.	No.	No.	do.	do.	No.	6 weeks.	Slightly fouled.	do.	
6.27	S. 100.5 P. 100.3	4.26	13	Black, but easily dissipated.	do.	No.	Considerable soot.	Once in 48 hours.	Yes.	No.	10 months.	Foul.	None.	
8.24	42	4	7	Dark, but not heavy.	Rather small.	No.	No.	Every fourth day.	Yes, if not exceeding 3/4".	No.	26 days.	Very clean.	+¼ knot.	Coal coked well, but showed tendency to clinker.
2.75	79.32	2.43	14.5	Not dense, but full of cinders.	Large.	Yes.	Yes.	In all boilers, once during trial.	No trial.	No.	7 months.	Foul.	Little or none.	Hard to keep steam, hard work for firemen on account of large amount of clinkers and ash. Tube sweeping has to be carried on constantly; had to use five boilers to make the speed usually made by four easily.
5.72	69.5	2.27	17	Dense, dark in color.	Very little.	No.	Yes.	After the run.	Yes.	No.	6 weeks.	Clean.	1 knot retarded last 24 hours.	

*Fires have to be cleaned very often; after 4 hours' steaming the fires become very dirty, and after 6 hours' steaming the grate becomes so filled with a small clinker that it is necessary to remove nearly all the contents of the furnace in order to clean the fire, and much is lost by this frequent cleaning. The coal does not burn freely, but has to be worked continually in order to get it to burn with any degree of rapidity. The use of forced draft improved the burning to some extent.

GEORGES CREEK—CONTINUED.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—CONTINUED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Solace	800	Guantanamo	Coal schr. "Sarah Palmer."	Unknown.	Small lumps and slack.	Unknown	In schooner.	111 hours	Good	Natural	Good	360	12.9	2,700	175	5,596
Terror	250	Philadelphia	Madeira, Hill & Co.	$2.07	Good proportion of lumps.	do	Unknown, shipped by boat.	16 hours	Fairly clean.	Natural, assisted.	Fair to good.	315	7.15	538.8	99.05	2,818
Yankee	1,000	Gauntanamo Bay, Cuba.	Schr. "Frank S. Palmer."	No invoice.	Poor	About 2 weeks.	From hold of schr.	4 hours	Good	Natural	Good	450	13.7	3,520 Est., no indicator.	275	6,631

GREAT WESTERN NAVIGATION.

Bancroft	203	Smyrna, Asia Minor.	C. Whittal & Co.	4.19	Good; large amount of lump.	Less than a month.	Under	72 hours	Good, clean.	Natural	Good	87.75	7.39	218	30	844
Bancroft		do	do	4.19	Good; large amount of lump; free from slack.			10 hours	do	do	do	43.87	5.3	92	5	583
Bancroft		do	do	5.35	Good; large amount of lump.	About 1 month.	Under	6 hours	Good	do	do	87.75	7.42	230	35	750
Bancroft		do	do	5.96	do	2 weeks	do	59 hours	do	do	do	87.75	8.39	223	38	780
Boston	495	Chefoo, China	Fergusson & Co	12.29	About 20 per cent lump.	8 months	do	20 hours	Fair	do	do	286.5	11.99	1,281.13	90	3,160
Cincinnati	460	Smyrna, Asia Minor.	Whittal & Co	4.25	50 per cent lump.	20 days	do	12 hours	Good	do	do	337	9.5	973	60	3,800
Minneapolis	1,891	Smyrna, Turkey	C. Whittal & Co.	4.20	Large proportion of slack.	44 days	do	2 days	Clean	do	do	541.44	8.22	1,216.8	60	4,643
Minneapolis		do	do	4.16	Considerable slack.	32 days	do	48 hours	do	do	do	336	8.55	1,176	60	4,633
Minneapolis		Gibraltar	Turner & Co	4.56	Fair proportion lump.	25 days	do	42.316 hours	do	do	Fair	560.1	9.457	1,484.1	55	4,395.4
Minneapolis		do	do	4.56	do	do	do	96.10 hours	do	do	do	560.1	10.22	1,647.8	55	5,152.83
Minneapolis		do	do	4.56	do	do	do	62.71 hours	do	do	do	560.1	10.25	1,625.46	55	4,864.2
San Francisco	627	Smyrna, Asia Minor.	C. Whittal & Co.	4.25	Fair proportion lump; no slate.	Just ar'v'd on steamer Theodesia.	do	32 hours	do	do	Good	276.5	9.9	1,575.4	72	4,281.2
San Francisco		do	do	4.19	do	About 16 to 20 days. From cargo of steamer Theodesia.	do	24 hours	Fair	do	do	276.5	9.13	1,359.60	72	3,900
San Francisco		do	do	4.16	do	About 24 days.	do	24 hours, 17 minutes.	Fairly clean.	do	do	276.5	9.64	1,265.80	72	3,550.2

GEORGES CREEK—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
5.1	71	2.2	16	Very light	Few, but large	No	No	After 10 days	Yes	No	5 months	Fair	None	
5.6	47.17	4.42	13	Light in color, easily dissipated.	Not large	No	No	Once in 24 hours	Yes	No	4 months	Slightly foul	½ knot	
4.63	67.7	1.88	14.78	Easily dissipated	Large	Very	Excessive.	Every 24 hours	No	Yes	About 11 months.	Very foul	Smooth sea, wind favorable to draft, no sail, wind ahead and on starboard bow.	

GREAT WESTERN NAVIGATION.

19.5	126.05	3.4	10.08	Thin, easily dissipated.	Not large in size or quantity.	No	No	Every 48 hours	Yes	No	7½ months	Very foul	None	
20.3	84.5	6	12.1	Light in color and quantity.	Not large	No	No	Once in 24 hours	Yes	No	3 months	Fair	Nil	The coal burns freely, with long flame; requires but little working.
20	129.9	2.83	10	Thin, easily dissipated.	Small in size and quantity.	No	No		Not tried.	No	do	Dirty	do	A good, clean steaming coal.
24	129.5	2.98	11.6	do	do	No	No	Once in 24 hours	do	No	2 months	Clean		
8.507	52.99	2.305	8.83	Easily dissipated	Not large	No	No	Every 60 hours	Yes	No	163 days	Slightly foul	None	
5.6	69	3.9	14	Not dense and brown.	Small	No	No	Not swept	Yes	No	5 months	Fair	do	
3.934	53.4	3.63	10	Dark	Large	No	No	2½ days	Yes	No	60 days	Foul		
4.12	53.23	3.74	13.8	Moderate	Large in size and quantity.	Yes	No	4 days	(*)	No	90 days	Foul in places		
4.819	55	2.855	8.3	Very dark brown and dense.	Small in size; considerable quantity.	No	No	Once in 4 days	No trial.	No	5 weeks	Clean	None	This Great Western Navigation is generally of dull fracture, though some fractures have quite a luster. Is a soft variety of bituminous coal.
4.443	60	3.026	13.6	do	do	No	No	do	do	No	6 weeks	do	do	
4.72	60	2.894	9.1	do	do	No	No	do	do	No	do	do	do	
5.23	68	2.60	10.8	From gray tinged with brown to very dark gray; easily dissipated.	Very few and small.	No	No	Once in 3 days	do	No	7 months, 26 days.	Foul	do	Coal burns freely and is consumed rapidly. Smoke was dense only during coaling of fires; at other times no smoke or very little.
5.25	64.57	2.72	10.82	From gray to very dark gray; easily dissipated.	Not large	No	No	do	do	No	7 months, 27 days.	do		Burns very freely and is consumed rapidly. Smoke was quite dense during coaling of fires; at other times none or very little.
6.08	62.56	2.65	12.06	Gray to dark gray; easily dissipated.	do	No	No	Not swept	do	No	8 months	do	None	This coal burns freely and is rapidly consumed. Smoke dense when coaling fires; at other times there is very little or none.

* Can be used, but is not of best quality.

HENRIETTA.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.783	2.417	14.707	77.222	4.207	0.664	----------	Trace.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Annapolis	225	Key West, Fla.	Columbia Coal Mining Co., Philadelphia, Pa.	$3.05	Fair	7 months, 10 days.	Under.	10 hours	Good	Natural	Good	98	10	382.71	8	875
Montgomery	340	Naval Station, Key West, Fla.	G. S. K	3.05	30 per cent lump.	30 days	do	19⅓ hours	do	do	Fair	252.85	12.84	1,197.65	62	3,790
Montgomery	-------	do	do	3.05	do	do	do	11½ hours	do	do	do	291.58	13.58	1,955.4	62	4,968
Newport	238	do	do	3.05	Large proportion of slack; no impurities observed.	5 weeks	do	36 hours	Excellent	do	Good	78	8.75	315.83	8.17	1,108

HOOD'S MERTHYR.

Minneapolis	1,891	Piraeus, Greece	Geo. Casanova	4.62	Good proportion of lump.	30 days	Half under; half not.	61.780 hours	Clean	Natural	Good to fair.	560.1	11.52	2,950.93	65	6,582
Minneapolis	-------	do	do	4.62	do	do	do	59.650 hours	do	do	do	560.1	10.52	1,449.6	55	4,872.5
Minneapolis	-------	do	do	4.62	do	do	do	158.083 hrs	do	do	do	522.7	10.25	1,663.73	55	5,324
Raleigh	460	do	Glamargan Coal Co., Limited.	4.50	A fair amount of lump.	43 days	Under.	22 hours	Some leaks; fairly clean.	do	Fair	342	8.6	922	7	4,100
San Francisco	627	Naples, Italy	Volpicelli & Co.	3.59	Fair proportion of lump.	2 weeks	Not	60 hours	Clean	Assisted draft, $\frac{1}{8}$" to $\frac{3}{8}$" pressure.	Good	276.5	10.25	1,098	72	3,220

HOSKINS & LLEWELLYN'S NO. 1 COLLIERY, SCREENED LARGE STEAM (WELSH).

Alliance	159	Queenstown, Ireland.	Clyde Shipping Co.	4.92	Good proportion lump.	About 10 days.	Under.	10 hours	Good	Natural	Fair	96.3	6.8	126	None	1,320

LEWIS MERTHYR.

Bancroft	203	Lisbon, Portugal.	Abecassis Bros.	4.58	Good, large amount of lump.	Out of steamer.	Under.	95.4 hours	Good	Natural	Good	87.75	9.9	310	35	904

HENRIETTA.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Alleghany Co., Washington, D. C.	12	42,389	4,980	12.2	8.5	9.94	11.2	42	72.2	----------	July 14, '97	----------	Burns with long yellowish flame; smoke of light-brown color.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
26.9	100	2.56	5.5	Dark ----------	Not large--------	No --	No --	Once in 20 hours---	Yes--	No --	3½ months-	Clean -------	None------	
Average 7.47.	109.7	3.01	9.18	Brown, easily dissipated.	Very few; small -	No --	No --	Once in 96 hours---	Yes--	No --	60 days----	----do -------	----do -----	
6.12	125.8	2.46	7.25	----do ----------	----do ----------	No --	No --	----do ----------	Yes--	No --	55 days----	----do -------	----do -----	
17.7	97.5	3.42	10.75	Dark ----------	Not large--------	No --	No --	Not swept during period reported on.	Yes--	No --	1 month---	----do -------	Speed decreased .15 knot.	The coal is friable; large proportion of slack probably due to rehandling; fine coal coheres in coking; forms considerable quantity of ashes, not much clinker, and no glassy slag.

HOOD'S MERTHYR.

3.92	73.88	2.182	12	Not dense, light brown, easily dissipated.	Not large--------	No --	No --	Not swept ---------	No trial; probably is.	No --	1 month---	Clean -------	None------	Different trials of same coal. The first is for 61 hours, 47 minutes; speed, 12 knots, approximately; smooth sea. The second is for most economical speed for this coal; smooth sea. The third is for revolutions 60, 61, and 62; sea rough part of the time. This coal is quite a hard variety of bituminous coal, has quite a brilliant luster when broken, and would probably answer well for forced draft, it being not so soft as some other coals.
4.83	60	3.238	11.6	----do ----------	----do ----------	No --	No --	Once in 5 days -----	--do -	No --	----------	----do -------	----do -----	
4.315	60.95	3.2	10.6	----do ----------	----do ----------	No --	No --	Once in 4 days -----	--do -	No --	6 to 7 weeks	----do -------	Probably one-half to three-fourths.	
4.75	64.5	4.2	13	Easily dissipated-	----do ----------	No --	No --	Not during run----	Not tried.	No --	4 months--	Not very foul-	----------	
7.02	62	2.75	11.4	----do ----------	----do ----------	No --	No --	Not swept ---------	Yes--	No --	63 days----	Clean -------	----------	

HOSKINS & LLEWELLYN'S NO. 1 COLLIERY, SCREENED LARGE STEAM (WELSH).

11.6	40.8	10.4	15.6	Dense----------	Considerable and large.	Yes--	Yes--	Every 12 hours ----	Not determined	No --	3 months, 23 days.	Fair --------	Little or none.	

LEWIS MERTHYR.

24	141	2.62	10.15	Thin, easily dissipated.	Not large--------	No --	No --	Once daily --------	Not tried.	No --	3¾ months-	Clean, bottom scoured by current in Tagus River.	Nil--------	An excellent steaming coal.

LOCKITTS MERTHYR.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons											*Sq. ft.*	*Knots.*			
Detroit	340	Chefoo, China	Fergusson & Co	$10.80	Small per cent lump.	Unknown	Under	24 hours	Clean	Natural	Fair	260.32	11.11	1,536.76	35	3,690
Machias	292	do	do	13.00	Bright in appearance, lumpy.	1 month	do	48 hours	Good	do	do	120	10.7	492.75	26	1,350

MARINE MERTHYR.

Bancroft	203	Beirut, Syria	C. Fargialla	6.23	Good, fair amount of lump.	1 month	Under	7 hours	Good	Natural	Good	87.75	7.48	146	10	673
Bancroft		do	do	6.44	Good, large amount of lump.	do	do	21 hours	do	do	do	87.75	8.01	175	38	766
Raleigh	460	do	Carstantine Fargialla.	6.14	Good, 25 per cent lump.	1 month, 27 days.	do	24 hours	Good and clean.	do						
San Francisco	627	Venice, Italy	Medikus, Leskovic & Co.	5.10	60 per cent slack.	Unknown	Not	7 hours	Good	Natural and assisted draft.	Good	276.5	9.57	958	50	3,120

MIDVALE.

Marblehead	340	Pensacola, Fla	G. S. K., Navy Y'd, Pensacola.	2.85	Very small per cent lump.	Not known	Not	10 hours	Good, clean.	Natural	Fair	183	10.1	860	50	2,730

MILLDALE.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.080	1.200	27.430	69.230	1.770	0.284		0.007

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Marblehead	340	Pensacola, Fla	G. S. K	$2.85	Small per cent of lump.	2 days	Not	48 hours	Clean	Natural	Fair	178.8	7.9	511	40	1,900
Montgomery	340	do	Carey & Co	2.85	Nearly all slack.	Not known	Not known.	28 hours	do	do	do	203.26	9.75	954	62	2,645
Montgomery		do	do	2.75	15 per cent lump.		In cars	18 hours	Good	do	Good	296.58	14.1	2,291.5	62	5,317

LOCKITTS MERTHYR.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
6.75	S. 103.6 P. 103.5	2.32	11.6	Dark	Large per cent clinkers.	Excessive.	Not excessive.	Once in 24 hours	No	No	7 months, 23 days.	Foul		
16	136	1.36	15	Easily dissipated	Large	No	No	Once in 48 hours	Yes	No	2 months, 20 days.	Good	None	

MARINE MERTHYR.

24	110.4	4.31	11.4	Little smoke, thin, light in color.	Small in size and quantity.	No	No	Unnecessary	Not tried.	No	3 weeks	Clean	No effect	The coal burns freely without working.
23.4	117.87	3.59	7.33	Little smoke, light color, easily dissipated.	do	No	No	Not swept	do	No	2 months	Fair	do	The coal requires little working and burns freely.
6.91	(*)	3.10	11.3	Easily dissipated	Large in size and quantity.	Yes	Yes	Once	No	No	51 days	Fair		

* S. engine uncoupled; P. engine running 70 revolutions.

MIDVALE.

8.65	97	3	9.2	Moderately dense, dark, not easily dissipated; dark-gray color.	Not large	No	More so than Pocahontas.	Not done	Yes	No	2 months	Clean	None	

MILLDALE.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
9.2	80	3.4	10	Dark and moderately dense.	Not large	No	No	Not swept	Yes	No	3 months	Fairly clean	None	
8.26	93.3	2.60	8.40	Dark	do	No	No	Not at all	Yes	No	116 days	Very foul	do	Area of grate, condition of engines, boilers, and weather, all favorable for economical steaming, so that this may be considered the best that can be done with Milldale coal. The small speed was wholly due to condition of the bottom.
5.9	127.4	2.32	8	Gray, easily dissipated.	do	No	No	60 hours	Yes	No	131 days	Foul		

MORRISDALE.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.593	1.347	14.197	77.320	6.077	0.466	0.853	0.012

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alliance	159	Tompkinsville, S. I.	Morrisdale Coal Co.	$1.90	Slack	96 hours out of mine.	Under	20 hours	Good	Natural	Good	96.3	4.8	98	None	1,140
Amphitrite	250	New York	New York, N. Y.	1.90		Just received.	Not	44 hours	Clean	do	do	252	6	525	25	3,539
Annapolis	225	Navy Y'd, New York.	W. C. Barber	1.90	Good	From railroad cars.	do	2 hours	Good	do	Poor	98	10	557	8	1,600
Annapolis		New York	do	1.90	Slack	Direct from mines.	From R. R. cars.	8 hours	do	do	Good	98	8.6	350	8	1,100
Detroit	340	Navy Y'd, New York.		1.90	30 per cent lump. Traces of sulphur.	Not known, as it was in cars.	Not	120 hours	do	do	Fair	223.66	9.7	725	85	3,000
Indiana	1,597	Tompkinsville, N. Y.	Warren C. Barber.	1.90	Fair	Direct from mines.	do	24 hours	Clean	do	Good	552	10.1	2,549.2	80	8,270.8
Marblehead	340	Navy Y'd, New York.	W. C. Barber, contractor.	1.90	Good when inspected.	Loaded into lighters direct from cars.	do	27 hours	do	do	Good to fair.	178.80	9.9	784.39	40	2,461.7
Montgomery	340	do	G. S. K., Navy Yard, New York.	1.90	25 per cent lump.	Taken from cars.	do	8 hours	Good	do	Fair	291.58	14.5	1,873.2	62	4,964
Montgomery		do	do	1.90	do	do	do	48 hours	do	do	do	208.26	11.58	917.62	62	2,990
New York	1,290	do	Morrisdale Coal Co.	1.90	Very poor	Direct from mines.	do	16 hours	Excellent	do	Good	494	10.9	1,750	117	5,902
Terror	250	do	W. C. Barber	1.90	A fair proportion of lump.	Unknown	Unknown.	4 hours	Fairly clean.	Assisted draft.	do	378	9.65	1,183.3	110	4,313.75
Terror		New York	do	1.90	do	do	do	20 hours	Clean	Natural	Good	315	8.24	701.2	110	3,500
Texas	850	Navy Y'd, New York.	G. S. K	1.90	Fair	No data	No data	24 hours	Good	do	Fair	398.7	8.8	1,213	28	5,515
Texas		New York City	G. S. K., Navy Yard.	1.90	Poor, much slack.	do	do	3 days	do	do	do	398.7	9.37	1,065	35	5,744
Wilmington	300	Jacksonville, Fla.	J. K. Munneslyn Gen'l Mngr. Southern Fuel & Supply Co.	4.25	Fair	20 days	Not	do	do	do	Good to poor and poor to fair.	105	7.3			2,333

MORRISDALE.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
W. C. Barber, 1 Broadway, N.Y.	12	41,509	5,470	11.4	7.58	8.87	13	40	70	566	Sept. 4, '97	Chiefly lump	The sample furnished consisted chiefly of lump coal. Fire was started with wood and steam was raised to 40 lbs. Then coal fire was started with wood embers.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
9.4	35.1	11.7	21.2	Dense, dark	Considerable and large.	Yes	Yes	Every 12 hours	Not determined.	No	8 months	Fair	½ to 1 knot	Wind favorable.
3.79	43.3	6.43	9.6	Dense	Large	Yes		Once in 16 hours		No	1 month	Clean		Very difficult to keep steam with this coal, and exhausting on the firemen, who are required to work the fires constantly.
14	104	2.8	25	Dark	Not large	No	No	Every 12 hours	Yes	Yes	18 days	do	None	
16.24	98	3.08	20	Dense	Large	Yes	Yes	Every 8 hours	No	No	9 months	Good	Retarded ½ knot.	
7.23	91.5	3.7	13	Dark gray	Moderate	No	No	Once in 48 hours	Yes	No	76 days	Clean	0.9 knot	
2.73	83.4	3.14	15.1	Dark gray; not easily dissipated.	Considerable in size and quantity.	Not particularly so.	Yes	At end of trial	Not tried.	No	15 months and 28 days.	Foul	None	
8.6	S. 94.5 P. 94.6	2.9	9 (about)	Dark in color	Large	More than usual.	Not excessive.	Two or three times a week.	do	No	129 days	Presumably foul.	do	
6.5	124.7	2.57	9.2	Dark	Not large, fair quantity.	No	No	Once in 96 hours	Yes	No	51 days	Clean	do	
8.7	97.9	3.05	14.7	do	do	No	No	do	Yes	No	do	do	do	
4.13	65	3.16	13.77	Dense and dark	Not large	(*)	A considerable amt.	Not necessary to sweep tubes during time reported on.	No trial.	None	1 month and 14 days.	Clean	Little or none.	
5.011	64.63	3.33	18.8	Dark	Moderate in size, normal quantity.	Yes	(†)	Twice daily	Yes	No	1 month	do	None	
5.1	55.1	4.3	15.2	do	Not large	No	No	Once in 48 hours	Yes	No	46 days	Fairly clean		
3.5	66.7	4.4	14	do	Large	Not unusually so.	No	On arrival in port	Not tried.	No	8 months	Foul	Variable	Poor in quality, dirty, large percentage of ashes; does not supply steam sufficiently.
3.6	64.5	5.222	18	Dense	Large in size and quantity.	Yes	Medium.	do	do	No	2 months	Good	do	
7	S. 162.3 P. 163.8		16.6	Light brown, easily dissipated.	Small and clung to the grate bars.	Slightly so.	Yes	Once in 24 hours	Not tested	No	About 3 months.	Not clean	+.2	

* No. Running at too slow speed to necessitate excessive work.

† Above the average for good coals.

MOSHANNON CREEK.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.430	1.310	21.951	67.968	7.251	1.090	----------	0.003

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
New York	1,290	Tompkinsville, N. Y.	G. S. K., Navy Yard, New York.	$2.00	Nearly all slack, dirty.	Freshly mined.	Not	16 hours	Clean	Natural	Good	659	13.34	4,345.76	117	10,063

NANAIMO.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
3.352	1.998	33.762	46.001	14.322	0.565	----------	0.018

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Adams	150	Honolulu, H. I.	Consul General	$7.98	Fair	2 months	Under	16 hours	Clean at start.	Natural	Fair to good.	64.2	6.54	275	0.0	1,405
Baltimore	1,143	do	do	7.98	Lumpy	3 months	Not	9 hours	Clean	do	Good	656	13.05	3,029.78	75.75	12,940
Bennington	403	do	U. S. Government coal pile.	7.98	Good	About 4 months.	do	60 hours	Good	do	do	165	6.9	767	40	2,567
Monterey	236	San Diego, Cal.	Spreckles Bros.	8.65	do	About 1 month.	Under	97 hours	Fair	do	do	292	7.96	695	90	2,857
Monterey		U. S. collier Brutus, Guam, Ladrone Isl'ds.	U. S. S. Brutus.	7.50	do	About 2 months.	do	56½ hours	do	do	do	292	7.9	635	90	2,874

MOSHANNON CREEK.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Clearfield bituminous Coal Corporation.	24	89,168	11,350	12.15	7.856	9.173	11.9	39.16	72.44	Zinc slightly fused.	July 28, '93	50 per cent.	Burned freely. Long yellow flame. Cakes very slightly. Clinkers small in amount and size. White ash. Light lead-colored smoke.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
2.97	85.63	2.25	9.08	Dark	Large clinkers that stick close to the bars.	Yes	Yes	Not swept during run, but dirty at end of trial.	No trial.	No	4½ months	Foul	None	(*)

*This coal, *per se*, is of good quality. It is, however, of a low commercial grade, mostly slack, containing a large per cent of dirt-fine coal. Much falls through the grate bars, and much passes up through the smoke pipes with only a moderate draft. In the bunkers this coal tends to heat, and has so much dust that it facilitates spontaneous combustion. It makes the work at the fires excessive, and involves a large coal consumption.

NANAIMO.

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND, CAL.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
John Rosenfelds' Sons.	12.33	25,217.5	3,875	14.35	6.5077	7.6315	15.45	42.75	69.3	Strips of lead and tin were melted in the uptakes; zinc was not.	Sept. 1, 1897		

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
10.8	43.38	5.1	9.8	Very dense	Large	Yes	Yes	Every other watch	No	No	1 year	Coppered	None	
2.25	75	4.1	24	Dense	do	Yes	Yes	Tubes swept before and after trial.	No	No	4 months	Foul	Inappreciable.	A substance of a tarry appearance melted from coal, covered grate and hung down in strings in ash pits, between grate bars.
6	81	3.2	13	Dark brown	Large in size and quantity.	Yes	Yes	12 hours	No	No	8 months	Very foul	2 knots	
6.26	80	3.64	16	Dense, dark; not easily dissipated.	Large	Yes	No	Every 12 hours	For moderate draft, yes.	No	20 days	Clean	Retard about ¼ knot.	
6.1	78	4.5	22	do	do	Yes	No	do	do	No	2 months	do	Very slight	

NANTYGLO.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Detroit	340	Gibraltar	A. Mateos & Sons.	$4.74	Fair per cent lump.	Unknown	Under	24 hours	Clean	Natural	Good	172.32	10.825	886.28	28	3,023
Raleigh	460	Gibraltar	A. Mateos & Sons.	4.31	About 30 per cent lump.	Direct from mines.	From collier.	9 hours	Not very clean and leaking.	do	Fair	394	10	1,080	60	5,006

NATIONAL MERTHYR.

Bancroft	203	Alexandria, Egypt.	E. Barber & Son.	5.23	Good, considerable lump.	1 week	Under	42 hours	Good	Natural	Good	87.75	7.83	162	40	769
San Francisco	627	Havre, France	I. Rud & Co	4.01	60 per cent lump.	Not known	From covered barges.	24 hours	do	Both	Fair	276.5	11.4	1,296.25	70	3,733.3

NEWCASTLE.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
13.59	3.32	28.99	48.32	5.78	0.164	3.78	Trace.
7.992	3.598	25.433	53.806	8.023	1.148		

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alert	190	Navy Y'd, Mare Island.	G. S. K	$5.88	90 per cent lump.	2 months	Under	13 hours	Clean	Natural	Good	*63	7.45	261.65	None in use.	1,081
Bennington	403	Jiquilisco Bay, San Salvador.	Puget Sound, Cen'l American S. S. Co.	13.00	Lumpy	Brought in ship from mines.	From ship's hold.	64 hours, 36 minutes.	do	do	Fair	165	8.08	801.18	38.9	3,250

*One boiler only—half boiler power.

NEWCASTLE (BOWLER).

Raleigh	460	Messina, Italy	Errauti, Flino & Rickards.	3.86	Good; about 30 per cent lump.	1 month	Under cover.	72 hours	Clean and good.	Natural	Fair	280	8.65	732	85	3,900

NANTYGLO.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
8	87.6	3.4	9.8	Dark gray	Not large	No	No	Once in 24 hours	Yes	No	6 months, 19 days.	Foul		
4.46	70	4.4	16	Rather smoky	do	No	No	About every 48 hours.	Not tried.	No	4½ months	Somewhat foul.		The coal burns well but very rapidly. During the time this coal was being used, the expenditure per day was very large in proportion to the distance covered.

NATIONAL MERTHYR.

22.6	113.82	3.8	9.56	Thin, light in color and quantity.	Small in size and quantity.	No	No	Not necessary	Apparently; not tried.	No	1 week	Clean	Not appreciable.	Coal burns freely and requires little working.
6.86	66.1	2.73	17	Easily dissipated	Not large	No	No	Not swept	Yes	No	12 days	Good	None	

NEWCASTLE.

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND, CAL.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Oregon Improvement Co.	12.11	24,456	4,100	15.14	5.965	6.996	10.5	43.6	69	Lead and tin melted.	Sept. 14, '97		Hard semibituminous coal, not easily broken, and of a grayish-black color, with a dull luster. Burns with long, reddish-yellow flame, but takes several minutes after throwing fresh coal on fire before it becomes thoroughly ignited. Moderate amount of brownish-gray smoke, easily dissipated. Swells but little, and does not cake. Moderate amount of clinker.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
15.43	48.5	4.13	23	Dark gray, great volume, dense, not easily dissipated.	Large both in size and quantity.	Yes	Yes	Intervals of 8 hours	No	Yes	40 days	Clean	None	(†)
5.57	83.88	3.86	12.97	Dark brown in color.	Not large	Yes	Yes	Daily		No	5 months	Foul	Inappreciable.	(‡)

† This coal, Newcastle No. 4, is entirely unsuited to naval purposes, being very inferior in quality, difficult to fire, and forming large quantities of soot. This latter igniting in uptakes and smoke pipes results in excessive heating of, and serious injury to, those parts.

‡ This coal makes a very dirty fire, excesssive quantity of soot causing the tubes to foul very soon. Burns freely but makes no body. Is an expensive fuel, from greatly increased expenditure required to do the same work, compared with Cardiff or Comox. In cleaning fires the whole fire is practically removed, due to its dirty condition. Altogether, would not call it an efficient or economical fuel.

NEWCASTLE (BOWLER).

4.96	61	4.7	13	Not dense, easily dissipated.	Not large	No	No	Not during run	Not tried.	No	1 week	Clean	None	

NEW RIVER.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
1.018	0.834	18.933	71.054	7.976	0.185	0.631	0.089

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alliance	159	Newport News, Va.	C. & O. R. R. Co.	$2.75	Good	Direct from mines.	From cars.	48 hours	Clean	Natural	Good	96.3	6	264		1,040
Annapolis	225	do	do	2.08	do	From cars	Direct from mines.	4 hours	Good	do	do	98	7.82	275.57	10	800
Bancroft	203	Boston, Mass	C. A. Campbell & Co.		Nearly all slack; 3 per cent lump.	Taken from barge same day.		24 hours	Fair	do	do	87.75	10.3	390	25	1,155
Castine	292	Newport News, Va.	Chesapeake & Ohio R. R. Co.	2.25	Good	Fresh from mines.	Not	4 hours	Good	do	do	120	9.4	360	40	1,200
Columbia	1,670	do		2.25	Fair	Direct from mines.	In open cars and lighters.	8 hours	do	do	do	1,008	15.75	4,342.05	90	16,065
Detroit	340	Bermuda	St. Georges Coal Co.	7.79	No lump	Unknown	Unknown.	48 hours	Clean	do	Fair	356	12.83	1,667.45	50	4,853
Indiana	1,597	Newport News, Va.	Chesapeake & Ohio R. R. Co.	2.75	Fair	24 hours	Not	12 hours	Good	do	do	552	10.18	3,241.87	40	8,600
Indiana		do	do	2.75	Fair per cent of lump.	Direct from mines.	do	2 hours	Fair	do	do	552	10.65	3,356.43	40	8,750
Indiana		do	do	2.08	Fair	do	do	168 hours	do	do	Medium	494.16	7.4	1,569.5	62.78	6,259.3
Iowa	1,795	do	do	2.08	Fair per cent lump.	Fresh from mines.		24 hours	Clean and good.	do	Good	472.5	9.7	3,592.13	160	7,500
Iowa		do	do	2.08	do	Not known; fresh from mines.	Not	24 hours	do	do	do	472.5	8.98	1,817.3	177	5,842
Maine	896	do	do	2.08	About 20 per cent lump.	Direct from mines.	do	40 hours	Clean	do	Poor	430.38	11.6	2,952	350	6,978
Marblehead	340	Navy Yard, Boston.	G. S. K	3.05	Per cent lump small, clean.		Under	24 hours	do	do	Fair	183.76	9	600	50	1,963
Massachusetts	1,597	Newport News, Va.	C. & O. R. R.	2.38	Fair			53 hours	Good	do	do	414	8.96	1,871.8	60.2	5,244
Newport	238	Boston	E. B. Townsend	3.23	Large proportion slack; no impurities.	Not stored	Delivered from vessel.	10 hours	Excellent.	do	Good	78	7.1	404.7	9.3	1,180
Newport		do	do	3.23	do	do	do	16 hours	do	do	do	78	8.98	198.66	6.84	1,100
New York	1,290	Newport News, Va.	Chesapeake & Ohio Co.	2.75	Large per cent of lump.	Direct from mines.	Not	20 hours	Fairly clean.	do	do	329	7.64	758.24	117	4,071
New York		do	do	2.75	do	do	do	4 hours	Clean	do	do	987.97	18	9,296.51	191	18,147
New York		do	do	2.08	Good	do	do	48 hours	Excellent.	do	do	329	7.48	930	117	4,240
Raleigh	460	Key West, Fla.	G. S. K	3.20	Fair	8 months	Under	19 hours	Good	do	Fair	392	10.9	1,400	100	5,985

NEW RIVER.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Chesapeake & Ohio R. R.	24.42	87,367	11,200	12.07	7.8006	9.179	6.288	39.88	64.88	Lead and tin melted.	Oct. 11, '93	In bags	Burned freely. Long yellow flame. Cakes quickly. Small amount of coke fell through bars. Clinkers small and hard. Light-gray ash. Dark-colored smoke. Crumbles slightly in handling. Traces of slate.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
13	40	3.35	10	Dark	Not large	No	No	24 hours	Not tried.	No	8 months	Fair	None	
21.9	88	2.8	10	do	do	No	No	Once in 24 hours	Yes	No	6 months	Clean	do	
19.90	145.4	2.78	11.46	Not very dense except with strong draft.	None	No	Yes	do	(*)	No	1 week	do	do	
18.5	123.3	3.2	8	Easily dissipated	Not large	No	No	do	Yes	No	23 days	do	do	
2.19	S. 86.2 P. 82.9	3.6	9.5	Dark, not easily dissipated.	do	No	No	Not swept	Not tried.	No	64 days			
5.94	116	2.6	14.6	Dark	do	No	No	do	No	No	7 months, 4 days.	Foul		
2.63	S. 87.7 P. 88.1	2.62	9.8	Dark brown	do	No	No	Once in 24 hours	Yes	No	10 months	do	None	
2.44	S. 88.6 P. 90	2.57	6.2	Easily dissipated	do	No	No	do	Yes	No	12 months	Very foul	do	
2.38	S. 67.7 P. 68.1	3.86	10.9	Not dense, dark, easily dissipated.	do	No	No	Once in 48 hours	Not tried, I think yes.	Yes	5 months			
2.9	63	2		Dark brown, easily dissipated.	Not excessive	No	No	Not during trial	No trial.	Yes	5 months, 20 days.	Not clean	Little or none.	
3.42	58.8	2.8	9	do	do	No	No	do	do	None	9 months, 14 days.	Foul	No effect	
3.7	82.1	2.11	8	Moderate, dark, easily dissipated.	Not large	No	Large quantity.	In 48 hours	Yes	No	4 months	Good	None	
10	89	3	10	Light gray	do	No	No	1 time in 3 days	Yes	No	1 week	Clean	do	
2.96	73.9	2.71	7.34	Medium	Medium	Not excessive.	No	48 hours		No	4 months	Dirty		
13.5	97.2	2.85	6	Dark	Not large	No	No	Not swept	Yes	No	Not known	Clean	Speed decreased 2 knots.	
18.3	89.3	5.35	13.3	do	do	No	No	Not swept during time reported on.	Yes	No	1 month	do	Speed increased 1.2 knots.	
4.20	47.6	4.65	12.3	Not dense; brown in color.	do	(†)	No	Not swept	No trial.	None	1 month, 7 days.	do	Little or no effect.	
2.22	108	1.91	(‡)	do	do	No	No	Not necessary	do	do	2 months, 6 days.	Fairly clean	Very slight effect.	
3.95	47	4.05	9.95	Medium	do	No	No	Not at all	do	do	2 months, 9 days.	Clean	None	
3.61	76.9	4	12	Easily dissipated	do	Yes	No	Once in 24 hours	No	No	5 months, 11 days.	Foul	Unimportant.	

* Not as received; lump of same grade would be.

† No; rate of consumption per hour was too small to cause excessive work.

‡ No opportunity to hoist and weigh ashes during trial.

NEW RIVER—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Solace	800	Newport News, Va.	N. N. S. & D. D. Co.	Not known.	In lumps; very few impurities.	From cars direct from mines.	Not	81.75 hours	Excellent.	Natural	Good	360	12.2	2,500	175	5,786
Solace		Guantanamo Bay.	Schr. "Wm. B. Palmer."	Unknown.	Small lumps; very few impurities.	Unknown	Under	48 hours	Good	do	do	360	13	2,650	180	5,645
Texas	850	Newport News, Va.	C. & O. R. R. Co	$2.75	Very little lump.	Not determinable.	Not determinable.	36 hours	do	do	do	531.6	7	No data.	No data	4,370
Texas		Boston	G. S. K., Navy Yard.	3.45	Fair; many lumps.	No data	No data.	24 hours	do	do	do	398.7	10.4	1,288.9	25.7	6,127
Vesuvius	152	do	C. A. Campbell & Co.	3.15	Nearly all slack.	2 days	Not	36 hours	Clean	Forced ½" pressure.		150	13	Est. 900	16	1,700
Vesuvius		Jacksonville, Fla.	J. C. L'Engle	3.85	Good; principally slack.	About 2 months.	do	2 hours, 48 minutes.	do	Forced to ½" water pressure.	Good	146.25	15	Est. 1,325	25	
Vesuvius		do	do	3.85	do	do	do	3 hours	do	do	do	146.25	14.6	Est. 1,300	25	
Yankee	1,000	Navy Yard, New York.	Contractor	1.75	Poor, fine; a good deal of slack.	Fresh from mine.	do	4 hours	Good	Natural	do	450	13.5	3,300 Est. No indicator.	275	6.720

NIXON'S NAVIGATION.

Bancroft	203	Smyrna, Asia Minor.	C. Whittal & Co	6.002	Good, fair amount of lump.	3 weeks	Under	5 hours	Good	Natural	Good	87.75	8.26	225	35	815
Essex	175	Plymouth, England.	Emerson's	4.25	20 per cent slack.	3 days	do	14 hours	Fair	do	Fair	64.2	5	Not indicated.	None	960
Machias	292	Algiers, Algeria	Warnes Co	5.87	No impurities; lump and slack equal.	Direct from collier.		39 hours	Clean and good.	do	Good	120	11.06	493.647	25	1,380
Machias		Funchal, Madeira.	Blundy Bros. Co	4.74	Fair proportion of lumps.	2 days	Under	24 hours	Good	do	do	120	11.3	611.286	25	1,380
Raleigh	460	Gibraltar	A. Mateos & Sons.	4.74	Good, 40 per cent lump.	26 days	Yes, in hulks.	24 hours	Fairly clean.	do	Fair	280	8.9	580	60	3,750
Raleigh		Hongkong, China.	Carlowitz & Co	11.80	Good, fair proportion of lump.	3½ months	Said to have been under cover all the time	60 hours	Good	Moderate forced draft.	Good	495	10.8	1,460	105	5,480

OCEAN MERTHYR.

Castine	292	Bahia, Brazil	Wilson Sons & Co., Ltd.	9.48	Good	Unloading from vessel.	Unloading from vessel.	24 hours 10 minutes.	Good	Natural	Good	120	8.7	458	40	1,560
Castine		Montevideo, Uruguay.	do	8.52	Large proportion of lump.	From vessel.	From vessel.	3 hours	Clean	do	do	120	9.46	445.78	40	1,300
Castine		Buenos Aires	do	8.15	do	Unloading from vessel.	Unloading from vessel.	3 hours 49 minutes.	Good	do	do	120	10 Est.	483.17	40	1,450
Castine		Montevideo, Uruguay.	do	7.92	Good	Fresh from steamer.	Fresh from steamer.	89 hours 20 minutes.	Clean	do	Fair	120	7.62	483.53	40	1,541
Castine		Rio de Janeiro, Brazil.	do	9.73	do	3 weeks	Under	125 hours 45 minutes.	Good	do	Good	120	7.09	462.02	40	1,540

NEW RIVER—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swep?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
5	71.8	*Lbs.* 2.2	15	Very light	Small and few	No	No	After 10 days' run	Yes	No	1 month	Clean	Reduced ½ knot for 24 hours.	
5.3	73.4	2.25	14	Easily dissipated	Few, small clinkers.	No	No	10 days	Yes	No	3 months	Good	None	
3.6	57.6	No data.	8.4	Dark in color	Not large	No	No	When ship arrived in port.	Yes	No	2 months, 25 days.	do		
3.8	70.6	4.6	11	Dark	do	Not usually so.	No	On arrival in port	Not tried.	No	5 months, 23 days.	Ordinary	Variable	
17.3	156.1	1.89	14.8	Easily dissipated	Small	No	No	Not swept	Yes	No	2 months	Clean		
	184.7			Not very dense; not dark; easily dissipated.		No	No		Yes	No	6 months	Docked Aug. 18, 1897, but fairly clean.	Practically nothing.	
	183.1			do		No	No		Yes	No	do	Fairly clean	.2 or .3 of a knot.	
4.5	63.6	1.8	14 Est.; no means of weighing.	Easily dissipated	Very large	Yes	Very thick.	Every 24 hours	No	Yes	About 7 months.	Foul	Wind favorable to draft; sea smooth; no sails.	

NIXON'S NAVIGATION.

22	129.8	3.13	11	Thin, easily dissipated.	Small in size and quantity.	No	No		Not tried.	No	1½ months	Clean		
11.6	38		12	Light brown	Not large	No	No	About every 3 days	Yes	No	2 months, 10 days.	do	1½ knots	This kind of coal is of an excellent steaming quality.
17.5	140.7	3.57	8.6	Dark, easily dissipated.	Considerable amt. of small clinkers.	No	No	Were not swept once in 48 hours.	Yes	No	6 days	Good	0.75 knot increase.	
18.3	145	2.1	10	Dark, but not easily dissipated.	Large, but easily broken up.	No	No	Once in 24 hours	Yes	No	16 days	do	0.1 knot increase.	
5.3	63	5.8	20	Medium	Not large	Considerable.	No	Not on run	Not tried.	No	About 4 months.	Fairly clean		The steering engine, the ventilating engines, and dynamo engine were shut down much of the time, which accounts for the economy shown. The coal lies dead on the grates and when the fires are worked runs through like sand.
4.45	79.5	3.5	15	No smoke	No clinkers	No	No	Not during run	Not if speed is required	No	Just out	Clean		

OCEAN MERTHYR.

12.5	121.7	3.13	11.8	Easily dissipated	Not large	No	No	Once in 24 hours	Yes	No	1 month 24 days.	Fair		
16.2	227.23	2.67	4	do	do	No	No	Once in 48 hours	Yes	No	1 month 29 days.	do	None	
15 Est.	255.21	2 7	4	do	do	No	No	do	Yes	No	5 months 6 days.	do	do	
10.9	120.2	2.9	13	do	Small	No	No	do	Yes	No	3 months 28 days.	Foul, slightly	do	
10.26	116.8	3.06	10	Light, easily dissipated.	Not large	No	No	Once in 24 hours	Yes	No	4 months 5 days.	do		

OCEAN MERTHYR—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Castine	292	Pernambuco, Brazil.	Wilson Sons & Co., Ltd.	$9.24	One-half lump.	About 1 month.	Under.	81 hours 40 minutes.	Good	Natural	Variable	120	7.63	427.72	40	1,538
Detroit	340	Port Said, Egypt	Port Said and Suez Coal Co.	4.86	Fair per cent lump.	Unknown	Covered	136.6 hours	Clean	do	Good	130	9.2	564.64	25	2,350
Lancaster	326	Montevideo, Uruguay.	T. H. Mudd & Co.	7.17		2 months	Under.		Fair			294	8.5			
Lancaster		do		8.51		9 days	do		do			294	8.35			
Lancaster				9.48		Direct from ship by lighter.	Direct from ship by lighter.		do			147	4.5			
Lancaster		Rio Janeiro		9.36		51 days	Not		do				7.65			
Lancaster		Montevideo, Uruguay.		7.78		6 days	Under.		do				9			
Machias	292	Chefoo, China	Ferguson & Co.	11.15	Fair proportion of lump.	5 months	do	24 hours	do	Natural	Good	120	9.4	700	30	1,480
Machias		Port Said, Egypt	Suez Coal Co.	5.10	Lumpy, very little slack.	2 weeks	do	do	do	do	do	120	10.2	698.92	25	1,840
Machias		Gibraltar	A. Mateos & Sons.	5.35	do	2 days	do	do	Good	do	do	120	10.5	469.07	25	1,380
Oregon	1,594	Callao, Peru	Grace & Co.	(*)	Fair	Not known	do	4 days	do	do	do	414	11.3	26.37	140	7,357
Oregon		do	do	(*)	do	do	do	9 hours	do	Assisted draft, 1/4" pressure.		552	14.6	6,180.85	250	17,614
Oregon		do	do	(*)	do	do	do	4 days	do	Natural	Good	552	12.2	3,440	140	9,211
Philadelphia	1,085	do	Grace Bros. & Co.	15.00	Lump and slack.	do	do	97.42 hours	do	Both	do	312	13.32	2,139	30	4,538
Philadelphia		do	do	15.00	do	do	do	118 34 hours	do	do	do	312	11.10	1,441	30	3,820
Philadelphia		do	do	11.75	Slack chiefly	do	do	171.41 hours	do	do	do	312	12.87	1,974	30	4,600
Philadelphia		do	do	11.75	Slack	do	do	122.69 hours	do	do	do	312	12.34	1,886	30	5,150
Raleigh	460	Port Said, Egypt	Port Said and Suez Coal Co.	5.35	Good; about 30 per cent lump.	Arrived in collier the day before the purchase.		140 hours	do	Natural	Fair	24 hrs., 298; 67 hrs., 254; 49 hrs., 394.	9.29	920	76	3,957
San Francisco	627	Gravesend, Eng		20 shillings.	25 per cent good.			20 hours	Fair	do	do	276.5	10.9	1,433.6 Est.	75	3,536.6

*$15 delivered on board, $13 delivered alongside.

PARDEE.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.598	1.342	18.248	72.993	6.309	0.509		0.003

OCEAN MERTHYR—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
11.12	117.6	3.2	10.8	Light gray, easily dissipated.	Not large	No	No	Once in 48 hours	Yes	No	4 months 13 days.	Foul		
8.78	78.6	3.3	9.5	Dark gray	do	No	No	Once in 60 hours	Yes	No	6 months 5 days.	Partly foul		
7.2		3.41	12.2	Medium volume, light brownish color.				Once in 48 hours			2 years 4 months.	Covered with grass.		
6.56		3.22	11.5	do				do			3 years	do		
7.2		2.57	13	do				Once in 24 hours			3 years 4 months.	Covered with grass and small barnacles.		
6.4		2.92	12.1	do				do			3 years 3 months.	do		
6.25		2.6	11.2	do				do			do	do		
12.5	139.6	2	14	Easily dissipated	Moderate in size and quantity.	No	No	Every 48 hours	Yes	Yes; due to imperfect construction.	6 months 10 days.	Foul	Very slight	
16	144	2.63	14	Not dense, but dark in color, not easily dissipated.	Thin but very bad.	Yes	Yes	Once in 24 hours	No	No	1 year 10 days.	do	About 0.3 knot.	
17	137	3.5	14	Dark	Large	Yes	Yes	do	No	No	9 days	Good	0.2 knot increase.	
3.42	82	3.6	8.5	Not dense, dark, easily dissipated.	Not large	No	No	do	Yes	No	2 months	Fairly clean	Minus ¼ knot.	
2	107.3	2.78		do	do	No	No	Not blown during the trial.	Yes	No	do	do	None	
3.01	91.7	2.57	7.7	do	do	No	No	Once in 24 hours	Yes	No	do	do	Minus ¼ knot.	
6.50	74.34	2.09	9	Light	Small	No	No	In 4 days	Yes	No	do	Fair	Not known	
9.27	65.61	2.59	9	Not dense	Not large	No	No	Once in 2 days	Yes	No	1½ months	do	do	
6.30	72.93	2.29	13	Dense	Very large	Excessive.	No	Each 48 hours	No	No	2 months	do	do	This coal inferior. Very destructive to grate bars.
5.34	71.80	2.87	18	Not dense	Large	do	No	Once in 16 hours	No	No	do	do	do	
5.26	66.1	3.97	9.4	Moderate in amount and easily dissipated.	Not large	No	No	About once in 72 hours.	Not tried.	No	About 3 months.	Clean		This coal burned out a good many grate bars, but otherwise was very good.
7.3	68.94	2.3	14	Easily dissipated	Small	No	No	48 hours	Yes	No	6 months	Moderately foul.	Nothing	

PARDEE.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
David Duncan & Son.	12	44,281	5,400	11.25	8.2001	9.5797	11.296	40.75	72.625	Tin, lead, and zinc melted.	Aug. 10, '96		Good coal for ordinary natural draft. The coal is bituminous. No clinker. Antimony placed in front connection was intact.

PARDEE—CONTINUED.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Amphitrite	250	Navy Y'd, New York.	G. S. K	$2.63	Fair	Unknown	Unknown.	12 hours	Fair	Natural	Fair	252	6.6	699	40	3,260
Annapolis	225	Key West, Fla	Peale, Peacock & Kerr.*	2.85	Slack	5 days	Under	4 hours	Good	do	Good	49	6.6	141.6	6	550
Castine	292	U. S. Naval Station, Key West, Fla.	G. S. K		Two-thirds slack.	9 days	do	8 hours	do	do	do	120	8.4	Not indicated.	40	1,320
Columbia	1,670	Navy Y'd, New York.	David Duncan & Son.	2.63	Fair	Direct from mines.	In open lighters.	21 hours	do	do	do	672	11.3	2,251	80	6,214.7
Iowa	1,795	do	Duncan & Son, 1 Broadway, New York.	1.90	Fair per cent lump.	Fresh from mines.	Not	16 hours	Clean and good.	do	do	378	9.3	2,043.4	177	5,332
Texas	850	Dry Tortugas, Fla.	David Duncan & Son, Philadelphia, Pa.	2.95	Fair	Not known. Bill of lading January 17.	Under	34 hours	Good	do	Fair	398.7	10.7	1,288.6	51.4	5,629.7

* Old Pardee.

PARDEE PATTON.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.606	1.344	13.901	74.165	9.291	0.693	0.644	0.000

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Indiana	1,597	Off Tompkinsville, N. Y.	D. Duncan & Son, 1 Broadway, New York.	$2.63	Mostly slack	24 hours	Not	Full speed. Natural draft; 24 hours.	Good	Natural	Good	552	By patent log, 9.46; by bearings, 8.9.	2,906.66	44.54	8,952.7
Maine	896	Navy Y'd, New York.	David Duncan & Son.	2.63	Largely slack, run of mine.	Direct from mines.	do	1 day	Clean and good	do	do	430.38	12	3,138.20	400 At 20 pounds steam per H. P. per hour.	6,448
Massachusetts	1,597	do	do	2.63	20 per cent lump.			9 days, 22 hours.	Good	do	Good and fair.	552	9.21	2,058.6	60	7,598.5
Massachusetts		Dry Tortugas		2.95	Fair	Unknown	Unknown.	3½ days	Excellent	Natural and induced.	Poor	552	9.58	3,354.1	80	9,233
Montgomery	340	Navy Y'd, New York.	G. S. K	2.63	About one-half lump.	Not known	Not known.	97 hours	Good	Natural	Good	252.88	10.9	850	60	2,981
Texas	850	New York City	Duncan & Son	2.63		No data	No data.	3 days	do			531.6	12.4			

PARDEE—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
4.54+	S. 48.7 P. 48.1	52+	10.1	Dark	Not large	No	No	24 hours		No	4½ months	Foul		
26.4	70	3.8	13	do	do	No	Yes	Every 12 hours	Yes	No	8 months	Good	One	
15.8	119.5		15	Dark, but easily dissipated.	do	No	No	Once in 72 hours	Yes	No	1 month, 16 days.	Fair	None	
4.09	71	2.33	11	Dark, easily dissipated.	do	No	No	Not swept	Not tried.	No	1 week	Clean		
4	59.7	2.69	11	do	Not excessive	No	No	Not during run	No trial.	No	8 months, 20 days.	Foul	No effect	
4.26	69.6	4.2	11.25	Dark	Not large	No	No	Not swept up to end of time reported on.	Not tried.	No	27 days	Clean	1½ knots adverse.	

PARDEE PATTON.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
2.36	P. 83.1 S. 83.3	3.03	11.5	Light brown, not dense.	Not large	No	No	Not time to determine.	No	Natural draft, no; forced draft, yes.	9 months	Supposed to be foul.		
4.02	84.96	1.8	9	Dense, dark, and not quickly dissipated.	do	No	No	Not swept	Yes	No	4 months	Good	No effect	
2.64	S. 78.19 P. 78.22	3.02	10.12	Medium	Small	No	No	24 hours	Yes	No		Moderately foul.		A fairly good coal.
2.3	S. 87.45 P. 87.43	2.68	13.43	Dense, dark	Not large	No	Yes	Every 24 hours	No	No	11 months	Very foul	1 knot per hour against the ship for about 10 hours.	Although there was a fair amount of lump in this coal, it seemed to fall to pieces easily, and when thrown into the furnace a large percentage was carried up the smoke pipe.
8.23	S. 96.32 P. 96.34	3.2	8.42	Dark	Medium	No	No	Once in 2 days	Yes	No	3 days	Clean	Sea reduced speed 3 knots.	
3.6		4.12	16	Dark, medium density.				Twice during run and in port.			2 months, 13 days.	Good		

PATENT FUEL, ANCHOR BRAND.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Raleigh	*Tons.* 460	Beirut, Syria	Carstantine Fargialla.	$5.85	No lump; fine coal.	Taken from collier.	Taken from collier.	24 hours	Good and clean.	Natural	Good	*Sq. ft.* 254	*Knots.* 9	700	77	3,680

PRINCE BRAND, PATENT FUEL (BRIQUETTES).

Bancroft	203	Mersina, Asia Minor.	G. Tattorachi & Son.	8.02	Briquettes	1 month	Under	60 hours	Good	Natural	Good	87.75	6.65	180	35	1,110

PENRIKYBER NAVIGATION.

Marietta	236	Acapulco, Mex.	B. Fernandez & Co.	18.00 American gold.	Good	Not known, probably short time.	Under	53.57 hours	Good	Natural	Fair to poor.	47	8.23	256	17	667.5
San Francisco	627	Genoa, Italy	Penna & Co	5.11	Fair proportion of lumps.	Taken from steamer "Gladyswith," but in lighters 3½ days.	do	5 hours	Clean	Forced	Good	553	18.20	7,280	188.50	17,788

PENLLYN MERTHYR.

Castine	292	Montevideo, Uruguay.	J. Mudd & Co	7.54	Large proportion of lump.	Received direct.	From importing ship.	8 hours, 59 minutes.	Good	Natural	Good	120	9.06	392.3	35	1,100
Castine		Buenos Aires	do	8.02	do	3 weeks	Not	10 hours, 25 minutes.	do	do	do	120	10.1	470.21	40	1,190
Castine		Montevideo, Uruguay.	do	7.78	Large proportion of slack and impurities.	2 months	Under	7 hours	One clean, one dirty.	do	Poor	120	8.386	515.03	40	1,900

PITTSBURGH.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
2.59	1.55	30.12	63.01	2.75	0.172	0.300	

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Maine	*Tons.* 896	New Orleans, La	W. G. Coyle & Co	$2.55	Run of mine. About 40 per cent lump.	About 3 months from mine.	By uncovered boat.	4 days	Clean and good.	Natural	Good	*Sq. ft.* 358	*Knots.* 9.3	1,382	400	4,400
Texas	850	do	do	2.55		No data	No data	3 days	Good			531.6	9.5			

PATENT FUEL, ANCHOR BRAND.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
5.4	60	*Lbs.* 4.75	14	Moderate in amount and not very dark.	Not large	No	No	Once in 48 hours	Not tried.	No	82 days	Clean		

PRINCE BRAND, PATENT FUEL (BRIQUETTES).

134	117.8	5.16	12.4	Thick and dark, not easily dissipated.	Small in size, moderate quantity.	Yes	Yes	Every 12 hours	Not tried.	No	3 months	Dirty	¾ knot adverse.	

PENRIKYBER NAVIGATION.

27.6	S. 140.2 P. 140.1	2.41	13.2	Dark in color	Moderate in size and quantity.	No	(*)	Once every 4 hours with air; once every 24 hours with steam.	Not tried; probably not.	No	Between 5 and 6 months.	Probably good.	None	(†)
2.28	116.73	2.38	10.6	Easily dissipated	Not large	No	No		Yes	No	47 days	Clean		

*Yes; considerably more than "Albion Cardiff."

†The trial above reported was under same conditions as trial IV in report dated February 9, 1898, on Albion Cardiff coal, received at San Francisco, Cal., January 3, 1898, except that there was during the trial now reported about 90 tons more coal in bunkers. A comparison shows about 11 per cent more coal per H. P. per hour necessary with this coal. In trial III, report of February 9, a mean of 160 revolutions and a mean speed of 9.5 knots was made for 47.6 hours with one boiler. An attempt to do the same with this coal was unsuccessful and very severe on grate bars.

PENLLYN MERTHYR.

18.8	124.2	2.6	8.1	Dark, easily dissipated.	Not large	No	No	Alternate days	Yes	No	5 months, 13 days.	Fair	None	
19.07	133.6	2.5	12	do	do	No	No	do	Yes	No	7 days	Good	do	
9.78	167.14	3.4	13	do	do	No	No	Once in 48 hours	Yes	No	2 months, 8 days.	Foul, slightly		

PITTSBURGH.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
4.85	66	*Lbs.* 2.5	11	Dense, dark and slowly dissipated.	Not large	No	No	Not swept	Not well suited	No	6 months	Fair	None	This coal is free burning, moderately caking and easily worked. It burns with much flame, and if pressed with forced draft, heating of smokestacks and uptakes would be expected.
3.8		5.49	14.8	Very dense				On arrival in port			3 months and 13 days.	Good		

POCAHONTAS.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.430	0.590	13.593	80.103	5.147	0.137	----------	0.004
1.337	0.583	13.650	78.980	5.250	0.200	----------	Trace.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alert	190	Honolulu, H. I.	U. S. coal depot.	$8.10	About 90 per cent lump.	9 months	Under.	72 hours	Clean	Natural	Good	63	5.46	235	No auxiliaries.	707
Amphitrite	250	Norfolk, Va	G. S. K., Navy Yard.	2.75	Fair	Unknown	Not	4 hours	Fair	do	Fair	315	9.4	943.02	40	3,825
Amphitrite		Charleston, S. C.	Wm. Johnson & Co.	3.05	do	1 month	Under.	6 hours	do	do	Good	378	10.72	1,535.32	45	3,735
Amphitrite		do	do	3.05	Good, mostly slack.	Unknown	Not	95 hours	Clean	do	do	304.2	4.88	Not taken.	Not taken	2,232.6
Amphitrite		Norfolk, Va	Castner & Curran.	2.75	do	Just mined.	do	30 hours	do	do	do	378	7.74	do	do	3,189
Amphitrite		Lamberts Point	Navy Yard, Norfolk, Va.	2.08	About 35 per cent lump.	Just received.	do	60.42 hours	do	do	do	252	7.26	586	30	2,978
Annapolis	225	Guanica, P. R.	No information obtainable.	No invoice received.	Good	From collier Hannibal.	Under.	6 hours	Good	do	Fair	98	8.3	233	8	675
Bancroft	203	Navy Yard, Norfolk, Va.	----------	----------	Bright, lustrous; about 55 per cent lump.	----------	----------	21 hours	Fair	do	Good	87.75	9.55	345	25	933
Castine	292	Norfolk, Va	G. S. K	2.75	Good	Fresh from mines.	Not	22 hours	Good	do	Good	120	10	498	40	1,400
Castine		St. Lucia	Peter & Co	4.37	do	Not known	do	24 hours	do	do	do	120	9.6	474.62	40	1,450
Castine		do	do	4.25	do	Unloading from vessel.	Unloading from vessel.	41 hours	do	do	do	120	10.1	562.68	40	1,711
Dolphin	273	Charleston, S. C.	Wm. Johnson & Co.	3.05	do	3 weeks	Not	3 hours	Fair	do	do	222	13.3	1,286.3	8.57	2,943
Hamilton		Navy Yard, Norfolk.	----------	----------	Slack and clean.	Not known	do	109 hours	Good	do	Fair	53.9	9	168	10	586
Hamilton		Charleston, S. C.	Wm. Johnson & Co.	4.00	Fairly lumpy and clean.	2 days	do	72.3 hours	do	do	do	53.9	9	193.4	10	606.2
Iowa	1,795	Portland, Me.	Randall, McAllister & Co.	Invoice not received.	Large per cent slack.	----------	Under.	48 hours	Good and clean.	do	Good	472.5	8.7	1,601.5	177	5,038
Iowa		From colliers	Loaded at Norfolk.	Not yet invoiced.	Good coal, fair per cent lump.	Unknown	do	21 hours	Dirty	do	Generally fair.	756	11.3	4,339	155	9,280
Marblehead	340	Navy Yard, New York.	G. S. K	2.63	Fair	Not known	Not	9 hours	Clean	do	Fair	226	12.3	1,300	60	3,090
Marblehead		Charleston, S. C.	Wm. Johnson & Co.	3.05	do	Unknown	do	24 hours	do	do	Good	273	10	850	50	2,950

POCAHONTAS.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Navy Yard, Norfolk.	24.66	89,729.75	11,280	12.034	7.9548	9.38	8.39	40.04	62	Tin partly fused.	May 15,'94	Practically all lump.	Burned freely. Short flame. Did not cake. Small coal fell through bars. Insignificant amount of clinker, and that of friable nature. Small amount of brown soot. Breaks readily. Irregular lustrous black fracture, somewhat slaty appearance.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
17.30	46.50	3.008	16	Dark gray, dense.	Medium	No	No	Intervals of 20 hours.	Yes	No	7⅛ months.	Foul	None	This coal has proved very satisfactory in the Alert's boilers.
5.5	S. 58.2 P. 58.4	3.89	2.23	Easily dissipated.	Not large	No	No	Not during trial	Do not know.	No	1 month	Excellent		
6.429	S. 70 P. 66	2.43	Not known.	do	do	No	No	do	do	No	2½ months.	Good	1 knot	
4.90	S. 36.3 P. 36.2	No data	8	Light and easily dissipated.	do	No	No	Once in 48 hours	Yes	No	4 months	Slightly foul.		
5.34	S. 56.1 P. 55.5	do	7.5	do	do	No	No	do	Yes	No	5 months	do		
5.56	45.2	4.83	11.8	Easily dissipated.	do	No	No	Once in 24 hours	Yes	No	2 months	Clean		
2.8	81.9	2.8	13	do	do	No	No	do	Yes	No	13 months.	do	None	
21.05	136.1	2.75	11.5	Not dense; dark gray, easily dissipated.	Little or no clinker.	No	No	Once in 36 hours	Yes	No	2 weeks	do	do	This coal burns with a long flame, the only working necessary at the fires being an occasional breaking up of the fires by means of a slice bar. This coal is very well suited for steaming purposes with any kind of draft.
17	122.7	2.6	9	Easily dissipated.	Not large	No	No	Once in 24 hours	Yes	No	1 month	Clean	None	
15.8	125.2	2.78	10	do	do	No	No	do	Yes	No	1¼ month.	do		
13.3	136	2.8	12.5	Light brown, easily dissipated.	do	No	No	Once in 96 hours	Yes	No	11 days	do	None	
9.8	64	2.2	12	Dark brown	Small	No	Yes	About every 4 days when steaming.	Yes	Yes	9 months	Fair		This speed is for three successive hours, and is higher than is generally obtained.
34.1	73.7	3.29	18.37	Easily dissipated.	Not large	No	No	After 109 hours' steaming.	No means of determining.	No	About 10 days.	Good	1.5 knots	
32.52	72.8	2.97	17.65	do	do	No	No	Not necessary during run.	Not determinable.	No	20 days	Clean	None	
3.8	52.8	2.83	10.3	Light, easily dissipated.	Not excessive	No	No	Not during trial	No trial.	No	About 151 days.	Slightly foul.	No effect	
2.76	78.06	2.06	10.2	Not dense, dark brown, easily dissipated.	Not large	No	No	Not during run	No trial.	No	1 year, 3 months.	Very foul	No material effect.	
8.9	110.8	2.27	9	Not dense or dark, easily dissipated.	do	No	No	Not swept	Yes; very well.	No	3½ weeks	Clean	None	
7.99	96.5	3.3	11.6	Not dense, moderate color, easily dissipated.	do	No	No	Not done	Yes; fairly so.	No	6 weeks	do	do	

POCAHONTAS—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.—Continued.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Marblehead	340	Key West	G. S. K	$3.65	Fair	2 months	Under	72 hours	Fairly clean.	Natural	Good	183	8.7	600	50	2,155
Marblehead		do	do	3.65	do	3½ months	do	do	do	do	do	183.75	8.8	620	50	2,223
Massachusetts	1,597	Portland, Me	Randall & McAllister.	3.35	Good			37 hours	Clean	do	do	414	10.34	1,739.2	70	6,484
Massachusetts		Boston, Mass	Curran & Burton.	3.45	do		Under	146 hours	Very good.	do	do	552	12.15	3,650	75	9,299.58
Massachusetts		Portland, Me	Randall & McAllister.	3.20	do			72 hours	Clean	do	Fair and poor.	414	8.93	926.80	75	4,857.6
Michigan	125	Detroit, Mich	Stanley B. Smith & Co.	3.36	do	Fresh from mine.	Not	12 hours	Good	do	Good	91	9.8	350.66	None in use.	1,439
Michigan		Chicago, Ill	F. G. Hartwell & Co.	4.15	do	do	do	do	do	do	do	91	9.81	325.06	do	1,389.58
New Orleans	800	Hampton Roads, Va.	Wm. Lamb & Co., Newport News, Va.	2.33	Good, fair amt. of lump.	Unknown	Under	27.3 hours	do	do	do	360	12.66	1,230	127	4,005
New Orleans		Guantanamo Bay, Cuba.	do		Good	Received from collier.	do	47½ hours	do	do	do	360	11	995	150	3,963
New York	1,290	Sewells Point, Va.	G. S. K., Navy Yd., Norfolk, Va.	2.08	do	Direct from mines.	Not	72 hours	Excellent	do	do	329	7.08	950	117	3,939
New York		Key West, Fla	G. S. K., Naval Station, Key West, Fla.	No invoice received	do	Not known, taken from schooner.	Yes, in hold of schoon'r	24 hours	Good	do	do	494	6.4	761.98	117	4,894
Petrel	200	Honolulu	Government coal pile.	8.10	3 per cent lump.	Arrived Honolulu, May, 1896.	Under open shed.	10 days, 10 hours.	Clean	do	Fair	73.2	10.25	381.25	6	1,164
Puritan	410	Portland, Me	R. McAllister	3.35	Very good	Taken from schooner.	Under cover.	72 hours	do	do	do	350	6.99	821.24	37.39	3,848.6
Puritan		Norfolk, Va	Pocahontas Coal Co.	2.08	Good	Direct from mines.	Open cars.	28 hours	do	do	Good	350	6.654	1,186.22	47.45	4,514
Solace	800	Boston, Mass	Steam collier "Massapequa."	Unknown.	Principally slack.	Unknown	In steamer's hold	24 hours	Good	do	do	360	13	2,700	175	5,600
Terror	250	Lamberts Point, Va.	Wm. Lamb	2.08	Good appearance, fair proportion of lump.	do	Unknown.	3 hours	Fairly clean.	Assisted draft.	Fair	252	7.8	665.8	100	3,240
Terror		From Lighter at Navy Yd., Norfolk, Va.	do	2.08	Good proportion of lump.	do	do	24 hours	do	do	Good	315	8.54	752.3	110	3,458
Terror		Norfolk, Va	do	2.08	do	do	do	do	do	Natural	do	315	7.8	747	110	3,578
Terror		Charleston, S. C	Johnson & Co	3.50	do	do	do	do	do	do	do	315	7.1	595.1	110	2,980
Terror		Key West, Fla	Naval Station	Unknown.	do	do	do	do	Good	do	do	315	6.9			3.147
Terror		At sea	Unknown	do	do	do	do	48 hours	do	do	Fair	315	6.4			3,251
Terror		do	do	do	do	do	do	24 hours	Fairly good.	do	do		In tow by "Niagara."			646
Terror		Key West, Fla	Naval Station	3.87	do	do	do	12 hours	Good	do	Poor	315	7.2			3,341
Terror		Off Cardenas	Collier "Pompey." Unknown.	Unknown.	Fair proportion of lump.	do	do	48 hours	do	do	Fair	315	7.7			3,333
Terror		Guantanamo	Collier "Southery." Unknown.	do	do	do	do	72 hours	do	do	do	315	6.4			3,122
Terror		Port Guanica	Collier "Hannibal." Unknown.	do	Good proportion of lump.	do	do	56 hours	do	do	do	315	6.6			3,049
Terror		Mole St. Nicholas, Hayti.	Sch'ner "Benj. Poole." Unknown.	do	do	do	do	48 hours	do	do	do	315	6.7			3,275
Texas	850	Newport News, Va.		2.25	Good	No data	No data	24 hours	do	do	do	398.7	7.4	1,735.1	14.7	4,853

POCAHONTAS—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED—Continued.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
9	87	3.3	6.5	Light gray, easily dissipated.	Not large	No	No	Not any this time	Yes	No	4½ months	Slightly foul	None	
9	88	3.3	12	Dark gray	do	No	No	Once in 3 days	Yes	No	5½ months	Moderately foul.	do	
3.54	S. 77.52 P. 77.69	2.89	8.31	Light, easily dissipated.	do	No	No	2 and 3 days	Yes	No	1 month, 26 days.	Fair		
2.93	S. 94.35 P. 94.36	2.49	9	Medium	do	No	No	Not often	Yes	No	7 weeks	Clean		
4.12	S. 65.53 P. 65.53	2.82	12.74	Light	do	No	Moderate.	2 days	Yes	No	3 months, 11 days.	Fair		
15.25	18.8	4.01	7.7	Gray, easily dissipated.	do	Yes	No	Once in 24 hours	Yes	No	8 months	Clean	None	
17.82	17.87	4.27	6.4	do	do	No	No	do	Yes	No	10 months	do	do	
7.08	87.5	2.95	14	Dark, easily dissipated.	do	No	No	Once in 48 hours	Yes	No	Unknown	Clean, bottom sheathed.	Nil	Three boilers in use; two would have been sufficient for the speed.
6.2	81.5	3.46	12.8	Light, easily dissipated.	do	No	No	Once	Yes	No	do	do	do	
4.03	43.81	3.69	11.9	Medium	do	No	No	Not at all	No trial.	None	2 months, 25 days.	Clean	None	
3.06	43.2	5.5	11.5	Dense	do	No	No	Once during time reported on.	do	No	6 months, 20 days.	Foul	Very little	
19.77	98.09	3.10	10	Easily dissipated	Large quantities large lumps.	Great	No	Once in 10 days	Not well.	No	3 months	Clean	1 knot	(*)
3.597	39.5	3.959	13.9	Not dense or dark, easily dissipated.	Not large	No	No	Not swept during trial.	No trial.	No	6 months	Not known, presumably very fair.	Decreased speed ¼ knot per hour.	
2.934	41.78	4.45	7.84	do	do	No	No	Not during trial	Not tried. I think yes.	No	6 months	Foul	½ knot	
4.8	70.1	2.4	15	Light smoke	No clinkers	No	No	Swept after run	Yes	No	5½ months	Fair	None	
5.4	53.6	4.23	13	Easily dissipated	Not large	No	No		Yes	No	2 months	Fairly clean	do	
5.54	57.4	4.01	10.6	Moderately dense	do	No	No	Once in 48 hours	Yes	No	20 days	do		
4.9	54	4.2	10	Dark	do	No	No	do	Yes	No	48 days	do		
5.3	51.4	4.08	10	do	do	No	No	do	Yes	No	52 days	do		
4.3	48		9	do	do	No	No	do	Yes	No	103 days	Fair		
4.4	43.6		11.6	do	do	No	No	do	Yes	No	121 days	do		
			11	do	do	No	No	do	Yes	No	130 days	do		
4.6	50		11.5	do	do	No	No	do	Yes	No	182 days	Moderately foul.		
4.3	54		11	do	do	No	No	do	Yes	No	191 days	Foul		
4.8	51		10.3	do	do	No	No	do	Yes	No	195 days	do	Nothing	
4.6	51		11.8	do	do	No	No	do	Yes	No	235 days	do		
4.9	51.5		13	do	do	No	No	do	Yes	No	237 days	do	Nothing	
3.4	56.35	6.3	17	do	do	No	No	On arrival in port	Not tried.	No	3 months, 26 days.	Fair	Variable	

* This coal was stored in a temporary open shed in Honolulu, exposed to sun and rain. The coal coked readily but the fires had to be carried heavy and worked constantly. Dampening the coal with water improved its burning, caking and lasting qualities.

POWELL DUFFRYN.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Detroit	*Tons.* 340			$11.79	Large amount of slack.	Unknown	Under		Clean			*Sq. ft.* 265.82	*Knots.* 11.9	1,403.48		

POWHATTAN (KEYSTONE).

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.
3.13	1.38	1.06	86.67	7.56	0.331	1.11

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Miantonomoh.	*Tons.* 260	League Island Navy Yard.	Madeira, Hill & Co.	$1.70	Clean, fair proportion of lump.	Not known.	Not known.	6 days steaming with main engines.	Fairly clean.	Natural	Fair	*Sq. ft.* 246	*Knots.* Varied from 3½ to 7.	650	50	3,200

PRATT.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
0.360	1.740	25.773	68.351	3.703	0.073		0.079

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Detroit	*Tons.* 340	Mobile, Ala	Gulf City Coal Co.	$2.25	Rich, clean, 80 per cent lump.		Not	38 hours, 56 minutes.	Fair	Natural	Fair	*Sq. ft.* 223.66	*Knots.* 10.4	988.71	85	3,844.50

POWELL DUFFRYN.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
5.69	----------	*Lbs.* 3.19	15.3	Gray----------	----------	------	------	Once in 24 hours---	------	------	5 months--	Fair --------	----------	This coal had evidently been mined a long time.

POWHATTAN (KEYSTONE).

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
Madeira, Hill & Co.	*Hrs.* 12	*Lbs.* 40,335	*Lbs.* 5,400	*Lbs.* 11.25	*Lbs.* 7.47	*Lbs.* 8.896	*Per cent.* 10.4	*Lbs.* 40.1	° 44	----------	Feb. 15, '98	About 40 per cent.	Light-brown smoke. Moisture in coal 2.38 per cent.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
*3.9	44.9	*Lbs.* 4.55	12	Not dense, but not easily dissipated.	Large in size and numerous.	No --	No --	Every two days----	Not known.	No --	About 20 months.	Not known, presumably clean.	----------	This coal is of fair quality.

*The weather during five days of the time covered by this report was bad, so that the knots per ton of coal is by no means true as to speed that may be made under favorable conditions.

PRATT.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
6.706	S. 100 P. 98	*Lbs.* 3.34	20.5	Dense, brown----	Moderate--------	Moderate.	Moderate.	Every 36 hours ----	Doubtful.	No --	219 days---	Moderately foul.	Minus 1 knot.	A rich, clean, good-looking coal, resembling Newcastle in its cubical fracture. About 20 per cent slack. Makes a dense brown smoke, and after firing about 12 hours a troublesome clinker forms on the bars and clogs the air spaces, necessitating considerable labor to clear.

RESERVE, CAPE BRETON.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Marblehead	*Tons.* 340	Charlottetown, P. E. Id.	Peake Bros.	$3.07	Fair	1 month	Under	12 hours	Clean	Natural	Fair	*Sq. ft.* 183.75	*Knots.* 9.7	600	50	2,535

REYNOLDSVILLE.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Montgomery	*Tons.* 340	Port Tampa, Fla.	Plant Steamship Line	$5.60	About one-fourth lump.	Not known	Not	20 hours	Fairly clean.	Natural	Fair	*Sq. ft.* 165.72	*Knots.* 9.7	920	62	2,950
Montgomery		do	Plant S. S. Co.	4.20	30 per cent lump.		do	19 hours	Fair	do	do	256.88	11.4	1,110	60	3,543

STANDARD MERTHYR.

Bancroft	203	The Piraeus, Greece.	Franguli Bros.	4.86	Good, fair amount of lump.	3 weeks	Under cover.	23 hours	Clean	Natural	Good	87.75	8.87	260	40	900

WALLSEND.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
2.540	2.160	28.731	60.393	6.001	0.175		Trace.
3.392	3.768	23.281	56.014	13.161	0.384		0.003

RESERVE, CAPE BRETON.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
8.6	90	*Lbs.* 3.9	6	Dense and dark	Very clinging clinker, moderate quantity.	No	Yes	Once in 24 hours	No	No	1 month	Clean	None	Coal very light and much lost up stack. Clinkers hard to clear from bars. Quick burning but too light for forced draft.

REYNOLDSVILLE.

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
Geo. R. Dilker & Co.	*Hrs.* 12	*Lbs.* 47,036	*Lbs.* 6,180	*Lbs.* $12\frac{73}{80}$	*Lbs.* 7.611	*Lbs.* 9.125	*Per cent.* 9.6278	*Lbs.* 41.7916	° 44	Tin and lead were melted in uptake.	----------	About 60 per cent.	(*)

* Coal suitable for ordinary forced draft. Used 1,380 pounds of wood to raise steam. Weather cloudy and rainy. Coal has bright fracture and burns very rapidly, with red-yellow flame; forms heavy black smoke when firing, and considerable all the time; requires to be frequently charged into furnaces. Slice bar not required. Steam pressure fluctuating and difficult to control. Soot formed mostly in tubes. Zinc and antimony placed in the front connection remained intact. Clinker, 83 pounds; soot, 88 pounds.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
7.4	92.6	*Lbs.* 3	8.2	Dark brown	Not large	(†)	No	Not at all	Yes	No	104 days	Very foul	Inappreciable; slip of screw 16.8 per cent.	(‡)
7.2	103.5	3.03	5.72	Dense, gray; easily dissipated.	----do	No	No	Not necessary during run.	Yes	No	176 days	Foul	----------	

† Work heavy on account of insufficient grate surface.

‡ On February 3, 1897, when the bottom was clean, the ship averaged for ten hours 11.8 knots; 97.8 revolutions per minute; I. H. P. 795, and the mean draft exactly the same, viz: 14′ 5″. Slip of screw 4.3 per cent. By comparison of the two runs it is obvious that the difference of speed of 2.1 knots is wholly due to the condition of the bottom, and is not due to the quality of the coal. The large amount of coal per H. P. is due to the insufficient grate area used.

STANDARD MERTHYR.

21	133.7	3	17	Dark, heavy smoke.	Small in size; quantity considerable.	Frequent cleaning necessary.	Yes	Every 12 hours	Not tried.	No	10 days	Clean	3 knots adverse.	A poor steaming coal.

WALLSEND.

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND, CAL.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
J. C. Wilson & Co.	*Hrs.* 12	*Lbs.* 25,361.7	*Lbs.* 3,635	*Lbs.* 13.46	*Lbs.* 6.977	*Lbs.* 8.17	*Per cent.* 13.94	*Lbs.* 42.4	° 70.9	Tin and lead melted; zinc did not.	Sept. 15, '97	----------	Moderate quantity of dense, dark lead-colored smoke.

WALLSEND—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Adams	150	San Diego, Cal.		$8.00		3 months	No; in open coal pockets.		Good			64.2	7.6			
Bennington	403	do	Spreckles Bros. Comm. Co.	8.50	Moderate amount of lump.	Unknown	Under	24 hours, 19 minutes.	Clean	Natural	Fair	165	10.46	788.30	38.5	2,712
Monadnock	250	do	do	8.50	Fair; little slack.	3 months	do	8 hours	Good	do	Good	200	8.25	929.82	80	3,675
Monterey	236	do	do	8.00	Good	2 months	Not	61 hours	do	Both	do	307	7.94			4,297

WELLINGTON.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
2.09	2.05	36.85	46.16	12.85	0.563	1.22	0.009
1.821	1.979	27.927	52.602	15.007	0.664		

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Concord	401	Treadwell City, Alaska.	Alaska Treadwell G. M. Co.	$10.00	Good; no impurities.	Not known	Under	4 hours	Clean	Natural	Good	165	11.33	962.6	43	2,520
Concord		Sitka, Alaska	U. S. F. S. "Albatross."	9.92	Fair	do	Not									
Mohican	150	Honolulu, H. I.	U. S. consul general.	10.75	Free from slack and fairly lumpy.			6 hours	Clean	Natural	Good	160	10.2	595.56	3	2,166
Monterey	236	do	U. S. consul	13.25	Good	Not known	Under	60½ hours	Fair	do	do	292	8.15	697	90	2,577

WALLSEND—Continued.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
16.48	----------	*Lbs.* 3.37	15 (About.)	Considerable amount; dark gray, almost black.	----------	------	------	Trial not long enough to determine.	------	------	3 months..	Probable slight marine growth.	----------	
8.63	96.5	3.28	11	Dark brown, dense, not easily dissipated.	Not large-------	No --	Yes--	Once in 24 hours---	Yes--	No --	35 days----	Clean -------	Inappreciable.	
5.53	90.3	3.49	16.33 (Wet.)	Very dense, flame came out of top of smoke pipe.	Large ----------	Yes--	Yes--	Once in 8 hours----	No --	(*) --	5½ months.	Foul --------	----------	
4.14	50 to 100 88.5 ave.	--------	12	Dense and dark--	Not large-------	No --	Yes--	Every watch-------	No --	Yes--	7 months--	---- do -------	Retarded ½ knot.	Steamed in company with the "Monadnock," and speed so constantly varied that no fair estimate of I. H. P. can be given. On account of the large amount of soot this coal is not adapted for use on this ship, with or without forced draft.

*Heating cracked all paint on afterside smoke pipe, and carried away one guy.

WELLINGTON.

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND, CAL.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
R. Dunsmuir, Sons & Co.	*Hrs.* 12.5	*Lbs.* 26,013	*Lbs.* 3,640	*Lbs.* 13.48	*Lbs.* 7.146	*Lbs.* 8.389	*Per cent.* 11.87	*Lbs.* 42	° 68	Tin and lead melted, zinc did not.	Aug. 25, '97	----------	

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
10.07	104	*Lbs.* 2.51	7.1	Dense ----------	Small in size and quantity.	No --	Yes--	Once in 12 hours---	Not well adapted.	None with natural draft.	5 months and 10 days.	Fair -------	None------	Ship was making inside passage from Juneau, Alaska, to Sitka, Alaska. The day's run was short and tubes were swept and fires cleaned while at anchor at night. The smoke was dense. Coal burned quickly, and steam and revolutions were kept practically constant with ease.
----------	----------	----------	----------	----------	----------	------	------	----------	------	------	----------	----------	----------	Used only for auxiliary purposes.
10.5	49.6	3.6	14	Easily dissipated-	Not large-------	No --	No --	----------	Yes--	No --	----------	----------	----------	Steam follow .33 of stroke in high-pressure cylinder, .70 in low-pressure cylinder; vacuum 25 inches, both cylinders developing an equal amount of power. Coal good.
6.1	80	3.3	17	Dense, dark, not easily dissipated.	Large ----------	Yes--	No --	Every 12 hours ----	For moderate draft, yes.	No --	1 month---	Clean -------	Added ¼ knot per hour.	

WEST HARTLEY.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Marion	*Tons.* 129	Iquique	E. A. Sartori & Co.	$7.67	Fair per cent small lump, clean.	Received from steamer.	Under	14 hours	Good	Natural	Good	*Sq. ft.* 128	*Knots.* 6.4	305.6		1,188

WESTMINSTER BRYMBO.

Alert	190	Corinto, Nicaragua.	E. Palazio & Co.	18.00	40 per cent lump.	3 months	Not	14 hours	Good	Natural	Good	100	6.66	355	None in use.	1,248
Alert		do	do	18.00	do	4 months	do	48 hours	Fair	do	Fair	126	6.30	475	do	1,600

WESTPORT, NEW ZEALAND.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
1.630	1.020	34.929	61.798	0.199	0.424		Trace.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
Alert	*Tons.* 190	San Francisco	John L. Howard.	$9.00	20 per cent slack.	Just received.	From ship's hold.	75 hours, 30 minutes.	Good, clean.	Natural	Fair	*Sq. ft.* 126	*Knots.* 8.043	470	None in use.	1,490
Monadnock	250	do	Oregon Imp. Co., Contractors, G. S. K., Mare Island.	7.24	Good	Taken direct from vessel.	Taken direct from vessel.	3 hours	Good	do	do	100	5.6			1,875
Monterey	236	Sausalito	Oregon Imp. Co.	7.14	do		Under cover.	6 hours	do	do	Good	238	9.6	1,070	90	4,715
Wheeling	236	San Francisco	G. S. K., Navy Yard, Mare Island.	7.25	Clean and fair lump.	Ship discharging at S. F.	Taken direct from ship.	12 hours	do	Moderate forced—$\frac{1}{4}$ inch in ash pit.		60	11.05	S. 337.3+ P. 315.4= 652.7	12	Gross 1,250. Net 1,200.

WEST HARTLEY.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
12.07	38	*Lbs.* 3.88	6	Dark brown	Not large	No	Considerable.	Twice per day	No	No	13 months	Clean	None	

WESTMINSTER BRYMBO.

11.95	55.13	3.51	8	Light gray, easily dissipated.	Not large	No	No	Not determined	Not tried.	No	80 days	Fairly clean	— 20 per cent.	
8.82	58.68	3.36	11	Gray, easily dissipated.	Large	Yes	Yes	12-hour intervals	Not tried.	Yes	132 days	Very foul	None	

WESTPORT, NEW ZEALAND.

BOILER TESTS MADE AT NAVY YARD, MARE ISLAND, CAL.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
Oregon Imp. Co.	*Hrs.* 12^{59}_{60}	*Lbs.* 26,691.878	*Lbs.* 3,250	*Lbs.* 11.25	*Lbs.* 8.212	*Lbs.* 9.76	*Per cent.* 4.27	*Lbs.* 42.7	° 64		Oct. 27, '97		This coal is remarkably free from ash and clinker; the refuse resulted from hauling the fire only, together with a small quantity of soot.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
12.091	60.40	*Lbs.* 3.17	12	Black, dense, not easily dissipated.	None	No	No	Daily	Not tried.	No	156 days	Foul	None	
6.7	57.1		16.7	Dense	Not large	No	No	Once in 24 hours		No	1 month	Clean		
4.56	96	4.06	10 (About.)	Very dense and dark.	Medium	No	Yes	Every watch	No	No	4 months	Fair	None	This coal ignites quickly and burns freely. In a run of a day or longer it would be necessary to sweep tubes oftener than once a watch. With a strong draft the uptakes of the Ward boiler on this vessel *would* become unduly heated.
20.62	S. 188.5 P. 188.1	1.8	6.6	Under natural draft dark and dense, under forced draft moderate.	A thin tenacious clinker on grates.	Considerable work to keep grates clear.	Moderate.	For efficiency, a nest was swept every watch.	Yes	No		Should be clean.	Smooth sea and light winds on quarter.	With the exception of a thin tenacious clinker on the grates, requiring considerable work to keep them clear, the coal gives good results under a light forced draft; attempt to use it under natural draft was not satisfactory.

YOUGHIOGHENY.

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.
1.51	0.90	29.69	64.96	2.94	0.024	0.359
1.58	1.20	26.76	62.26	8.20	0.022	0.318

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Michigan	125	Duluth, Minn.	Pioneer Coal Co.	$2.68	Good	Fresh from mine.	Not	6 hours	Good	Natural	Good	91	9.2	328.39	None in use.	1,260

HIGHLAND (ANTHRACITE).

New York	1,290	Tompkinsville, N. Y.	Anthracite Coal Operators' Association.	Not known.	Uniform pea size and no dirt.	Some months; was the last of a large pile.	Probably not.	12 hours	Good	Natural	Fair	493.98	7.1	580	30	4,435

LEHIGH (ANTHRACITE).

Marblehead	340	Port Tampa, Fla.	Plant system	5.85	Good	About 3 weeks.	Not	14 hours	Clean	Natural	Fair	358.17	13	1,932.92	50	6,307

MOREA (ANTHRACITE).

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.
1.115	1.285	10.473	76.192	10.763	0.172	----------

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Montgomery	340	Naval Station, Key West, Fla.	G. S. K	$5.46	Nearly all lump.	25 days	Under	32 hours	Clean	Natural	Strong	241.96	9.75	847	62	4,116
Raleigh	460	Key West, Fla	G. S. K	5.46	Fair	Direct from mines.	do	24 hours	Numerous leaks.	do	Fair	393	8.8	720	80	5,988

YOUGHIOGHENY.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
16.3	17.8	*Lbs.* 3.83	10.8	Dense and dark	Not large	No	Yes	Once in 12 hours	Yes	No	8 months	Clean	None	

HIGHLAND (ANTHRACITE).

3.5	S. 38.66 P. 38.66	7.26	18.322	Very little smoke	Large in size and quantity.	Required frequent cleaning.	No	Trial too short to determine.	No	No	About 9 months.	Foul	None	

LEHIGH (ANTHRACITE).

5.2	131	3.13	21.8	No smoke	Not large	No	No	About once in 4 days.	Yes	No	8 months, 9 days.	Probably foul	None	Coal was "stove" size, free from slack.

MOREA (ANTHRACITE).

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
5.3	94	*Lbs.* 4.53	12.5	Very light	Not large	Excessive.	No soot.	Not at all	Totally unfit.	No	38 days	Clean	Reduced speed 1 knot.	
3.3	62.9	7.48	17.5	No smoke	do	Yes	No	Once in 72 hours	Not tried.	No	5 months, 28 days.	Foul	Unimportant.	(*)

* The coal was screened, steamboat size. It ignited readily, made some clinker and much ashes. The inferior economic results obtained are in part due to the condition of engines and boilers, and in part to the inexperience of the firemen, who had never before fired with anthracite.

NATALIE (ANTHRACITE).

CHEMICAL ANALYSIS MADE AT NAVY YARD, WASHINGTON, D. C.

Moisture.	Noncombustible volatile matter.	Combustible volatile matter.	Fixed carbon.	Ash.	Sulphur.	Increase in weight at 250° F.	Phosphorus.
1.739	1.461	2.099	79.244	15.239	0.218	----------	0.024

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Name of ship.	Coal.							Length of trial.	Condition of boilers.	Tried with forced or natural draft.	Kind of draft.	Area of grate surface.	Average speed.	Average I. H. P. of main engines.	Estimated H. P. of of auxiliaries.	Pounds of coal consumed per hour.
	Approximate bunker capacity.	Where received.	From whom.	Price per ton.	General appearance as to lump and slack.	How long in store.	From under cover or not.									
	Tons.											*Sq. ft.*	*Knots.*			
Alliance	159	Key West, Fla.	G. S. K.	$5.40	Anthracite	9 months	Under.	24 hours	Good	Natural	Good	96.3	6.3	123	None	1,035
Annapolis	225	do	John Miller, Wash., D. C.	5.40	Lump; anthracite.	7 months, 10 days.	do	5 hours	do	do	do	98	9.2	223.63	8	666
Detroit	340	do	Naval Station	5.40	Dull, deteriorated appearance; 5 per cent slate.	Freshest out 6 mos.; remainder several years.	do	72 hours	Clean	Both natural and assisted.	do	269.5	8	677.91	75	4,776
Montgomery	340	do	G. S. K.	5.40	10 per cent slack.	----------	Cover.	24 hours	Fair	Last hour forced draft.	Fair	252.88	11.8	1,021	62	3,396
Montgomery	-------	Naval Station, Key West.	do	5.40	do	Not known	do	41 hours	do	Natural	do	256.88	11	868.98	62	4,110.5

SCRANTON EGG (ANTHRACITE).

Essex	175	Navy Yard, New York.	D. L. & W. Coal Co.	4.25	2 per cent slack.	1 day	Not	4 hours	Fair	Natural	Poor	64.2	6	Not indicated.	None	800

NATALIE (ANTHRACITE).

BOILER TESTS MADE AT NAVY YARD, NEW YORK.

Coal furnished by—	Duration of test.	Water evaporated (calculated).	Coal consumed.	Coal per hour per square foot of grate surface.	Water evaporated per pound of coal.	Equivalent evaporation from and at 212° per pound of coal.	Refuse.	Steam pressure per gauge.	Temperature of feed water.	Temperature of uptake.	Date.	Lump coal.	Remarks.
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*	°				
Natalie Anthracite Coal Co.	12	40,379.5	5,652	11.7	7.14	8.58	20.5	41.66	41	----------	Jan. 30, '97	----------	Coal delivered contained 10 per cent moisture. Burns very freely with short yellow flame and no smoke. Easily worked.

SHIPS' TESTS, ALPHABETICALLY ARRANGED.

Knots per ton of coal consumed for all purposes.	Revolutions of main engines.	Coal consumed per H. P. per hour.	Per cent of refuse. Dry.	Character of smoke.	Quantity of clinkers.	Was working of fires excessive?	Was soot excessive?	How often were tubes swept?	Is this coal suited for forced draft?	Any undue heating of smoke stack?	How long ship out of dock?	Condition of ship's bottom.	Estimated effect of wind, sea, and sails upon speed.	Remarks.
		Lbs.												
13.6	40.4	8.4	18.8	None----------	Small in size, but considerable.	Yes--	No --	Every 4 days ------	Not determined	No --	8 months--	Fair --------	1 to 1½ knots	
30.6	90	2.8	5	Easily dissipated-	Not large -------	No --	No --	Once in 24 hours---	Yes--	No --	3½ months-	Clean -------	None------	
3.75	S. 79.94 P. 80.08 Av. 80.01	6.34	25	No smoke -------	Large ----------	Yes--	No --	Once in 7 days-----	No --	No --	143 days---	Moderately foul.	2 knots----	(*)
7.82	103.1	3.32	17.3	Not dense or dark; easily dissipated.	Not large -------	Yes--	No --	24 hours----------	Yes--	No --	68 days----	----------	----------	
5.96	98.4	4.42	11.5	----do ----------	----do ----------	Yes--	No --	----do ----------	Yes--	No --	158 days---	Foul ------	----------	

* This coal is weatherworn and deteriorated; after being ignited, it makes an intense local heat of short duration, breaks up, lays dead with a dull-red heat and runs into clinker and ash. It required an assisted draft with the blowers; required about 2 tons of it to do the work of 1 ton of ordinary bituminous. Caused several bulges in the back connection sheets of boilers A and C, and is totally unfit for use on naval steamers.

SCRANTON EGG (ANTHRACITE).

16.8	38	--------	8	None----------	Not large--------	No --	No --	Once in 2 weeks----	Yes--	No --	20 days----	Clean -------	¼ knot-----	

REPORT OF BOARD ON INVESTIGATION OF THE SPONTANEOUS IGNITION OF COAL.

NAVY YARD, WASHINGTON, D. C., *January 27, 1898.*

SIR: 1. In obedience to your order, dated December 9, 1897, and the inclosed instructions, we have investigated the subject of the spontaneous ignition of coal and its prevention, primarily with the view of ascertaining the causes of fires in coal bunkers of ships and in coal piles on shore, and respectfully submit the following report.

2. We have considered the details of these instructions, especially those of the Assistant Secretary of the Navy, as an outline of suggestions rather than as a specific order to examine exhaustively every item mentioned therein, both on account of verbal supplementary instructions and because we found that to procure reliable information with respect to some of them would necessitate making experiments involving an expenditure of time and money which we were informed were not contemplated. We have, however, endeavored to investigate every item mentioned, and, in general, to carry out the investigation of the subject as thoroughly as possible.

3. To this end we examined all the literature on the subject of spontaneous ignition which a careful search disclosed (a list of these authorities being appended, marked B), and made application to professional men who were likely to have investigated it to secure their cooperation, either by references to reports or by a contribution of their own experience. The various Bureaus and the Office of Naval Intelligence were consulted and letters were addressed to the Commander-in-Chief of the North Atlantic Station, the naval attachés, numerous coal operators, agents of steamship lines, consulting engineers, chemists, engineers of gas works, and other works handling large quantities of coal, notifying them of the object of the Board and requesting their assistance.

We have also carefully investigated every case of spontaneous ignition in the bunkers of our naval vessels, and in coal piles at the navy yard of which reports could be obtained, and have consulted many officers of the service.

It may be remarked in the beginning that the consideration of the subject of spontaneous ignition is confined to bituminous or "soft" coal, inasmuch as we have not learned of a case of fire due to this cause in anthracite coal on shipboard, and all the printed discussions of the subject refer to bituminous coal.

FIRES IN COAL BUNKERS.

1. The Report of the Royal Commissioners of Great Britain on fires in coal cargoes, published in 1876, and the paper of Prof. Vivian B. Lewes, of the Royal Naval College, Greenwich, published in 1891, are most important contributions to the literature of this subject.

These reports are in practical accord on the important points, and, in our opinion, as a result of careful study, give the true explanation of spontaneous ignition of coal. The paper of Professor Lewes was reprinted by the Bureau of Equipment in 1897, in the back of "Report on the Efficiency of Various Coals used by U. S. Ships, 1895–96," and a copy is to be found on all ships in commission, and at all navy yards.

2. According to Professor Abel, Dr. Percy, and Professor Lewes, the causes of spontaneous ignition of coal are:

3. First (and chiefly): The condensation and absorption of oxygen from the air by the coal, which of itself causes heating, and this promotes the chemical combination of the volatile hydrocarbons in the coal and some of the carbon itself with the condensed oxygen. This process may be described as self-stimulating, so that, with conditions favorable, sufficient heat may be generated to cause the ignition of portions of the coal.

The favorable conditions are: A moderately high external temperature; a broken condition of the coal, affording the fresh surfaces for absorbing oxygen; a supply of air sufficient for the purpose but not in the nature of a strong current adequate to remove the heat; a considerable percentage of volatile combustible matter or an extremely divided condition.

4. Second: Moisture acting upon sulphur in the form of iron pyrites.

5. The heating effect of this second cause is very small, and it acts rather by breaking the coal and presenting fresh surfaces for the absorption of oxygen.

6. While the condensation and absorption of oxygen is always going on to a limited extent, the general immunity of our bunker coal from spontaneous ignition shows that there must be some exciting cause, sufficient to stimulate the action to greater rapidity when fires do occur, and this we believe to be due chiefly to external heat. The analysis of the bunker fires on our own naval vessels indicate this very strongly.

7. In former days, when ships were under steam only part of the time, when steam pressures were lower, when there were no protective decks and bunkers over the boilers, and there was ample circulation of air around the boilers, cases of spontaneous ignition were almost unknown in bunkers; but modern war vessels have all these conditions changed, and for some bunkers there is sure to be, when adjacent boilers are in use, a sufficiently high external temperature to cause the spontaneous ignition of any coal at all liable to that phenomenon.

8. It should not be inferred, however, that spontaneous ignition is a frequent occurrence, even under the more favorable modern conditions. The total number of fires due to this cause, in the last three and one-half years, counting the fire in each bunker as a separate fire, is only 20 on 10 ships, and when we reflect that during that time there have been at least 40 ships in commission, averaging probably 40 bunkers each, which have probably coaled an average of 20 times, the percentage of bunker fires is seen to be very low.

9. While it is desirable, if possible, to eliminate bunker fires altogether, yet if the precautions necessary to this end require great expense or are undesirable for other good reasons, we must adopt such reasonable expedients as commend themselves to practical considerations, and to the need of each particular case.

10. In a modern war vessel, great coal-carrying capacity is one of the first considerations, and ready access to the coal from the fire rooms is almost as important. Both compel the construction of the coal bunkers in close proximity to the boilers. Moreover, the structure of such a vessel from necessity prevents any general circulation of air sufficient to prevent a considerable elevation of temperature near the bunkers. We have data of cases where such temperatures have attained 200° Fahr. Professor Lewes recommends provision for a water wall between the bunkers and boilers or uptakes in such cases, but there are several practical objections to such a plan which we consider conclusive. A double bulkhead with air circulation involves practical objections which will be obvious on consideration, so that, in our judgment, except as stated in the next paragraph, we do not recommend any structural changes.

11. There are some bunkers in which a fire would involve great danger, namely, those adjacent to magazines, while in others the loss of the coal would be a serious matter if the ship had a small bunker capacity and was making a long passage, and in time of action such a fire, calling for extra work on the part of the engineer's forces, would be a serious matter. On the *New York* and on the *Cincinnati* there were fires in bunkers next to the magazines which caused the charring of woodwork in the latter, and if they had not, fortunately, been discovered in time, there might have been in each case a terrible disaster. For such cases, we do consider structural provision as absolute necessity, and that no magazine should ever be separated from a coal bunker by a single bulkhead only. There should always be a double bulkhead with at least 4 inches between the walls of the bunkers and magazines and with provision for a good circulation of air to carry off any heat that may come from the bunker. In order to avail ourselves of expert opinion on the structural question, we requested the views of the Chief Constructor of the Navy, and find from his reply that he had anticipated this important point, and provision is made in the new battle ships on practically the plan which we recommend, while the Board on Construction had recommended the fitting of an additional bulkhead in the bunkers of the *New York* and adjacent to the magazines, with provision for air circulation. The precautions considered necessary to prevent fires and to discover and extinguish them in bunkers not adjacent to the magazines are presented further on.

With regard to fires in bunkers, we submit the following recommendations:

1. No magazine should be separated from a coal bunker by a single bulkhead only, but in all cases there should be a double bulkhead with efficient air circulation, artificial if necessary.

2. The temperature of spaces near bunkers, where it is likely to be high, should be observed, and where it will be sufficiently great to be likely to cause spontaneous ignition, there bunkers should be kept normally empty if the total coal capacity is sufficiently great. If they must be kept filled a coal should be chosen which is least likely to give trouble.

On our eastern coast, anthracite coal fulfills this condition completely, as diligent inquiry has not developed a single instance of spontaneous ignition of anthracite in such sizes as come on board ship. In Europe and many foreign ports, this condition would be met by briquettes or "patent" fuel. This is composed of bituminous slack bound together by tar, pitch, or flour paste, and from its nature and method

of manufacture has not the conditions for absorbing oxygen. Where neither of these is attainable, a semibituminous coal with a low percentage of volatile combustible matter should be chosen and stowed in large lumps only.

With respect to the temperature likely to cause ignition, Professor Lewes states: "If the bunker coal next the bulkhead be kept at 120° F., any coal with a tendency to absorb oxygen will run a great chance of igniting within a few days." He assumes this as a probable temperature if that outside the bulkhead is 200° F. This is a point that can only be settled by experience, as the data available to us do not warrant a definite limit being assigned. Where bunkers are exposed to such great heat they should be examined, if practicable, at regular intervals, to ascertain if the temperature rises or if vapor or smoke is emitted.

3. There should be as much space as practicable between the bunkers and boilers or uptakes. This is a question of design and no hard and fast rule can be laid down. We would recommend, however, a minimum space of 10 inches from the shells of cylindrical boilers, and at least 18 inches from uptakes and the casings of water tube boilers where the latter really serve as uptakes; and, if practicable, there should be air circulation.

4. Lump coal of large size and as free from small coal and slack as possible is to be preferred. In the ordinary purchase of coal, some slack is inevitable, but where there is room for choice, other things being equal, large lumps should be chosen. If practicable to get it, coal that was screened before shipment should be preferred.

5. Coal with a very high percentage of combustible volatile matter should be avoided when possible. Tables of the analyses of various kinds of coal are usually readily obtainable, so that the percentage referred to can be found. When a coal is offered of which there is no record in accessible tables, the percentage composition can probably be obtained from reputable coal dealers, and, we may add, in our opinion, contracts should be placed only with such dealers.

6. The coal should not contain a large amount of pyrites.

7. In choosing coals, the "Coal Efficiency Reports" will indicate the relative values of those that have been used at home and abroad, and the Admiralty list will also aid in the selection on foreign stations. In any case, coals of established reputation should be chosen, even at a higher price. This is authorized by law, and the practice is strongly urged. A standard coal is apt to be freer from slack and pyrites than coal of poor quality, and not only less liable to spontaneous ignition, but also cheaper in the end. The reports show that the *Philadelphia* can steam 7,170.6 knots, using Albion Cardiff coal, at a total cost of $7,282.8, and that it would cost $7,433.7 using Comox coal, although the former costs $7.14 a ton and Comox $5.65 a ton.

8. With respect to moisture, we consider it preferable on every ground to take the coal on board dry; but, when necessary to take it on board wet, such coal should be used first if practicable, and the bunkers in which it is put examined at regular intervals.

9. In general, recently mined coal should not be taken. The authorities already cited explain this fully. The fresh coal is more greedy of oxygen than after the absorbing process has proceeded for some time. Ordinarily our ships on foreign stations can not get freshly mined coal, so that they avoid this risk. The coal should be at least a month from the mine.

10. Precautions should be taken to prevent waste or oil from getting into the bunkers, and old coal should be used before that recently received.

11. With respect to the extinguishing of fires in bunkers, the means now provided appear the best practicable. The Bureau of Steam Engineering provides a steam pipe to each bunker in order that, in case of fire, an atmosphere of steam which will not support combustion may drive out the air. The reports show that these have been employed effectively; but it has been suggested that, if the pipes for admitting the steam were placed on the bottom of the bunker instead of the top, the system would prove more efficient. Otherwise the steam escapes through the bunker exhaust pipes. The bunkers can always be flooded through the coal scuttles if that be found necessary. As a rule, the coal should be removed from the bunker after it has once fired. The facility of removal depends on the location of the bunker and the total amount of coal on hand. With the extensive water-tight subdivision now carried out, and the inevitable restrictions on design in war vessels, we are not aware that any change could be made to facilitate the emptying of bunkers when a fire has occurred.

Before leaving the subject of bunker fires, we may mention briefly one point, to make our report complete, namely, why, if anthracite coal is absolutely free from danger of spontaneous ignition, it should not be used exclusively.

The practice of the Navy Department in using bituminous coal exclusively for the past fifteen years after a previous extended use of anthracite is sufficient to show that there are good reasons for preferring bituminous coal, and we give some of them:

1. The slower rate of combustion of anthracite with natural draft, thus involving greater weight and space for boilers to give same power.

2. Greater cost of anthracite than bituminous.

3. Practical impossibility of procuring anthracite except on our own Atlantic coast, so that bituminous coal would have to be used everywhere else.

4. Greater difficulty in firing anthracite than bituminous.

It thus appears that anthracite is, on the whole, distinctly inferior to bituminous for naval use except in the freedom from spontaneous ignition, and the comparative rarity of this phenomenon on our ships shows that we could not for a moment allow this advantage to outweigh the numerous and important disadvantages.

FIRES IN COAL PILES.

For this part of the subject we could find very little literature, although it is touched on by the Royal Commission, and Professor Lewes makes some suggestions.

At our request the Bureau of Yards and Docks very kindly asked for information from all the navy yards on the number and circumstances of all fires that have occurred in coal piles as far as recorded. The replies received disclose that the records only show five or six fires in coal piles as having occurred in an indefinite period, which may be considered as at least twenty years, so that it is a very rare occurrence in our navy yards.

Information has been kindly furnished by a number of firms using large quantities of coal, but most of it was of a negative character, as they had never experienced spontaneous ignition in their own coal piles. A report by Assistant Engineers Nulton and Danforth to the Commandant of the New York Navy Yard (Commodore Erben) as a result of investigating the experience of the large gas works in Brooklyn shows that these concerns had been free from fires for long periods.

The Pacific Mail Steamship Company informs us that they had trouble in their coal piles, but found it due to sulphur, and after assuring the absence of this ingredient had no further trouble, whether the coal was wet or dry. Other firms have stated that in the rare cases of spontaneous ignition in coal piles, within their experience, they believed them due to the presence of sulphur.

Professor Lewes' recommendations on coal storage are as follows: "The coal store should be well roofed in, and have an iron floor bedded in cement; all supports passing through and in contact with the coal should be of iron or brick; if hollow iron supports are used, they should be cast solid with cement. The coal must never be loaded or stored during wet weather, and the depth of coal in store should not exceed 8 feet, and should only be 6 where possible. Under no condition must a steam or exhaust pipe or flue be allowed in or near any wall of the store, nor must the store be within 20 feet of any boiler, furnace, or bench of retorts. No coal should be stored or shipped to distant ports until at least a month has elapsed since it was brought to the surface. Every care should be taken during loading or storing to prevent breaking or crushing the coal, and on no account must a large accumulation of small coal be allowed. These precautions, if properly carried out, would amply suffice to entirely do away with spontaneous ignition in stored coal on land."

It is recommended that these precautions be taken, particularly at Key West and Honolulu, where the coal would otherwise be exposed to the sun for long periods with a temperature at times, at Key West, as high as 130° F. In such cases the roof, if of corrugated iron, should have a lining of wood separated from it by an air space.

From all that we can learn, it appears that when a coal pile has ignited the best way to extinguish the fire is to remove the coal, spread it out, and then use water on the burning part. The incandescent portion is invariably in the interior and, when the fire has gained any headway, usually forms a crust which effectively prevents the water from acting efficiently.

Before concluding our report, we would call attention to the fact that no experiments to determine, beyond question, the exciting causes of bunker fires have ever been made. The researches of the eminent chemists already mentioned, and a study of the conditions when bunker fires have occurred, enable conclusions to be drawn which we believe correct, and on these our recommendations have been based. The fact remains, however, that the very conditions which seem to have been the cause of a bunker fire on one ship have existed on many others without causing trouble.

Apparatus which would reproduce almost perfectly the conditions of the bunkers on board ship could be made at moderate cost, and then every condition supposed to be provocative of spontaneous ignition could be reproduced, carefully tested, and adjudged. The outcome of such a series of experiments would be absolute knowledge of the conditions and exciting causes of spontaneous ignition, and consequently of the means to be employed to prevent its occurrence.

The entire cost of such a series of experiments, including the apparatus, would probably not greatly exceed $5,000, and we respectfully recommend its consideration at the Department.

We desire to place on record our appreciation of the kindness of those gentlemen who have assisted us by advice and information.

Very respectfully,

(Signed) THOMAS D. GRIFFIN,
Lieutenant, U. S. N.
(Signed) W. M. MCFARLAND,
Passed Assistant Engineer, U. S. N.
(Signed) TOS. WESTESSON,
Chemist.

The SECRETARY OF THE NAVY.

APPENDIX B.

LIST OF WORKS TREATING OF THE SPONTANEOUS IGNITION OF COAL THAT WERE CONSULTED BY BOARD, OR THAT WERE MENTIONED BY CORRESPONDENTS.

Report of the Royal Commission of Great Britain on the Spontaneous Combustion of Coal Cargoes, 1876.

Lecture by Prof. V. B. Lewes, on Spontaneous Combustion of Coal, published in all technical English papers in latter part of 1891, and reprinted in pamphlet of Bureau of Equipment, entitled Efficiency of Various Coals, published in 1897.

Spontaneous Combustion, Journal of Industries for 1890, p. 386, by V. B. Lewes.

Journal Society of Arts, pp. 352–65, March, 1892, by V. B. Lewes.

Nature, vol. 48, p. 626, by V. B. Lewes.

Story of American Coals, Philadelphia, 1896, p. 333, by W. J. Nichols.

Franklin Institute, vol. 17, p. 16, 1834; vol. 21, p. 424, 1836.

Franklin Institute Journal, 1882 and 1885.

Overland Monthly, N. S., vol. 12, p. 585, by W. J. Eastman.

Popular Science Monthly, vol. 20, p. 717.

Scientific American Supplement, vol. 4, No. 81, by C. W. Vincent.

Ecl. Eng., vol, 17, p. 515, by C. W. Vincent.

Journal of Society of Arts, vol. 25, p. 711.

Engineering, January 30, 1886.

Practical Engineer, March 20, 1892.

Practical Magazine, vol. 6, p. 280.

American Arch., vol. 23, p. 248, Doring.

Colliery Guardian, vol. 69, p. 16, 1895; vol. 71, p. 63, 1896.

Institute of Naval Architects, vol. 31, p. 204, 1890; vol. 35, p. 276, 1894.

Practical Engineer, vol. V, p. 29, 1891.

Engineering Record, 1891, p. 197, vol. 23, December 6, 1890, to May 30, 1891.

Scientific American, vol. 74, p. 275, 1896.

Journal of Iron and Steel Institute, vol. 2, p. 171, 1891; vol. 2, p. 351, 1892.

Transactions of the Institute of Federated Mining Engineers, vol. 3, pp. 789 to 794.

Engineering for 1897, vol. 63, p. 431.

Causes of Spontaneous Combustion of Coal, London, 1894, by M. V. Jones.

Coal Dust, an Explosive Agent, London, 1894, by D. Staurt, M. D.

The Origin and Rationale of Colliery Explosions, London, 1895, by D. Staurt, M. D.

Stahl and Eisen vol. XII, p. 309.

Perry, Metallurgy of Fact and Metals.

Finely Divided Organic Substances and their Fire Hazard, by C. J. Hexamer. Journal fuer Gasbeleuchtung, 1897.

Chemie der Stein Kohle, F. Muck.

Chemiker Zeitung, 1893, Halpke.

Chemisches Reportorium, 1892; 1893.

Percy's Metallurgy of Fuels, p. 298.

Dingler's Journal, vol. 195, pp. 315, 499; vol. 196, p. 317.

Wagners Jahres-Bericht for 1870, vol. 16, pp. 758, 778.

T. W. Bunning, "On the Prevention of Spontaneous Combustion of Coal at Sea."

Transactions of the North England Institute of Mining and Mechanical Engineers, vol. 25, p. 107, 1875–76.

Spontaneous Combustion, Journal of the Society of Chemical Industry for 1890, p. 1112.

The Transactions of the American Institute of Mining Engineers, vol. 4, p. 60, 1876.

The Transactions of the American Institute of Mining Engineers, vol. 8, pp. 211, 217.

Return ordered printed by the House of Commons, August 14, 1878 (366). Coal Cargoes (Spontaneous Combustion, etc.).

Memorandum relating to Spontaneous Combustion of Coal and Explosion of Coal Gas on Board Ship, etc., by Thomas Gray Assistant Secretary of the Marine Department of the Board of Trade, England.

Collection of Statistics connected with the Coal Fields of the British Islands, by Richard Meade, Assistant Keeper of Mining Records, published by Crosby, Lockwood & Co., London, 1881.

LIST OF COALS BOUGHT FOR THE BRITISH NAVY AND KNOWN AS ADMIRALTY COALS.

[ARRANGED IN TWO CLASSES.]

Practically all in each class may be taken as equal in quality, although slightly varying in hardness and other points.

COLLIERY SCREENED AT TIME OF SHIPMENT.

Class 1.

Ferndale.
Nixon's Navigation.
Albion Merthyr.
Harris Deep Navigation.
National Merthyr.

Class 2.

Cambrian Navigation.
Ocean Merthyr.
Cory's Merthyr.
Hood's Merthyr.
Locket's Merthyr.
Powell's Duffryn.
Dowlais Merthyr.
Hills Plymouth Merthyr.
Standard Merthyr.
Cyfarthfa.

REPORTS OF COMMANDING OFFICERS UPON MOST DESIRABLE COAL.

In the month of August, 1898, the Bureau sent the following circular letter to the Commanders in Chief of the different squadrons on the Atlantic Coast:

NAVY DEPARTMENT, BUREAU OF EQUIPMENT,
WASHINGTON, D. C., *August 31, 1898.*

SIR: 1. The Bureau requests that you will direct the commanding officers of each of the naval ships under your command to address an official letter to this Bureau, stating the trade name of the American coal considered the most desirable for use on board of their respective ships for steaming and other purposes, with reasons for the selection made, so far as possible.

2. No further report is desired from ships which have already made a similar one.

Very respectfully,

(Signed) R. B. BRADFORD,
Chief of Bureau.

One hundred and twenty-three (123) answers were received as follows:

One hundred and seventeen (117) preferred Pocahontas coal.

One (1) preferred anthracite on account of type of boilers (Almy water tube).

One (1) gave no trade name, preferring bituminous or semibituminous coal.

One (1) preferred Cumberland.

One (1) had only tried New River and Georges Creek, and preferred the former.

And the other two classed Pocahontas and New River as equal generally, stating, however, that the former made less smoke and of a lighter color.

The principal reasons given for preferring Pocahontas coal were as follows:

1. It gives best results in speed per ton of coal consumed.
2. It contains the smallest percentage of ash.
3. Less smoke is given off in combustion.
4. It requires less working of fires to keep steam pressure uniform.
5. Better suited to forced draft.
6. Requires less sweeping of tubes.
7. Clinkers to less extent than some other coals

COAL.

EQUIPMENT EXPENSES ABROAD, 1902.

[Extract from report of the Chief of the Bureau of Equipment to the Secretary of the Navy, 1902, pages 47–71.]

EQUIPMENT EXPENSES ABROAD.

There was expended during the fiscal year, under the direction of commanders in chief of fleets and commanders of ships, the sum of $225,000 for supplies and services for equipment purposes, not including the amount expended for coal. This amount is approximate only, full returns not having been received.

COAL.

A total of 382,040 tons of coal, costing $2,220,211.09, at an average of $5.81 per ton, was purchased during the fiscal year.

The following table indicates the amount of coal purchased for steaming purposes since 1892 and the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.	Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.				*Tons.*		
1892	73,467	$550,451.35	$7.49	1898	452,551	$2,122,005.28	$4.68
1893	67,054	449,065.27	6.69	1899	281,169	1,679,510.55	5.97
1894	94,336	640,355.96	6.78	1900	228,395	1,572,652.97	6.88
1895	98,615	527,590.25	5.35	1901	324,108	2,273,111.81	7.01
1896	116,903	620,131.38	5.30	1902	382,040	2,220,211.09	5.81
1897	138,318	655,921.72	4.75				

DOMESTIC COAL.

Of the total amount purchased—viz, 382,040 tons—293,438 tons, costing, with the transportation thereof, the sum of $1,543,869.35, at an average of $5.26 per ton, were purchased within the limits of the United States.

The following table indicates the amount of coal purchased within the United States for steaming purposes since 1892 and the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.	Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.				*Tons.*		
1892	38,450	$221,918.66	$5.77	1898	378,437	$1,520,119.75	$4.02
1893	33,257	147,999.04	4.45	1899	195,216	1,238,355.40	6.34
1894	42,190	178,163.58	4.22	1900	141,921	834,527.34	5.88
1895	50,630	181,985.89	3.59	1901	219,042	1,379,433.51	6.30
1896	55,162	196,795.40	3.57	1902	293,438	1,543,869.35	5.26
1897	82,051	280,091.09	3.41				

FOREIGN COAL.

The balance of the 382,040 tons—viz, 88,602 tons—were purchased by paymasters of ships, mostly abroad, costing the sum of $676,341.74, at an average of $7.63 per ton.

The following table indicates the amount of coal purchased by ships for steaming purposes since 1892, with the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.	Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.				*Tons.*		
1892	35,017	$298,948.55	$8.53	1898	74,111	$601,885.53	$8.12
1893	33,797	301,066.23	8.91	1899	85,953	441,155.15	5.13
1894	52,146	462,192.38	8.86	1900	86,476	738,125.63	8.53½
1895	47,985	336,183.47	7.00	1901	105,066	893,677.81	8.50
1896	61,741	423,335.98	6.85	1902	88,602	676,341.74	7.63
1897	56,268	375,840.63	6.68				

The amount of coal used during the fiscal year was nearly 18 per cent greater than during the preceding year; it was 67 per cent greater than during the fiscal year ending June 30, 1900. It will be seen by the foregoing table that the amount of coal used in the Navy for steaming purposes has increased more than five times during the past ten years.

The cost of coal during the fiscal year was $1.20 or 20 per cent less per ton than during the preceding fiscal year.

The average cost of coal purchased in the United States during the fiscal year was $1.04 per ton less than during the preceding year.

The average cost of coal purchased by ships during the fiscal year was 87 cents per ton less than during the preceding year. The chief reasons for the above-mentioned reductions were due to a decreased cost of Welsh coal at Cardiff, Wales, and very low freights. During the last half of the fiscal year coal freights reached an unprecedentedly low figure. While they have since advanced a certain amount, they are still much below normal rates.

As stated in the last annual report of the Bureau, the price of the best coal mined in the United States was advanced on the 1st of April, 1900, more than 50 per cent of its former price. Since that time it has not been advanced, and at present, generally speaking, the Navy is being supplied with the best coal obtainable at about $2.50 per ton f. o. b. at the tidewater outlets of the mine.

The varying prices of coal shown in the foregoing table, which, for the most part, include the cost of transportation, are due not only to the fluctuating cost of coal itself at the point of shipment and the fluctuating cost of transportation, but to the locality where purchased. For instance, ships on our own coast and in the West Indies can be supplied with coal at very reasonable rates; but in the Pacific, where good coal is scarce and brought a very long distance, and in the Orient, the cost is twice or three times that in the above-mentioned localities. Ships must go wherever their presence is required, which can not be foreseen when preparing estimates, nor can the ever-varying cost of coal or freight be foreseen.

It is gratifying to report that while the total amount of coal consumed by the Navy during the fiscal year was increased 18 per cent the amount of foreign coal purchased was decreased 16 per cent and the amount of domestic coal increased 34 per cent.

The following table indicates the price of the best Welsh coal f. o. b. at Cardiff, Wales, from May, 1899, to date:

Prices of best Cardiff coal at Cardiff, Wales.

Date.	Price per ton.	Date.	Price per ton.	Date.	Price per ton.	Date.	Price per ton.
1899.		1900		1901.		1902.	
May	$3.12 to $3.24	January	$6.48 to $7.20	January	$4.80 to $5.04	January	$4.14 to $4.26
June	3.12	February	5.76 6.00	February	4.44 4.56	February	3.78 3.90
July	3.12 3.18	March	5.40 5.76	March	4.32 4.44	March	3.60 3.72
August	3.12 3.24	April	5.04 5.52	April	4.20 4.32	April	3.66 3.78
September	3.12 3.24	May	5.28 5.64	May	5.04 5.28	May	3.96 4.08
October	3.18 3.36	June	5.28 5.52	June	4.56 4.68	June	3.90 4.02
November	3.30 3.42	July	5.28 5.52	July	5.04 5.16	July	4.08 4.14
December	4.80 5.04	August	5.76 6.00	August	5.04 5.16	August	3.84 3.90
		September	6.48 6.96	September	4.80 4.92	September	3.96 4.02
		October	6.12 6.48	October	4.32 4.38		
		November	4.92 5.16	November	4.08 4.32		
		December	4.44 4.68	December	4.20 4.32		

CONSUMPTION OF COAL.

Of the total amount of coal used in the ships of the Navy 35,458 tons were consumed on board of colliers, torpedo boats, tugs, etc., from which no reports are made of the specific object of expenditure.

Of the balance 52 per cent was consumed for steaming purposes; 45 per cent for distilling, pumping, heating, ventilating, and lighting; 2 per cent for cooking purposes, and 1 per cent for steam launches.

Especial attention is invited to the large amount of coal used in ships for auxiliary purposes, viz, 48 per cent of the entire consumption.

TRANSPORTATION OF COAL.

The Bureau has continued the policy of supplying the best domestic coal obtainable for use on shipboard. This policy necessitates the transportation of coal to many ports of the world, where it can not be obtained at reasonable rates.

During the past fiscal year a total of 153,000 tons of coal were shipped to various foreign and domestic ports, the greater amount having been sent to the Asiatic Station. Of this amount 84,000 tons were sent in chartered vessels, mostly foreign, and 69,000 tons in navy colliers.

The following table will indicate the fluctuating rates of freight on coal from the Atlantic coast to the port of Manila:

Fiscal year.	Average rate per ton.	Fiscal year.	Average rate per ton.
1899	$6.99	1901	$8.63
1900	7.90	1902	5.83

The freight on coal from the Atlantic coast to the Pacific ports remains at a high figure. Cardiff coal can be purchased at San Francisco, duty paid, for considerably less than coal can be shipped from the Atlantic coast. The average price of Admiralty Cardiff delivered at San Francisco during the past fiscal year was $7.83 per ton; during the preceding year it was $9.29 per ton. The average price paid for the best Admiralty Cardiff delivered at Honolulu during the fiscal year was $8.57 per ton; during the preceding year, $9.87 per ton. But few American vessels are offered for coal freight, although it is gratifying to note that the number for coastwise and West Indian ports is increasing.

TRANSPORTATION OF COAL BY NAVY COLLIERS.

There are thirteen navy colliers in commission, manned by merchant crews, as follows:

Ajax.	*Nero.*	*Sterling.*	*Justin.*
Alexander.	*Hannibal.*	*Lebanon.*	*Nanshan.*
Brutus.	*Leonidas.*	*Saturn.*	*Pompey.*
Cæsar.			

The *Saturn, Justin, Nanshan,* and *Pompey* are attached to the Asiatic Squadron. At present the *Justin* is used as a station ship at Guam; she will, however, soon be relieved by the *Supply.* In the opinion of the Bureau the *Nanshan* and *Pompey* are sufficient for the distribution of coal from Manila, where a large amount is kept in stock. The small coal depots throughout the Philippine Islands are now well stocked.

It is recommended that the *Saturn* be sent to the Mare Island Navy-Yard and held for service on the Pacific; also that the *Justin,* when relieved by the *Supply,* be sent to the same place.

The *Hannibal, Leonidas, Sterling,* and *Lebanon* are used to stock coal depots on the Atlantic and Gulf coasts and in the West Indies; also to supply the fleet at points where no depots exist. When used for the latter purpose they perform the important function of exercising the crews of battle ships and cruisers in supplying coal to their ships under war conditions.

The *Ajax, Alexander, Brutus, Cæsar,* and *Nero* are used for the transportation of coal to the Pacific and Orient.

The Bureau again calls attention to previous recommendations advising the construction of two large steam colliers capable of carrying 10,000 tons of coal as cargo and 1,000 tons in bunkers, with accommodations for a naval personnel and liberal amount of stores, and a secondary battery. Such ships would be very useful in time of peace or war. They should be capable of making 12 knots when fully loaded and be economical in making long passages at a speed of 8 or 9 knots. Your attention is invited to the statement in the last annual report of the Bureau on this subject.

COAL TESTS.

Tests of coal have been continued during the year, as in past years. Evaporative or boiler tests are made the New York and Mare Island navy-yards, on all samples of 12 tons each, delivered free of cost to the Government.

A chemical analysis is made at the Washington Navy-Yard on all samples of not less than 4 pounds delivered to the Bureau free of cost.

Exhaustive tests were made during the early part of the year by the torpedo-boat flotilla at Norfolk on Georges Creek coal, from the Consolidation Coal Company, Baltimore, Md.; Pocahontas coal, from Castner, Curran & Bullitt, Norfolk, Va., and New River coal, from the Chesapeake and Ohio agency at Newport News, Va., in order to determine, if possible, which kind was best adapted for the use of torpedo boats. The result showed little difference when the coal was carefully selected in the three varieties.

The following tables contain the result of the chemical analyses of the various samples received. The samples are arranged in the order of the amount of fixed carbon they contain:

Chemical analysis of samples of coal at the Washington Navy-Yard, Washington, D. C.

[Arranged in order of percentage of fixed carbon. Sample selected officially is noted by an asterisk.*]

BITUMINOUS COALS.

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.		Moisture.	Ash.	Sulphur.	Increase in weight at 250° F.
			Combustible.	Noncombustible.				
Powhatan	Irvona, Clearfield County, Pa	86.670	1.060	1.380	3.130	7.560	0.331	1.110
Canmore*	575 miles east of Vancouver, British Columbia	86.367	9.716	.370	.730	2.676	.141	.....
Penrikyber Smokeless Steam	County of Glamorgan, Wales	85.960	9.540	1.250	.590	2.660	.020	.261
Albion Cardiff*	Glamorganshire, Wales	85.169	8.646	2.240	.570	3.237	.138	.....
Ledyob		84.700	.....	.500	1.880	12.920	.278	None.
Canmore*	575 miles east of Vancouver, British Columbia	84.610	9.930	1.380	.590	3.290	.200	.....
Bonanza	Bonanza, Ark	84.520	10.100	1.980	1.060	2.340	.221	.240
Tug River	McDowell County, W. Va	82.780	12.400	1.060	.980	2.780	.042	.323
Albion Cardiff*	Glamorganshire, Wales	82.446	12.397	1.598	.352	3.147	.060	.....
Old Victor		82.207	14.320	.830	.300	2.210	.133	.....
Coal Creek*	Coal Creek, Tenn	82.140	2.530	.830	1.500	13.000	.234	.133
Georges Creek Big Vein Cumberland.	Allegheny County, Md	81.953	11.070	1.681	.260	5.060	.077	.....
Hartford	Sebastian County, Ark	81.680	13.670	2.770	.550	1.330	.830	.040
Albion Cardiff*	Wales, England	81.490	15.010	.890	.750	1.860	.067	.180
Bonanza	Bonanza, Ark	80.746	14.590	.760	.840	2.870	.421	.212
Elk Garden Big Vein Cumberland.	Mineral County, W. Va	80.668	11.681	.630	.480	6.451	.090	.....
Bonanza	Bonanza, Sebastian County, Ark	80,610	14,100	1.250	.630	3.410	.365	.....
Lloydell	Lloydell, Cambria County, Pa	80.590	12.500	1.950	1.240	3.720	.108	.201
Pocahontas*	McDowell County, W. Va	80.580	12.340	.720	1.300	5.060	.129	.417
Tug River*	do	80.540	15.180	.970	.910	2.400	.088	.261
Argyle*	Dunlo, Cambria County, Pa	80.493	10.678	2.930	1.400	4.078	.421	.....
Pocahontas*		80.390	12.840	1.070	1.530	4.170	.276	.109
Lloydell	Lloydell, Cambria County, Pa	80.370	14.680	.635	.925	3.390	.098	.084
Eureka 12		80.318	14.280	.910	.200	4.090	.292	.....
Rockhill	Robertsdale, Huntington County, Pa	80.280	13.380	.860	2.067	3.420	.623	.....
Pocahontas*	Virginia and West Virginia, Tazewell and McDowell counties	80.103	13.593	.590	.430	5.147	.137	.....
Durham	Durham, Lookout Mountain, Georgia	80.068	14.594	1.930	.310	2.922	.176	.....
Tug River*	McDowell County, W. Va	80.040	14.170	1.090	.930	3.770	.213	.364
Argyle*	Dunlo, Cambria County, Pa	79.977	11.408	1.811	.899	5.068	.837	.....
Pocahontas*		79.890	12.600	.740	2.390	4.380	.255	.098
Pocahontas*		79.830	13.430	1.490	.640	4.610	1.300	.....
Powelton		79.820	12.560	.....	1.460	6.160	.014	.118
Pocahontas*		79.780	12.520	.600	1.720	5.380	.285	.160
Cameron	Cameron, Ind. T	79.760	4.740	.310	9.730	5.460	.213	.067
Loyal Hanna	Westmoreland County, Pa	79.677	12.107	1.740	.850	4.797	.829	.....
Sonman	Stony Creek Mine, Hoversdale, Somerset County, Pa	79.497	12.619	1.849	.721	5.089	.225	.....
New River	Fayette County, W. Va., near Thurmond	79.470	18.000	.570	.630	1.330	.188	.291
Miller Vein*	Cumberland County, Pa	79.384	10.951	2.107	1.333	5.251	.974	.....
Tug River*		79.350	14.090	1.110	.910	4.540	.693	.300
Elk Garden Big Vein Cumberland.		79.310	12.800	1.170	1.000	5.720	.338	.555
Atlantic No. 1		79.300	16.850	1.520	.250	1.920	.160	.....
Pocahontas		79.260	15.240	.590	.790	4.120	.081	.566
Acme Smokeless	Pennsylvania	79.174	9.050	.903	.557	9.690	.606	.....
Fairview	Somerset County, Pa	79.162	10.427	1.170	1.180	7.597	.464	.....
Yellow Run		79.078	14.140	1.660	.401	4.619	.102	.....
Listie Smokeless Steam	Listie, Somerset County, Pa	79.050	13.760	.810	1.310	5.070	.236	.262
Pocahontas*	Virginia and West Virginia, Tazewell and McDowell counties	78.980	13.650	.583	1.337	5.250	.200	.....
Tug River*		78.940	16.020	.780	.930	3.330	.370	.501
Davis Steam	Mineral County, W. Va	78.900	11.540	.760	.910	7.890	1.010	None.
Elk Garden Big Vein Cumberland.		78.850	13.040	.610	.960	6.540	.386	.558
Macdonald Colliery*	Fayette County, W. Va	78.790	17.230	1.020	.840	2.120	.199	.260
Pocahontas*	Majestic Mine	78.750	14.260	1.790	.040	5.160	.603	.085
Russelville	Russelville, Ark	78.640	11.020	.830	1.010	8.500	.108	.324
Spartan	Rendville, Fayette County, W. Va	78.510	17.440	1.420	1.320	1.310	.066	.251
Albion Cardiff*	Wales, England	78.480	16.760	.930	.640	3.190	.062	.121
Pocahontas*	McDowell County, W. Va	78.480	13.150	.780	1.220	6.370	.092	.364
Georges Creek Big Vein Cumberland.*	Allegheny County, Md	78.328	14.856	1.490	.510	4.576	.240	.....
Argyle	Dunlo, Cambria County, Pa	78.193	15.277	.803	.697	4.756	.274	.....
Elk Garden Big Vein Cumberland.	Mineral County, W. Va	78.145	15.115	.978	1.062	4.406	.294	.....
Georges Creek Big Vein Cumberland.	Allegheny County, Md	78.088	12.850	1.230	.500	6.830	.502	.....
Elk Horn	Lewis County, Wash	77.953	1.036	1.940	1.310	17.526	.235	.....
Davis Steaming		77.950	15.010	.950	.870	5.220	.463	.358
Prairie Creek or Huntington	Huntington Ark	77.830	14.030	1.180	1.330	5.630	1.330	.357
Macdonald Colliery*	Fayette County, W. Va	77.640	18.110	1.150	0.830	2.270	0.126	0.270
Pocahontas*	Virginia and West Virginia, Tazewell and McDowell counties	77.610	16.970	.700	.960	3.760	.431	.180
Pocahontas*		77.600	15.360	1.590	2.570	2.880	.280	.214
Sonman	Stony Creek Mine, Hoversdale, Somerset County, Pa	77.600	16.540	.270	.990	4.600	.173	.203
Morrisdale*	Morrisdale, Clearfield County, Pa	77.320	14.197	1.347	.593	6.077	.466	.853
Vinton	Vintondale, Pa	77.230	17.510	.190	1.000	4.070	.981	.211
Henrietta*	Dunlo, Cambria County, Pa	77.222	14.707	2.417	.783	4.207	.664	.....
Pocahontas*	Majestic Mine	77.130	13.420	2.130	1.060	6.260	.596	.122
Elk Garden Big Vein Cumberland.	Mineral County, W. Va	76.940	15.330	1.170	1.050	5.510	.210	.111
Pocahontas		76.900	15.470	.840	1.270	5.520	.109	.396
Fairview	Somerset County, Pa	76.139	12.859	1.039	1.381	8.134	.443	.....
Elk Garden	Mineral County, W. Va	75.890	16.700	.750	1.260	5.400	.355	.150
New River	Fayette County, W. Va	75.890	20.230	1.170	.980	1.730	.030	.245
Pocahontas*	McDowell County, W. Va	75.760	17.220	.970	1.110	4.940	.291	.450
Pocahontas*		75.600	16.800	.230	1.410	5.960	.....	.....
Georges Creek Big Vein Cumberland.*	Alleghany County, Md	75.400	16.460	.740	1.090	6.310	.229	.166
Pocahontas*		75.220	17.010	.270	1.390	6.110	1.198	.107
Thomas Steam or Cumberland *	Upper Potomac	75.209	17.411	.891	.749	5.561	.079	.....
Georges Creek Cumberland Big Vein.	Lonaconing, Md	75.160	17.380	1.070	.930	5.460	.175	.365

Chemical analysis of samples of coal at the Washington Navy-Yard, Washington, D. C.—Continued.

BITUMINOUS COALS—Continued.

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.		Moisture.	Ash.	Sulphur.	Increase in weight at 250° F.
			Combustible.	Noncombustible.				
Big Bend*	Twin Rocks, Cambria County, Pa	75.010	15.980	1.089	0.261	6.660	1.000	
Pardee	Patton, Cambria County, Pa	74.922	15.814	2.320	1.480	4.904	.560	
Tug River*	McDowell County, W. Va	74.900	16.060	1.110	.800	7.130	.295	0.479
Big Vein Cumberland	Elk Lick, Somerset County, Pa	74.870	16.114	.701	.995	7.320	.140	.300
Pocahontas*		74.810	17.630	.280	1.360	5.920	1.210	.110
Eureka 22		74.429	19.410	1.330	.310	4.390	.131	
Mount Vernon*	Houtzdale Clearfield County, Pa	74.198	17.404	1.289	.751	5.645	.713	
Patton	Patton, Cambria County, Pa	74.165	13.901	1.344	.606	9.291	.693	
Pocahontas*	Virginia and West Virginia, Tazewell and McDowell counties.	74.150	12.264	1.517	1.063	10.844	.162	
Pardee	Patton, Cambria County, Pa	72.993	18.248	1.342	.598	6.309	.509	
Pearson Warrior	Near Birmingham, Jefferson County, Ala	72.764	18.953	3.920	.940	3.283	.170	
Crows Nest	Fernie, British Columbia	72.690	19.010	1.820	.370	6.110	.097	.079
New River*	Fayette County, Va	72.640	18.200	.210	2.870	6.080	1.460	.102
Crows Nest	Fernie, British Columbia	72.500	18.610	1.720	.600	6.570	.021	.080
Davis Steaming		72.130	19.060	1.040	.970	6.800	.507	.445
Pearson Warrior	Near Birmingham, Jefferson County, Ala	72.030	23.960	1.840	.510	1.261	.399	
Pocahontas*	Majestic Mine	72.020	16.900	1.600	.900	8.580	.600	.089
Standard Eureka*	Berwind-White Co.'s mines, Clearfield County, Pa	71.632	20.054	1.551	.479	4.324	1.960	
Thomas Steam or Cumberland.	Upper Potomac	71.287	21.213	.751	1.059	5.543	.147	
Albion Merthyr	Glamorganshire, South Wales	71.268	19.940	2.050	.590	4.828	1.316	
New River	Fayette County, Va	71.054	18.933	.834	1.018	7.976	.815	
New Pardee	Patton, Cambria County, Pa	70.860	17.453	1.550	.650	9.340	.140	
Indiana	Glen Campbell, Indiana County, Pa	70.740	22.070	.830	.940	5.420	.431	.433
Spartan	Rendville, Fayette County, W. Va	70.700	18.560	1.290	2.050	7.400	.310	.121
Gazzam	Gazzam, Clearfield County, Pa	70.618	20.279	1.621	0.510	6.690	.282	
Pocahontas Lump	Poteau, Ind. T	70.500	19.020	1.240	.500	8.740	1.690	.218
Labuan		70.340	7.270	11.480	6.010	3.440	1.460	.159
Sloss	Coalburg, near Birmingham, Ala	70.311	24.197	2.000	.330	2.737	.425	
Glenwood	Glen Campbell, Indiana County, Pa	70.118	23.639	1.011	1.289	3.530	.413	
Clearfield Empire Big Vein*	Clearfield County, Pa	70.036	17.969	1.019	.831	8.729	1.416	
Albion Cardiff	Glamorganshire, South Wales	69.920	14.910	1.170	1.620	12.380	.077	.463
Comox*	Union, Vancouver Island, British Columbia	69.750	19.270	.920	1.100	8.960	.530	.250
Reynoldsville	Jefferson County, Pa	69.590	23.460	1.960	1.020	3.970	.671	.606
Pratt	Pratt Mines, Jefferson County, Ala	69.327	26.271	1.480	.410	2.321	.191	
Milldale	Milldale, Tuscaloosa County, Ala	69.236	27.430	1.200	.080	1.770	.284	
Montezuma	Near Fairfax, Pierce County, Wash	69.010	20.090	2.830	.640	7.440	.391	.173
Toms Creek*	Wise County, Va	68.380	25.870	1.230	1.110	3.410	.084	.383
Pratt	Pratt Mines, Jefferson County, Ala	68.351	25.773	1.740	.360	3.703	.073	
Comox	Union, Vancouver Island, British Columbia	68.255	16.301	8.290	.871	5.924	.359	
Metropolitan	27 miles from Sydney, New South Wales	68.170	16.250	1.090	.930	13.560	.091	.101
Albion*	Glamorganshire, South Wales	68.111	15.091	2.730	.460	13.509	.099	
Moshannon Creek	Gazzam Mines, Clearfield County, Pa	67.968	21.951	1.310	.430	7.251	1.090	
Toms Creek*	Wise County, Va	67.720	25.630	1.290	1.080	4.280	.280	.111
Cahaba	Blockton, Bibb County, Ala	67.430	24.940	3.130	1.030	3.268	.192	
Indianola Lump	No. 3 Shaft, Poteau, Ind. T	67.110	21.000	.160	.610	11.120	2.430	.209
Westport	Beulah River, Buller County, Nelson Province, South Island, New Zealand.	66.920	29.150	1.700	1.050	1.180	.741	.157
South Bulli*	South Bulli, New South Wales	66.910	20.040	1.260	.890	10.350	.401	.200
Toms Creek*	Wise County, Va	66.690	27.030	1.580	1.030	3.670	.282	.092
Toms Creek*	....do	66.540	26.590	1.250	.960	4.660	.200	.073
Osborne Wallsen	Illawarra district, New South Wales	66.110	16.840	.870	1.640	14.540	.727	.859
Crows Nest	Fernie, British Columbia	66.000	15.920	.580	.310	17.190	.020	.060
Loyal Hanna*	Westmoreland County, Pa	65.838	22.966	1.421	.610	7.886	1.280	
Dorchester	Dorchester, Va	65.660	28.520	1.040	1.320	3.460	.483	.416
Coal Creek	Briceville, Anderson County, Tenn	65.419	27.220	2.020	1.140	4.000	.201	
Youghiogheny	Ocean Mine No. 2, Fayette County, Pa	64.960	29.690	.900	1.510	2.940	.024	.359
Stonega	Stonega, Va	64.780	30.650	.830	1.370	2.370	.119	.551
Philippi	Philippi, W. Va	64.760	26.120	1.480	1.060	6.580	.894	.650
Meriden, Cumberland*	West Virginia	64.710	24.780	2.170	1.000	7.340	1.060	.400
Toms Creek	Wise County, Va	64.688	28.787	1.390	.860	4.150	.125	
Toms Creek	....do	64.510	29.204	1.690	.630	3.804	.162	
Mingo	Claiborne, County, Tenn	64.368	30.226	2.661	.949	1.656	.140	
Cahaba*	Blockton, Bibb County, Ala	64.329	25.705	1.900	1.320	6.695	.051	
Red Jacket	Matewan, W. Va	64.230	28.030	1.170	1.650	4.920	.685	.649
Mount Kembla	Illawarra district, New South Wales	63.940	18.680	.980	1.020	14.380	.059	.208
Black Diamond*	Coalcreek, Tenn., Black Diamond Coal Co	63.797	30.800	1.413	.497	3.297	.214	
Looney Creek	Looney Creek, Va	63.700	31.510	1.430	1.400	1.960	.225	.401
South Bulli*	South Bulli, New South Wales	63.640	23.150	.950	1.070	11.190	.196	.429
Southern Express No. 1		63.620	28.830	.910	1.050	5.590	.712	.392
Cripple Creek	Briceville, Anderson County, Tenn	63.420	30.040	1.430	1.770	3.340	.427	.314
Battleship	Coalcreek, Tenn	63.150	29.780	1.869	2.351	2.651	.199	
Pocahontas (Washington)	Palmer, King County, Wash	63.070	27.050	1.100	1.770	7.010	.165	.417
Black Diamond	Coalcreek, Tenn	63.036	30.409	2.138	.572	3.618	.227	
Pittsburg (mine No. 1)	Pittsburg Consolidated Coal Co., McDonald Station, Washington County, Pa.	63.010	30.120	1.550	2.590	2.750	.172	.300
Toms Creek*	Wise County, Va	62.890	29.210	2.730	1.320	3.850	.021	.550
Blue Canyon*	Blue Canyon Coal Co., Whatcom County, Wash	62.744	29.649	1.830	1.790	3.679	.308	
Fraterville	Coalcreek Coal Mines, Tenn	62.720	31.470	1.290	1.080	3.440	.299	.790
Flemington	Flemington, W. Va	62.720	31.750	.890	.670	3.970	1.400	.609
Battleship	Black Diamond mine	62.680	31.950	1.290	2.050	2.030	.248	.752
Kaiping No. 5 Lump*	Kaiping, 50 miles northeast from Tientsin, China	62.420	30.080	2.420	.970	4.110	.026	.166
Shawmut (mine No. 1)	Horton Township, Elk County, Pa	62.400	29.450	1.240	1.710	5.200	1.760	.534
Fairhaven	Skagit County, Wash	62.395	20.175	2.090	.310	14.885	.145	
Burnwood Colliery	Near Newcastle, New South Wales	62.270	29.400	.720	1.120	5.490	.097	.701
Youghiogheny (Ocean mine No. 1).	Fayette County, Pa	62.260	26.760	1.200	1.580	8.200	.022	.318
Gravity Creek	Near Westport, New Zealand	62.230	32.700	1.290	1.010	2.770	.453	.113
Hetton*	Bullock Island, opposite Newcastle, New South Wales, Australia.	62.193	30.466	1.317	2.143	3.569	.753	
Mingo	Claiborne County, Tenn	62.088	27.966	2.581	.959	4.666	1.740	
Pinesville	Pinesville Ky	62.070	33.590	1.310	1.940	1.090	.129	.603
Gamble	Alabama	61.960	24.670	.900	1.880	10.590	.435	.423
Shawmut (mine No. 2)	Horton Township, Elk County, Pa	61.920	27.000	1.400	1.140	8.540	1.960	.340
Kaiping	Kaiping, 50 miles northeast from Tientsin, China	61.920	22.890	1.250	.660	13.280	.594	.301
Jellico*	Campbell County, Tenn., and Wheatley County, Ky	61.868	31.559	3.710	.690	1.859	.314	
Westport*	Beulah River, Buller County, Nelson Province, South Island, New Zealand.	61.798	34.929	1.020	1.630	.199	.424	
Shawmut (mine No. 3)	Horton Township, Elk County, Pa	61.670	32.060	1.000	1.680	3.590	.278	.702
Pardee*	Patton, Cambria County, Pa	61.664	28.845	3.399	2.282	3.484	.326	
Philippi*	Meriden, W. Va	61.480	25.100	1.200	1.490	10.730	1.480	.390

Chemical analysis of samples of coal at the Washington Navy-Yard, Washington, D. C.—Continued.

BITUMINOUS COALS—Continued.

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.		Moisture.	Ash.	Sulphur.	Increase in weight at 250° F.
			Combustible.	Noncombustible.				
Paint Rock	Oneida, Tenn	61.440	28.110	2.940	2.110	5.400	0.185	1.120
A. & A. Co	Near Newcastle, New South Wales	61.390	31.470	.970	2.080	4.090	.288	.725
New Chum*		61.380	29.190	1.080	1.930	6.420	.160	.431
Kaiping	Kaiping, 50 miles northeast Tientsin	61.280	27.290	1.220	.580	9.630	.210	.294
Black Diamond*	Coalcreek, Tenn., Black Diamond Coal Co	61.191	31.985	1.291	.539	4.695	.299	.....
Swanbank*	Pinkerba, Queensland, Australia	61.220	24.220	2.000	1.880	10.680	.194	.661
Los Cerrillos	Santa Fe, N. Mex	61.180	26.500	3.870	1.430	7.020	.223	.439
Hetton	Bullock Island, opposite Newcastle, New South Wales, Australia.	61.051	30.481	1.917	1.883	4.492	.176	.....
Laurel County	Pittsburg, Laurel County, Ky	61.000	31.500	2.590	2.050	2.860	1.120	1.070
Killingworth	Near Newcastle, New South Wales	60.570	31.620	1.020	2.460	4.330	.192	.618
Wallsend	....do	60.393	28.731	2.160	2.540	6.001	.175	.....
Denniston	Near Westport, New Zealand	60.420	34.210	1.500	1.760	2.110	.396	.553
Guanta*	Naricual, near Guanta, Venezuela	60.240	35.410	.780	1.490	2.080	.824	.382
Stockton	Near Newcastle, New South Wales	60.170	33.800	.920	1.980	3.040	.115	.456
Wickham and Bullock Island	....do	60.170	29.640	1.070	2.250	6.870	.252	.418
New Swanbank*	Brisbane River, Queensland, Australia	60.150	26.380	1.020	3.630	8.820	.337	1.180
Hetton	Bullock Island, opposite Newcastle, New South Wales, Australia.	60.040	32.990	1.350	1.820	3.800	.167	1.230
Fairhaven	Skagit County, Wash	59.980	33.030	2.000	2.980	2.010	.202	.867
Sneddon	New South Wales	59.960	34.680	.730	1.980	2.650	.034	.319
Dudley	Near Newcastle, New South Wales	59.850	32.010	.850	2.100	6.190	.144	.820
Lambton	....do	59.790	28.540	1.060	2.570	8.040	.223	.974
Burke's or Bogside*	Pinkenba, Queensland	59.550	24.980	2.150	1.940	11.380	.450	.489
Cape Breton*	Reserve mines, Cape Breton	59.520	30.132	2.139	2.781	4.262	1.166	.....
Kanawha	Kanawha County, W. Va., near Charleston	59.350	30.930	2.650	2.150	4.920	.007	.....
Waratha	Near Newcastle, New South Wales	59.230	31.990	1.070	1.920	5.790	.071	.530
Corona	Corona, Walker County, Ala	59.170	30.930	2.320	.720	6.090	.770	.....
Wallarah*	Northumberland County, New South Wales	59.080	30.620	.770	1.940	7.590	.104	.375
Cooperative	Plattsburg, New South Wales	58.940	25.400	1.170	2.410	12.080	1.330	.605
Killingworth	West Wallsend, New South Wales	58.890	30.860	1.070	2.360	6.820	.124	.443
Lota*	Lota, Chile	58.760	32.620	1.870	3.900	2.850	3.400	.....
Sunnyside	Sunnyside, Utah	58.750	34.620	2.040	2.400	2.190	.627	.455
Duckenfield*	Australia	58.680	29.220	1.340	2.710	8.050	.274	.564
Carrington	Near Newcastle, New South Wales	58.570	32.780	1.320	1.650	5.680	.222	.754
Duckenfield		58.530	31.290	.950	2.300	6.930	.116	.977
American Cardiff		58.450	31.650	.900	1.850	7.150	1.630	.308
Comox*	Union, Vancouver Island, British Columbia	58.400	22.717	1.605	.745	15.867	.666	.....
Zunbunna	Victoria Colliery, 73 miles from Melbourne	58.320	25.240	1.650	4.380	10.410	.200	.715
Wear Lump	Pittsburg, Crawford County, Kans	58.230	29.600	2.960	.730	8.480	4.880	.656
Outtrim	Outtrim, Victoria, 76 miles from Melbourne	58.210	31.130	1.250	4.390	5.020	.071	.739
Manchester	Altamont, Ky	58.160	35.500	1.470	2.610	2.260	.461	1.050
Philippi*	Meriden, W. Va	58.090	22.430	1.320	1.510	16.650	1.980	.212
Coal Valley	Coal Valley, near Birmingham, Ala	58.084	28.968	3.190	1.220	8.218	1.220	.....
Whitwood*	Bundanba, 18 miles from Brisbane River, Queensland, Australia.	58.020	27.730	.920	3.710	9.620	.535	.795
Lambton Colliery	New South Wales	57.910	23.990	.960	2.520	14.620	.892	.521
Sunnyside*	Utah	57.890	34.590	2.530	2.310	2.680	.637	.678
Duckenfield	Brown's Colliery, near Newcastle, New South Wales	57.870	30.160	1.020	2.290	8.660	.220	.751
Northern Extended	Near Newcastle, New South Wales	57.750	30.000	1.180	2.520	8.550	.187	.158
Franklin	Near Seattle, Wash	57.580	33.860	1.500	3.260	3.800	.097	1.610
Newcastle Wallsend	Northumberland County, New South Wales	57.550	33.170	.470	2.390	6.420	.154	.677
Monongahela Gas Coal	First Pool Mine, Monongahela Gas Coal Co., Willack Station, Allegheny County, Pa.	57.500	32.880	.890	1.060	7.670	2.880	.406
Australian	Stewart, Klightley, New South Wales	57.350	35.030	1.310	2.100	4.210	.240	.231
Cooperative	Wallsend, Newcastle, New South Wales	57.350	30.480	1.020	2.480	8.670	4.530	.344
McAlester	Alderson, Ind. T	57.340	32.380	.980	2.300	7.000	.201	1.502
Hetton	Carrington, New South Wales	57.290	29.000	.810	2.450	10.450	.823	.400
New Winning	Newcastle, New South Wales	57.110	31.060	1.210	2.540	8.080	.468	1.230
New Vancouver*	Southfield Pit, near Nanaimo, Vancouver Island, British Columbia.	56.948	34.075	1.020	1.040	6.665	.252	.....
Wickham and Bullock Island	Carrington, New South Wales	56.920	29.040	1.080	2.730	10.230	.440	.752
Wilkeson*	Pierce County, Wash	56.895	22.505	1.040	.700	18.715	.145	.....
Providence	Providence, Ky	56.740	30.600	1.860	4.040	6.760	.807	1.170
Pacific Cooperative	Near Newcastle, New South Wales	56.490	30.800	1.030	2.790	8.890	.584	.465
Franklin*	(McKay vein) near Seattle, Wash	56.400	36.084	3.170	1.300	2.884	.162	.....
Wellington*	Wellington, Vancouver Island, British Columbia	56.400	25.300	6.970	1.603	9.520	.207	.....
Tagawa	Moji, Japan	56.130	36.080	1.110	2.910	3.770	.107	.463
Black Diamond	Near Seattle, Wash	56.084	31.246	5.320	3.040	4.166	.144	.....
Wallsend*	Newcastle, New South Wales, Australia	56.014	23.281	3.768	3.392	13.161	.384	.....
Muke	Kutchinatsu, Japan	56.000	31.560	.890	.770	10.780	.530	.201
Flemington	Flemington, W. Va	55.760	32.900	1.159	.601	9.580	1.880	.203
Wallarah	Catherine Hill Bay, New South Wales	55.760	29.020	.810	3.400	11.010	.204	.491
Coal Valley	Coal Valley, Walker County, Ala	55.750	31.220	2.800	1.180	6.650	2.400	.....
Corona*	Corona, Walker County, Ala	55.550	31.212	1.220	1.230	9.612	1.176	.....
Wallsend*	Near Newcastle, New South Wales	55.380	29.060	1.210	2.350	12.000	.417	.398
Yokoshima*	Nagasaki, Japan	55.220	35.860	2.450	1.440	5.030	.086	.774
Richmond Vale	Northumberland County, New South Wales	55.080	33.060	1.050	2.660	8.150	.406	.500
Takashima*	Nagasaki, Japan	55.040	33.980	1.130	1.190	8.660	.186	.258
Seahan	West Wallsend, New South Wales	54.940	33.270	.910	2.570	8.310	.111	.434
Tagawa	Bujen, near Kokura	54.560	35.460	.970	2.720	6.290	.038	.250
Roslyn	Roslyn, Killetas County, Wash	54.550	32.040	1.510	2.050	6.850	.106	.402
Brown's Duckenfield	Near Newcastle, New South Wales	54.510	31.490	1.120	2.650	10.230	.307	.495
Kemmerer	Mine No. 4, Kemmerer, Uinta County, Wyo	54.210	34.730	2.340	3.580	5.140	.414	.703
Hokoku	Moji, Japan	53.910	36.020	.890	2.800	6.380	.117	.562
Newcastle	Near Seattle, Wash	53.806	25.433	3.598	7.920	8.023	1.148	.....
Kokoku	Bujen, near Kokura	53.720	35.010	1.060	2.500	7.710	.082	.327
Roslyn*	Roslyn, Killetas County, Wash	53.656	30.824	1.970	1.450	11.944	.156	.....
Greta	Near Newcastle, New South Wales	53.640	35.580	1.320	1.670	7.790	.373	.193
Kemmerer	Mine No. 1, Kemmerer, Uinta County, Wyo	53.610	37.170	2.430	3.000	3.190	.414	.825
Kanada Lump	Tagawa, Bujen, near Kokura	53.580	34.030	1.210	2.710	8.470	.067	1.190
Coal Creek	Korumburra, Victoria	53.280	33.720	1.830	7.210	3.960	.002	1.482
Rock Springs	Rock Springs, Wyo	53.270	33.970	2.000	6.650	4.290	.399	.502
Kanada	Moji, Japan	53.250	38.100	1.160	2.870	4.620	.073	.370
Ohnoura Lump	Naokata, Chikujen, near Kokura	53.180	35.560	.970	2.110	8.180	.126	.992
South Prairie*	Pierce County, Wash	53.010	32.950	.890	1.560	11.590	.221	.340
Davis Mine	Near Tacoma, Wash	52.750	25.510	2.560	2.430	16.750	.160	None.
Kemmerer*	Kemmerer, Wyo	52.740	38.140	1.230	3.790	4.100	.284	.343
Wellington*	Wellington, Vancouver Island, British Columbia	52.602	27.927	1.979	1.821	15.007	.664	.....
East Greta	Near Newcastle, New South Wales	52.590	39.950	.930	2.020	4.510	.708	.671
Ocean Lump	Mineral County, W. Va	52.350	32.650	2.210	.880	11.910	2.690	.265

Chemical analysis of samples of coal at the Washington Navy-Yard, Washington, D. C.—Continued.

BITUMINOUS COALS—Continued.

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.		Moisture.	Ash.	Sulphur.	Increase in weight at 250° F.
			Combustible.	Noncombustible.				
Black Diamond*	Near Seattle, Wash	52.022	30.272	7.964	5.356	4.032	0.354	.....
Beaver Hill		51.984	33.165	4.379	7.101	2.825	.546	.....
East Greta	West Maitland, New South Wales	51.970	32.150	.990	2.070	12.820	1.660	0.304
Richmond Vale		51.940	34.200	1.130	2.100	10.630	1.640	.472
Castle Gate		51.940	33.000	1.490	2.840	10.730	.205	.250
Ida Lump	Tagawa, Bujen, near Kokura	51.910	35.150	.720	2.530	9.690	.993	.586
Yubari	Yubari, island of Hokkaido, Japan	51.420	40.600	2.050	1.350	4.580	Trace.	.....
Gilman		51.321	27.550	5.090	10.240	5.714	.085	.....
Yubari Lump	Yubari County, Ishikari Province, Japan	51.110	39.790	1.590	1.090	6.420	.081	.420
Labuan	Labuan Island, Borneo	51.100	36.710	2.740	6.010	3.440	1.460	.159
Akaike*	Tagawa Gun Bozen, Japan	51.090	28.020	1.040	3.390	16.460	.302	.708
Yoshinotani	Karatsu, Hijen	51.000	35.520	1.270	1.890	10.320	.536	.421
Miike Pillar	Chekugo, near Kokura	50.850	37.000	1.230	.820	10.100	1.010	.701
Ochi*	Kacatsu, Japan	50.810	36.390	2.370	2.390	7.540	.167	.400
Koinatsu*	Moji, Japan	50.600	35.400	2.690	2.770	8.540	.207	.733
Kakoiwa	Karatsu, Hijen	50.510	37.310	1.390	1.610	9.180	.993	.387
Kakoiwa Lump	do	50.260	34.700	.790	2.510	11.740	.619	.109
Roslyn*	Roslyn, Killetas County, Wash	50.109	30.633	3.642	2.718	12.753	.145	.....
Yoshinotani*	Karatsu, Japan	49.950	37.450	.670	2.520	9.410	.694	.352
East Greta	East Greta, near Newcastle, New South Wales	49.800	37.040	.990	2.010	10.160	1.020	.460
Wallsend	do	49.710	37.400	.930	1.540	10.420	1.910	.368
Yaniano	Moji, Japan	49.590	35.380	1.350	2.720	10.960	.154	.290
Thurber	No. 7 Shaft, Texas and Pacific Coal Company, Thurber, Tex.	49.430	32.930	2.220	3.350	12.070	.639	.491
Yaniano	Yaniano, Chikuyen, near Kokura	49.340	37.520	1.810	2.430	9.620	.601	.532
Yoshinotani	Karatsu, near Hijen	49.320	38.390	1.070	1.960	9.260	1.050	.900
Hikweangi	Whangario, Auckland, New Zealand	49.290	36.710	2.920	6.050	5.030	3.180	.372
Montevallo	Aldrich, Ala	48.990	34.850	1.330	.660	14.270	.672	.344
Namazutu	Koho Gun Chikuzen	48.960	32.480	1.070	1.260	15.230	.263	.305
Castle Gate	Castle Gate, near Helper, Carbon County, Utah	48.630	38.660	1.050	2.300	9.360	.200	.433
(A sample)	Outcroppings, Aleutian Islands, Alaska	48.320	31.020	2.420	4.320	13.920	.070	.600
Newcastle	No. 4 Vein, near Seattle, Wash	48.320	28.990	3.320	13.590	5.780	.164	3.780
Komatzu	Tagawa Gun Buzen	47.980	31.680	1.210	3.500	15.630	.085	.620
Kishima*	Moji, Japan	47.800	40.110	.820	2.160	9.110	.903	.508
Comox*		47.610	22.010	1.940	2.960	25.480	10.110	.203
Newcastle*	No. 4 Vein, near Seattle, Wash	46.815	29.798	3.047	12.573	7.317	.450	.....
Ohnoura	Moji, Japan	46.800	32.150	1.150	2.300	17.600	.036	.504
Franklin	Near Seattle, Wash	46.668	30.310	3.191	4.559	15.080	.192	.....
Bryant	Issaquah, Kings County, Wash	46.274	27.330	4.000	13.380	8.349	.217	.....
Wellington	Wellington, Vancouver Island, British Columbia	46.160	36.850	2.050	2.090	12.850	.563	1.220
Greta	Greta, Northumberland County, Newcastle	46.050	35.010	.860	3.160	14.920	2.030	.415
Nanaimo*	Nanaimo, Vancouver Island, British Columbia	46.001	33.762	1.998	3.352	14.322	.167	.....
Hondo	Kurate Gun Chikuzen	44.310	29.070	1.420	3.590	21.610	.183	.536
Newcastle*	No. 4 Vein, near Seattle, Wash	44.289	35.232	2.997	12.143	5.172	.167	.....
Nanaimo*	Nanaimo, Vancouver Island, British Columbia	44.122	35.383	1.980	2.080	15.682	.753	.....
Yubari	Yubari County, Ishikari Province, Japan	43.650	35.600	1.440	1.480	17.830	.138	.275
Cececapa	State of Vera Cruz, Mexico	39.100	30.070	3.590	17.470	9.770	.320	None.
Cook Inlet	Cook Inlet, Alaska	38.120	35.200	4.650	17.500	4.430	.073	None.
Pikesville	Pikesville, Ky	36.530	42.110	1.180	.640	19.540	2.580	.438
Canaval	Poteau, Ind. T	35.350	41.296	1.569	.601	18.506	2.678	.710

ANTHRACITE COALS.

Mahanoy Schuylkill, colliery No. 2.	Schuylkill County, Pa	94.630	2.154	0.141	0.309	2.633	0.133	.....
Morea Middle Lehigh	Lehigh County, Pa	93.990	1.114	.191	.779	3.793	.133	.....
Do	do	90.227	1.540	.401	.439	7.190	.203	.....
Kohonoor, colliery No. 1	Schuylkill County, Pa	87.966	1.863	.650	2.690	6.694	.137	.....
Mahanoy Schuylkill, colliery No. 2.	do	86.854	.901	.651	2.919	8.491	.184	.....
Shenandoah Schuylkill	do	85.250	1.060	.290	.501	11.810	1.080	.....
Wyoming Mine	Wyoming Mine, Pa	85.185	7.128	.000	.470	6.778	.439	.....
Bryn Blaen	Glamorganshire, Wales	84.600	7.400	.650	1.300	6.050	.198	0.409
Otto Mine	Pennsylvania	84.575	4.859	.349	.451	9.538	.228	.....
Lykens Valley	Dauphin County, Pa	84.343	5.192	.371	.309	9.622	.163	.....
Wilkesbarre	Wilkesbarre, Pa	83.971	3.668	.560	2.910	8.637	.254	.....
Kaska William		83.441	.614	.570	2.960	12.294	.121	.....
Lackawanna	Lackawanna County, Pa	81.716	6.793	1.357	1.773	8.012	.349	.....
Natalie	Shamokin district, Schuylkill County, Pa., Buck Mountain vein.	79.236	11.134	.057	.423	9.023	.127	.....
Glyn Neath	Glyn Neath, Glamorganshire, Wales	78.328	14.250	.690	2.700	4.576	.240	.....
Wilkesbarre	Wilkesbarre, Pa	77.122	1.611	.959	4.401	15.331	.576	.....
Chimbote	Near Chimbote, Peru	71.560	None.	10.440	10.370	7.630	.370	None.

ARRANGEMENTS FOR SUPPLYING COAL TO NAVAL SHIPS IN FOREIGN PORTS.

The Bureau has made agreements in sixty-one foreign ports to supply ships of the Navy with coal at below current rates. This method, inaugurated three years ago, has proved not only convenient but economical, and is generally adopted for all large navies of the world.

COAL AND WATER BARGES.

Extended reference was made in the last annual report of the Bureau to the necessity of providing ample coal and water barges for use at various naval and coaling stations, in order to insure supplying ships rapidly with coal and water. The first coal barge acquired for naval use was in February, 1898; at present there are, built and building, a total of 69 coal barges and 8 water barges.

NAVAL COAL DEPOTS.

The Bureau in its annual report for 1899 fully discussed all previous efforts of the Department to establish depots for supplying coal to our ships of war. By consulting this report it will be seen that these efforts were meager and the results small.

The great importance of the subject was forced upon the attention of the Department by the Spanish war. Since that event progress has been fair and appropriations liberal. The great need of deposits of coal for naval use wherever the presence of ships may be necessary is becoming more and more apparent every year, and is due to the increase of the Navy and the expansion of the country.

It may be expected that the demand for naval coal depots will be greater in the future; in the opinion of the Bureau this demand has only just begun. It is impossible at present to state definitely, with the changing politics of the world, what the needs of the future may be. Our needs at present, however, are sufficient to require the greatest efforts the Department can put forth in this direction.

An additional reason for always having large supplies of coal in store has been forced upon the attention of the Bureau during the past year, viz: The interruption in the flow of supplies by reason of strikes. The fleet narrowly escaped being left without coal last summer on this account. What has occurred in the past may be expected to occur in the future. Should there be a general strike of bituminous coal miners, or employees of railroads carrying coal to tide water, or in transportation lines generally, the ships of the Navy would at present be helpless. The Bureau knows of no way of overcoming this danger except by carrying large stocks of coal on hand. It appears appropriate, in this connection, to state that the French Government carries a stock of 200,000 tons of coal at Toulon and the Government of Great Britain nearly if not quite this amount at Malta.

The annual reports of the Bureau in the past have fully set forth the progress that has been made in establishing depots for coal. The present seems to be an opportune time to fully state the reasons that have influenced the Bureau in locating the depots that have been completed, those under construction and those projected.

NAVAL COAL DEPOTS ON THE ATLANTIC AND GULF COASTS.

A chart is appended showing the location of coal depots for naval purposes on the coast of the North Atlantic Ocean and the Gulf of Mexico.

Frenchman Bay, Maine.—This coal depot, described in the last annual report of the Bureau, has been completed in accordance with the original contract and partially stocked with coal. Certain additions to the depot not included in the original contract—viz, a concrete covering for the steel piles and an ice breaker—are in process of construction. In February, 1902, a contract was awarded to the Penn Bridge Company, of Beaver Falls, Pa., the lowest bidders, for the installation of a complete water-supply system for the use of the depot and for supplying ships, including a steel standpipe of 250,000 gallons capacity. With these additions and a number of lighters also under construction, the depot will be thoroughly equipped for furnishing ample supplies of coal and water and handling coal at the rate of about 200 tons per hour. The capacity for storage is about 10,000 tons. This storage capacity may be increased with comparatively little expense; an indefinite amount can always be stored in the open. In the opinion of the Bureau, its capacity should be increased to 20,000 tons.

Frenchman Bay was not the site on the coast of Maine originally selected by the Bureau. It was recommended, however, by a board of which Rear-Admiral George E. Belknap, U. S. Navy, retired, was president. The board was convened by order of the Department June 7, 1898, and made its report August 16, 1898. A copy of this report will be found in Appendix I.[a] The board recommended that the depot have a capacity for 15,000 tons.

The War Department has signified its intention, at the request of the Navy Department, to fortify the entrance to Frenchman Bay forthwith.

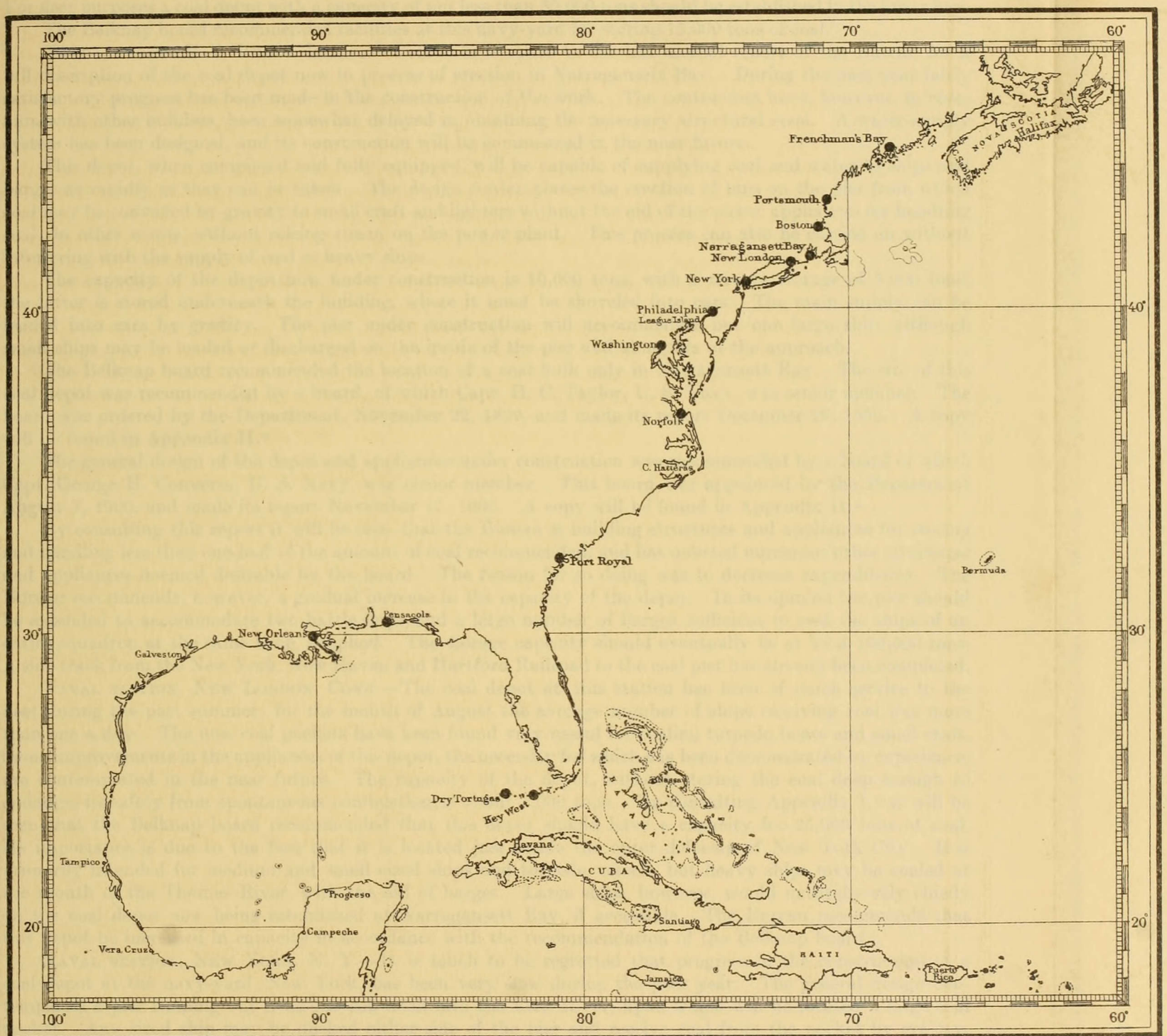
Naval station, Portsmouth, N. H.—This being a naval station, public works are under the cognizance of the Bureau of Yards and Docks. That Bureau has made a contract to construct a coal-storage plant with a capacity of 10,000 tons. While the material has been delivered the actual work of construction has not yet commenced. It is greatly needed for the use of the station and for ships which visit the yard for repairs or for other purposes.

Owing to the difficult approach to the navy-yard, this depot is of minor importance for supplying the fleet. In fact, it may be practically excluded for that purpose.

The Belknap board, already referred to, recommended that this depot be established and that its capacity be the amount provided for.

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[a] Report for 1902.



THE NORRIS PETERS CO., WASHINGTON, D. C.



NAVAL STATION, BOSTON, MASS.—The Bureau of Yards and Docks has under contract the construction of a coal depot at the navy-yard with a capacity of about 11,500 tons. At present the foundations are being prepared; the erection of the building and machinery has not been commenced. It is well located for yard use or for the use of ships at the navy-yard. It is not well located, however, for supplying coal to the fleet, owing to the long and tortuous channel leading in from the sea and the very restricted anchorage in its vicinity. For fleet purposes a coal depot with a capacity of not less than 50,000 tons should be established in the lower bay.

The Belknap board recommended facilities at this navy-yard for storing 15,000 tons of coal.

NARRAGANSETT BAY, RHODE ISLAND.—Reference is made to the last annual report of the Bureau for a full description of the coal depot now in process of erection in Narragansett Bay. During the past year fairly satisfactory progress has been made in the construction of the work. The contractors have, however, in common with other builders, been somewhat delayed in obtaining the necessary structural steel. A water-supply system has been designed, and its construction will be commenced in the near future.

This depot, when completed and fully equipped, will be capable of supplying coal and water to ships and barges as rapidly as they can be taken. The design contemplates the erection of bins on the pier from which coal may be conveyed by gravity to small craft and lighters without the aid of the power appliances for handling coal; in other words, without raising steam on the power plant. This process can also be carried on without interfering with the supply of coal to heavy ships.

The capacity of the depot now under construction is 10,000 tons, with a reserve storage of 5,000 tons; the latter is stored underneath the building, where it must be shoveled into cars. The main supply can be loaded into cars by gravity. The pier under construction will accommodate but one large ship, although small ships may be loaded or discharged on the inside of the pier and alongside of the approach.

The Belknap board recommended the location of a coal hulk only in Narragansett Bay. The site of this coal depot was recommended by a board, of which Capt. H. C. Taylor, U. S. Navy, was senior member. The board was ordered by the Department, November 22, 1899, and made its report December 28, 1899. A copy will be found in Appendix II.[a]

The general design of the depot and appliances under construction was recommended by a board of which Capt. George H. Converse, U. S. Navy, was senior member. This board was appointed by the Department August 7, 1900, and made its report November 17, 1900. A copy will be found in Appendix II.[a]

By consulting this report it will be seen that the Bureau is building structures and appliances for storing and handling less than one-half of the amount of coal recommended, and has omitted numerous other structures and appliances deemed desirable by the board. The reason for so doing was to decrease expenditures. The Bureau recommends, however, a gradual increase in the capacity of the depot. In its opinion the pier should be extended to accommodate two battle ships, and a large number of barges, sufficient to coal the ships of an entire squadron at the same time, supplied. The storage capacity should eventually be at least 100,000 tons. A side track from the New York, New Haven and Hartford Railroad to the coal pier has already been completed.

NAVAL STATION, NEW LONDON, CONN.—The coal depot at this station has been of much service to the fleet during the past summer; for the month of August the average number of ships receiving coal was more than one a day. The new coal pockets have been found very useful for coaling torpedo boats and small craft. Some improvements in the appliances of this depot, the necessity for which has been demonstrated by experience, are contemplated in the near future. The capacity of the depot, without storing the coal deep enough to endanger its safety from spontaneous combustion, is about 7,000 tons. By consulting Appendix I,[a] it will be seen that the Belknap board recommended that this depot should have a capacity for 25,000 tons of coal. Its importance is due to the fact that it is located just inside the outer defenses of New York City. It is primarily intended for medium and small sized ships and torpedo vessels, but heavy ships may be coaled at the mouth of the Thames River, with the aid of barges. Large ships, however, would naturally rely chiefly on the coal depot now being established at Narragansett Bay, if accessible. The Bureau recommends that this depot be increased in capacity in accordance with the recommendation of the Belknap board.

NAVAL STATION, NEW YORK, N. Y.—It is much to be regretted that progress in the construction of a coal depot at the navy-yard, New York, has been very slow during the past year. The general design contemplates a pier running out from the cob dock into the East River, upon which will be located a large coal pocket. Any sized ship may be docked either side of the pier and receive coal from the pocket by gravity. Coal may be distributed throughout the yard by means of cars which will be run under the pocket and loaded by gravity. The pier has not yet been completed, although nearly so. The contract for the pocket has been let, but work on it has not yet begun. This pocket only contemplates a capacity of 9,000 tons.

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[a] Report for 1902.

Battle ships and armored cruisers now have about an average of 1,500 tons coal-carrying capacity. The new ships of these types are to have a capacity of 2,000 tons. It will therefore be readily seen that 9,000 tons of coal will go only a short way toward supplying future squadrons that will rendezvous in New York Harbor. It may be said that coal dealers can be relied upon for this service; this is no doubt true, generally speaking. During war the Government would probably be justified in seizing coal if necessary, and possibly at such a time the patriotism of the people would prevent strikes. The only sure way, however, is to keep in stock a large amount of coal. The average amount which can be depended upon as available at any time at any depot is probably not more than one-half its storage capacity.

The Bureau recommends that the site of the old coal-storage sheds at the New York yard, which was temporarily loaned for other purposes, be utilized for the construction of an additional coal depot. It also recommends that a large depot somewhere in the lower bay or on the Hudson River be established. The Belknap board recommended a storage of 5,000 tons at this station.

Naval station, League Island, Pa.—There is an abundance of room at the League Island Navy-Yard for coal storage. An appropriation of $50,000, under the cognizance of the Bureau of Yards and Docks, is available for supplying coaling facilities. It is not enough, however, to build a good coaling pier. When the latter is constructed, the Bureau will keep in stock there a good margin of coal stored in the open if sheds are not available. It is deemed advisable to erect here large sheds for a reserve supply of coal for shipment elsewhere by colliers when required. It is not a depot that will be useful for coaling war ships, on account of its great distance from the sea.

While Philadelphia is connected by rail with the great coal mines of the State of Pennsylvania, which would seem to insure at all times an adequate supply of coal there at reasonable rates, yet this has not been the case during the past year. The contractor for coal when called upon to deliver a few thousand tons, failed to do so under the plea that the coal could not be obtained. It is the experience of the Bureau that it is unwise for the Department to rely wholly upon contracts for an adequate supply of coal for naval purposes. The Belknap board recommended that from 3,000 to 5,000 tons be kept in store at this station.

Naval station, Washington, D. C.—A building with a capacity for about 3,000 tons of coal, constructed by the Bureau of Yards and Docks for the use of this Bureau, has been practically completed.

The demand for coal for steaming purposes at Washington is small, averaging from 2,500 to 3,000 tons per year. With the contemplated improvement in the navigation of the Potomac River and Eastern Branch, no doubt the demand will increase in the near future. The requirements in time of war would probably be small, though considerably larger than during peace times. The Belknap board recommended a storage capacity of 1,000 tons, which is manifestly too small.

Naval station, Norfolk, Va.—There are no facilities at the navy-yard, Norfolk, for storing coal, except a dilapidated wooden shed with a capacity of about 2,000 tons. The only method of transportation to and from this shed is by carts.

In the opinion of the Bureau, every navy-yard should have facilities for storing in a safe and convenient manner at least 10,000 tons of coal, with appliances for handling it rapidly and cheaply. The demand for coal for the various shops and industrial purposes at a navy-yard, and for small craft, such as tugs, torpedo boats, etc., is constant. The latter especially require elevated coal pockets from which coal may be supplied by gravity. No improvements have ever been made at this yard for storing and handling coal.

Although Norfolk is a tide-water outlet for a large amount of coal, it is at this date suffering from a coal famine, and many industries are seriously crippled for the need of fuel. The only possible way the Department can escape calamities of this nature is to provide means for storing large quantities of coal, and to procure it when available at reasonable rates.

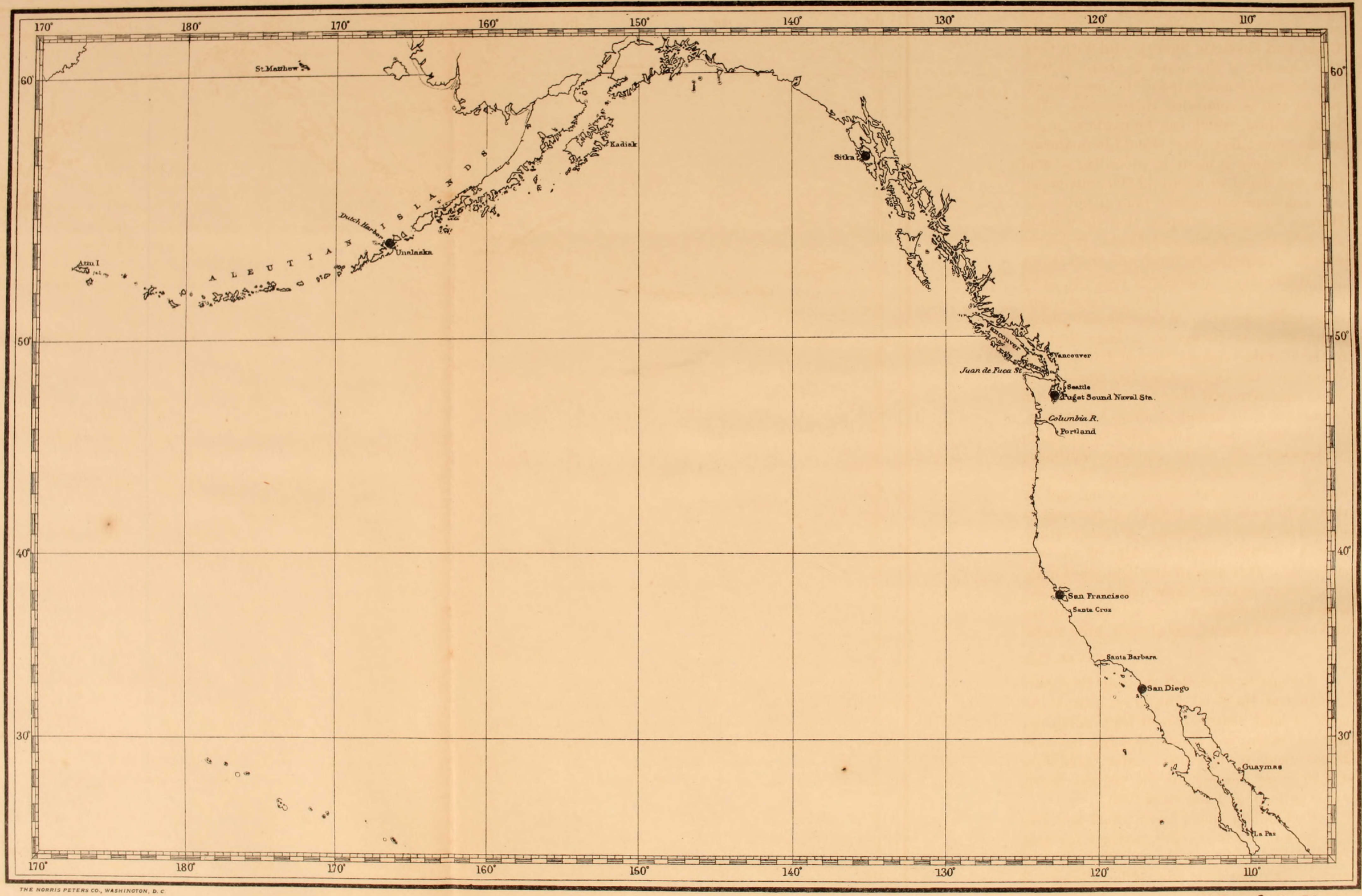
The Belknap board recommended that provision be made at the navy-yard for storing 5,000 tons.

The Bureau believes that appliances should, in addition, be provided elsewhere in this vicinity for storing 50,000 tons.

Naval station, Port Royal, S. C.—It is apparently the policy of Congress to abandon the use of Port Royal as a naval station. In the opinion of the Bureau, it is desirable to retain the site of the station for a naval coal depot. The magnificent waters of Port Royal Sound are well defended, and will always be a place of rendezvous for naval ships. It offers superior facilities for the location of a coal depot to Charleston, S. C., for the reason that the entrance to the latter point is, and must continue to be, through an under water canal.

There is a fine modern steel pier at the Port Royal Naval Station, and with the expenditure of a very moderate amount of money the buildings now there may be converted into excellent coal-storage houses with the necessary means for conveying coal to and from the pier. Funds have been appropriated for this purpose, but are held in reserve by the Bureau of Yards and Docks. The Bureau recommends that they be expended as originally intended.





THE NORRIS PETERS CO., WASHINGTON, D. C.

The Belknap board, see Appendix I [a] for report, recommended that a depot with a capacity of 15,000 tons be established at Port Royal.

In addition, the establishment of a naval coal depot at Port Royal was recommended by a board of which Capt. John J. Hunker, U. S. Navy, was senior member. The board was convened by order of the Department, April 13, 1901, and sent in its report on April 23, 1901. A copy will be found in Appendix III.[a]

Naval station, Key West and Dry Tortugas, Fla.—The coal depot at Key West has been fully described in previous reports. It has been exceedingly useful during the past year. The Bureau not only supplies coal to the other bureaus of the Department, but to the Revenue-Cutter Service, Light-House Service, Coast and Geodetic Survey, and Fish Commission from this depot. When storing coal at a safe depth only, the capacity of the depot is about 15,000 tons. The design of the appliances and storehouses at Key West was hurriedly made under the pressure of threatened war. One of the coal piers has been in use for a long period and is somewhat dilapidated. There are numerous changes in the depot necessary in order to bring it up to date, which can be made at a moderate cost. It is considered desirable that a depot so much used as the one at Key West should be maintained in the most efficient condition.

Reference is made to preceding annual reports of the Bureau for a complete account of the establishment of a coal depot of about 12,000 tons capacity at Dry Tortugas, especially for the use of deep-draft ships that can not approach nearer than 6 miles to Key West, or obtain a sheltered anchorage in that vicinity. The Bureau is pleased to report that the work on this coal depot, the construction of which is under the cognizance of the Bureau of Yards and Docks, is nearing completion, contracts finally having been made with apparently reliable companies to finish the work at once. Its completion has been due since September, 1898.

It should be understood that the two depots, Key West and Tortugas, are each enhanced in value by the existence of the other. Dry Tortugas, forming a salient extending into the Gulf of Mexico to the westward, is 60 miles from Key West; the two places are connected by a submarine cable. Tortugas affords a safe and commodious anchorage for a large fleet. It occupies a most important strategic position in close proximity to the Florida Channel, the old Bahama Channel, the Yucatan Channel, and the entrance to the Gulf of Mexico. While the War Department has transferred Fort Jefferson at Dry Tortugas to the Navy Department for a coal depot and removed therefrom all cannon and other war munitions, it has agreed, on request from the Navy Department, to install at Fort Jefferson a modern armament suitable for the defense of a coal depot.

As there exists a difference of opinion as to the value of Dry Tortugas for war purposes the Bureau refers, in Appendix IV, to the numerous authorities advocating its use as a naval and military base.

Naval station, Pensacola, Fla.—Reference is made to former annual reports for statements concerning the accommodations for storing coal at the navy-yard, Warrington, Fla. They are still in a crude condition, with shoal water at the coal pier and inefficient means for rapidly handling coal. The Bureau has recently improved these conditions by constructing a bin for open-air storage near a deep-water pier. As Pensacola Bay is a favorite resort for ships of war of moderate draft for winter exercises, the demand for coal here is considerable. It is also an excellent site for storing a reserve supply for the Gulf.

Naval station, New Orleans, La.—No progress has been made during the past year in establishing a naval coal depot at this station. An appropriation for the purpose, under the cognizance of the Bureau of Yards and Docks, has already been made.

NAVAL COAL DEPOTS ON THE PACIFIC COAST

A chart is appended showing the location of proposed coal depots for naval purposes on the Pacific coast.

Dutch Harbor, Amaknak Island, Alaska.—Since the last annual report of the Bureau a considerable tract of land, 600 feet deep from north to south and extending entirely across the island from the harbor to the sea, containing about 20 acres, has been formally transferred from the Treasury Department to the Navy Department, by Executive order dated June 10, 1902, for use as a naval coal depot. The site is an admirable one in every respect for the purpose intended. There is an abundance of fresh water easily accessible, the water is deep, and the shore bold.

Preliminary plans for a wharf and coal depot, with a capacity of about 5,000 tons, have been prepared.

Sitka, Alaska.—The contract for a coal depot at this port, referred to in the last annual report of the Bureau, has been completed. The plant consists of a house with a capacity of 2,500 tons, a Hunt elevator, and an automatic shuttle cable railway. The present wharf was built before the coal depot was established and is unsatisfactory, being large enough to accommodate barges only.

Capt. J. H. Pendleton, U. S. Marine Corps, in command of the marine guard at Sitka, had charge of the construction work of the new depot and performed this duty in a manner highly satisfactory to the Bureau.

In the opinion of the Bureau the capacity of this station should be increased eventually to 10,000 tons. Owing to climatic conditions all coal must be stored under cover for its preservation. The Bureau supplies

[a] Report for 1902.

coal to other departments of the Government at this station. The wharf should be increased in size sufficiently to accommodate ships alongside. Plans have been prepared for doubling the present capacity, making it 5,000 tons, also for enlarging the present wharf.

The correspondence on the subject of establishing coal depots in Alaska will be found in Appendix V. The arguments of the Bureau in favor of establishing naval coal depots in Alaska have been prepared with considerable care, and your attention to them is respectfully solicited. They are intended to deal with the subject not only from a military but from a commercial point of view.

Alaska produced, during the past summer, more than $20,000,000 of gold; her commerce is increasing with great strides; her fisheries, timber, and minerals are of immense value; yet she has not a single cannon mounted for defensive purposes, nor other warlike stores within her borders.

The War Department, however, has signified its intention of fortifying Sitka and Dutch Harbor, and coal depots for these harbors have been recommended by many officers who are familiar with Alaskan waters.

Naval station, Puget Sound, Washington.—The Bureau in its last annual report stated the necessities of this naval station in the way of coal storage. It desires to repeat and emphasize this statement. It is gratifying to report that work is now in progress, under the cognizance of the Bureau of Yards and Docks, on a coal-storage plant located at the navy-yard with a maximum capacity of 20,000 tons of coal. The Bureau has frequently called attention to the fact that there is no good coal obtainable on the Pacific coast, and that it is necessary to transport it about 15,000 miles by water. Under these circumstances, it will be readily understood that if the country is to be reasonably well prepared for emergencies a large storage of the best quality of coal must be constantly on hand, not only at Puget Sound, but elsewhere on the Pacific coast.

Naval station, Mare Island, Cal.—The coal sheds at the Mare Island Navy-Yard, originally designed for a capacity of about 7,500 tons, have been completed during the past year. Foundations have been prepared for an additional storage, which will make the total capacity about 20,000 tons. It is hoped that the facilities at Mare Island may be gradually increased so that 25,000 tons of coal can be stored under cover. At present there is one Brown conveyor for handling coal; it is necessary that another should be installed. An appropriation is available for this purpose.

San Francisco Bay, California.—A full account of the efforts of this Bureau to establish an adequate naval coal depot in San Francisco Bay will be found in its annual reports for the past three years. There has been no change in the status of Mission Rock since the Bureau's last annual report, the question of title thereto having been in the supreme court without action in the meantime. The Bureau has prepared preliminary plans for a coal depot on Mission Rock and is ready to push the work as soon as the question of title is settled.

It is much to be regretted that a place so important as San Francisco Bay can not be provided with a large stock of coal for naval purposes without delay. At present, oil is very largely used for fuel on this coast; this and a poor quality of coal are the only fuels found west of the Rocky Mountains. Most of the fuel used for industrial purposes, previous to the advent of oil, outside of that mined on the Pacific coast, has been brought from Australia and New Zealand. While better than Pacific coast coal, it is not sufficiently good for ships of war. Only the best coal mined on the Atlantic coast and Welsh coal are suitable for naval purposes in the Pacific. It is therefore self-evident that a large storage capacity is necessary in this bay in order that the Navy may be assured at all times of an adequate supply.

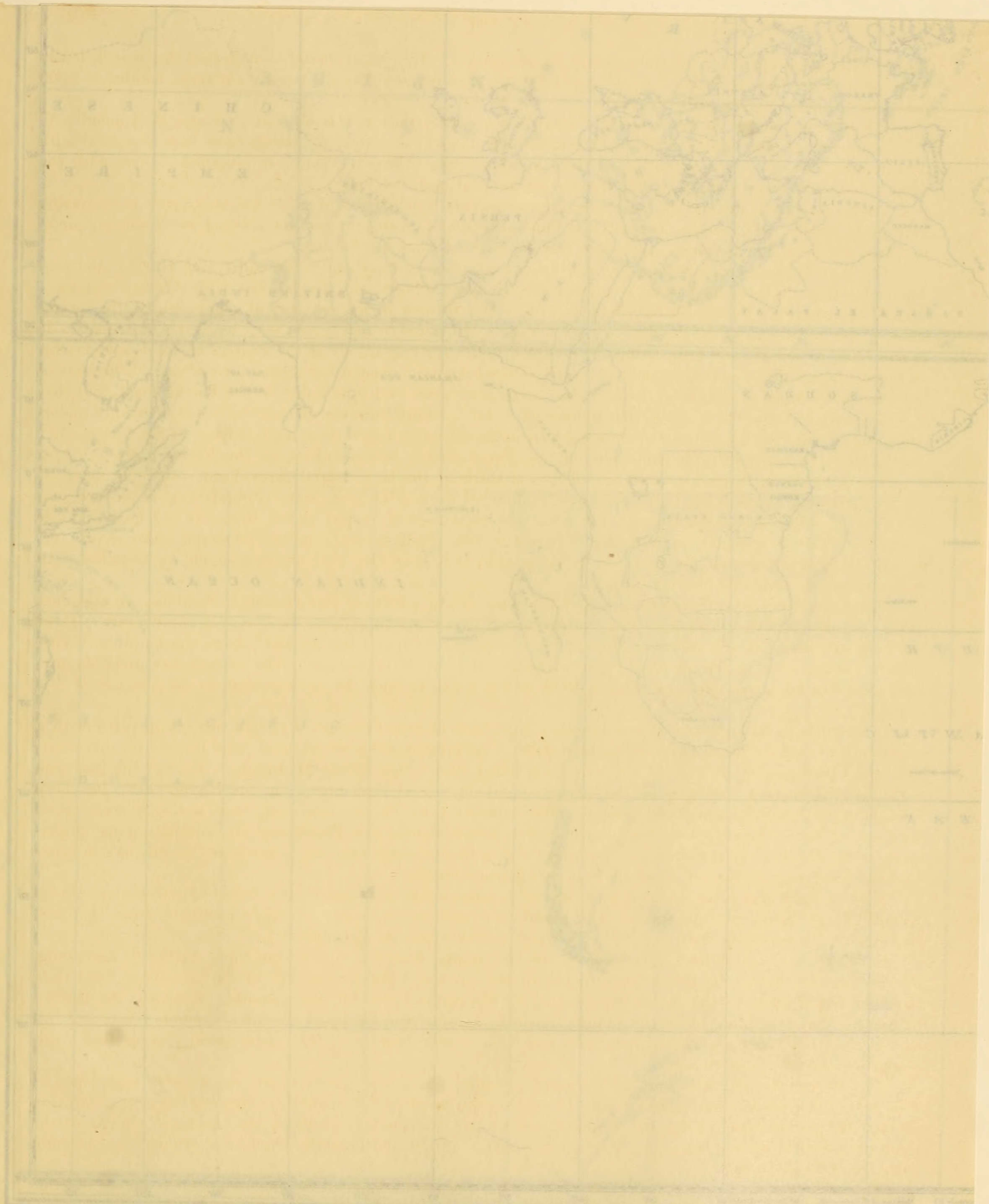
Mission Rock was recommended as a site for a large naval coal depot by a board of which Capt. Louis Kempff, U. S. Navy, was president. The board was convened by order of the Department June 16, 1898, and sent in its report on July 13, 1898. A copy will be found in Appendix VI.[a]

San Diego, Cal.—Reference is made to the last annual report of the Bureau for a statement concerning the advisability of locating a naval coal depot in this harbor. Also an account of the transfer of land from the War Department to the Navy Department by Executive order for this purpose. Recently the Bureau discovered that Congress had, in the sundry civil bill, transferred 6½ acres of the most valuable portion of this same land to the Treasury Department as a site for a marine hospital. This matter is at present being considered by the two Departments.

The Bureau in the meantime has prepared complete plans and specifications for a naval coal depot at this port. The plans contemplate a pier of steel construction, with cylindrical concrete supports, carrying an elevated pocket with a capacity of about 3,000 tons; two loading towers; a pier approach similar to the main pier in construction, carrying a steel trestle; and a storage and handling plant on shore with a maximum capacity of 25,000 tons.

The construction of a coal depot at this port has been contemplated by the Department for some time. On June 19, 1902, the Bureau requested authority to advertise for bids for a coal-storage plant in accordance with the designs above mentioned. Copies of the correspondence on the subject will be found in Appendix V.[a]

[a] Report of 1902.



Manila
(Cavite)
Guam
Honolulu
San Juan
Tutuila
(Pago Pago)
RUSSIAN EMPIRE
CHINESE EMPIRE
BRITISH INDIA
AUSTRALIA
GREENLAND
ICELAND
ALASKA
DOMINION OF CANADA
UNITED STATES
BRAZIL
ARGENTINA
NORTH PACIFIC OCEAN
SOUTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
ANTARCTIC CONTINENT
SAHARA EL FALAT
SOUDAN
PERSIA
ARABIAN SEA
BAY OF BENGAL
CORAL SEA
HUDSON BAY
BERING SEA
OKHOTSK SEA
CARIBBEAN SEA
MEXICO
PERU
BOLIVIA
ECUADOR
COLOMBIA
VENEZUELA
GUIANA
FRENCH CONGO
KONGO STATE
MADAGASCAR
CAPE COLONY
NEW ZEALAND
TASMANIA
PAPUA OR NEW GUINEA
BORNEO
JAPAN
PHILIPPINE IS
CAROLINE ISLANDS
MARSHALL IS
GILBERT IS
SAMOA IS
FRANCE
SPAIN
AUSTRIA
GERMANY
BLACK SEA
ALGERIA
MOROCCO
EGYPT
TRIPOLI
ARABIA
AFGHANISTAN
NORTH SEA
BRITISH ISLES
ABYSSINIA
ZANZIBAR
MOZAMBIQUE
ST HELENA
ASCENSION I
TRISTAN DA CUNHA
SANDWICH GROUP
SOUTH GEORGIA
ALEUTIAN ISLANDS
SAKHALIN I
KURILE IS
YEZO
HAWAIIAN IS
SOCIETY IS
TUAMOTU OR LOW ARCHIPELAGO
MARQUESAS IS
SAN FELIX
SAN AMBROSIO
JUAN FERNANDEZ
GALAPAGOS IS
REVILLA GIGEDO IS
DAVIS STRAIT
DENMARK STRAIT
JAVA SEA
ARAFURA SEA
SEA OF JAPAN
YELLOW SEA
100° 110° 120° 130° 140° 150° 160° 170° 180° 170° 160° 150° 140° 130° 120° 110° 100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110°
70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70°
20° West Longitude 10° Meridian of 0° Greenwich. 10° East Longitude 20°
THE HORRIS PETERS CO. WASHINGTON, D.C.
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INSULAR NAVAL COAL DEPOTS.

A chart is appended showing the location of naval coal depots, completed, building, or proposed, on the insular possessions of the United States.

NAVAL STATION, SAN JUAN, P. R.—This continues to be a very useful coal depot and supplies coal and water to a large number of ships of the Navy, particularly during the winter months. The storage of coal in the past has been circumscribed, owing to the small space available for the purpose. Recently, by Executive order, the area of the naval station has been much enlarged, and the Bureau has, therefore, been enabled to increase the amount of coal in stock. All coal is stored in the open without cover. A small wooden pier affords means of coaling one ship at a time; the coal is transported in baskets, and, owing to the large population available for such work, ships are coaled very rapidly. The accommodations for water supply should be improved. The Bureau supplies coal to all other bureaus of the Department at this station and to the War Department.

There are two completed coal lighters for use at this depot, and two more are under construction. This will enable more than one ship to be coaled at the same time.

It should be borne in mind that San Juan can only be used by ships of small and medium size, large ships being prevented from entering the harbor by reason of shoal water. It is therefore much to be regretted that the United States possesses no other coal depot in the West Indies.

NAVAL STATION, HAWAII, H. T.—The coal depot at Honolulu has been fully described in the former annual reports of the Bureau. It has recently been much improved by grading the grounds, planting shade trees, etc. The artesian well affords an abundance of water for irrigating purposes. The storage capacity has been increased to 30,000 tons. The piers are much used by army transports and merchant ships. As it will be some years before a naval station is established in Pearl Harbor, the depot at Honolulu should be kept in good condition. The land, buildings, slips, and piers are now very valuable.

The Bureau has supplied large amounts of coal in the past from this depot to army transports, and also to other departments of the government. On the occasion of a coal famine at Honolulu several mail steamers were supplied with coal that would otherwise have been obliged to lay up; also sugar plantations where the cane crop would otherwise have been ruined.

The value of this coal depot will soon be much enhanced by cable connection with the Pacific coast.

The Bureau has reason to believe that the great utility of Honolulu as a coal depot during the Spanish war largely influenced Congress in its decision to annex the Hawaiian Islands.

NAVAL STATION, TUTUILA, SAMOA.—A steel coal shed of 5,000 tons capacity and a steel pier, both of modern construction and excellent design, which have been under construction at this naval station during the past three years, and referred to in the annual reports of the Bureau, have been completed, and the depot is now stocked with coal.

As Tutuila has advanced from a naval coal depot to a naval station, public works there are now under the cognizance of the Bureau of Yards and Docks. That Bureau has an appropriation for extending the capacity of the coal depot and has already secured land lor the purpose. The extension will include better appliances for handling coal rapidly than now exist. In the opinion of the Bureau the capacity of this depot should not be less than 25,000 tons.

The port of Pago Pago, where the above-mentioned naval station is located, is the most valuable in the South Pacific Ocean, and should be fortified. It is already a port of call for the line of steamers between Australia and San Francisco, and is rapidly increasing in importance.

It should be borne in mind that the authority of the Department for establishing a naval coal depot at this port is the act of Congress approved March 2, 1889, as follows:

> For the purpose of permanently establishing a station for coal and other supplies for the naval and commercial marine of the United States, on the shores of the bay of harbor of San Pago Pago, on the island of Tutuila, Samoa, for the erection of the necessary buildings and structures thereon and for such other purposes as may, in the judgment of the President, be necessary to confirm the rights of the United States under article second of the treaty of eighteen hundred and seventy-eight, between the United States and the King of the Samoan Islands, and the deed of transfer made in accordance therewith, the sum of $100,000.

The establishment of a coal depot at the island of Tutuila was further approved by the Department and the naval war board during the Spanish war.

NAVAL STATION, GUAM.—Since the acquisition of the island of Guam at the conclusion of the Spanish war the Bureau has set forth in its annual reports in detail the great value of the island as a port of call for coal and other supplies for ships en route between the Pacific coast and the Philippine Islands. In the last annual report of the Bureau reference was made to a commission which, under a law of Congress, visited this island and, after a most careful and detailed survey, made recommendations and estimates for the improvement of

the port of San Louis d'Apra, the harbor of Guam, both for naval and commercial purposes. The report of this mixed commission, composed of navy and army officers, was published and copies supplied to the naval and commerce committees of congress. An appropriation of $150,000 for the improvement of this harbor passed the Senate, first, in the river and harbor bill, and, second, upon the nonconcurrence of the House, in the naval bill; as the House nonconcurred in the latter the result was nil. It is evident that much interest is taken in this port by the upper House of Congress, and it is only a matter of time when appropriations will be granted for its improvement.

The sum of $40,000, asked for by this Bureau for the acquisition of land, was granted by Congress. On August 9, 1902, the Bureau requested your authority to purchase the land desired and to commence work on the construction of a naval coal depot. To this end it is first desired to dredge a channel into a natural basin in order to secure the necessary protection from violent storms.

All coal used at this station, for whatsoever purpose, is supplied by this Bureau. In the opinion of the Bureau a storage capacity of 25,000 tons should eventually be secured with adequate means for handling rapidly. With the completion of a transisthmian canal this will undoubtedly become an important mercantile port of call.

The retention of Guam as an American possession after its capture, as provided for in the peace protocol at the close of the Spanish war, was for the express purpose of establishing a naval coal depot.

NAVAL STATION, CAVITE, P. I.—Considerable space has been devoted in former reports of the Bureau to the question of supplying and storing an adequate supply of coal for the Asiatic Squadron in the Philippine Islands. The situation at present is, briefly, as follows:

A contract has been awarded during the past year to the Atlantic, Gulf and Pacific Company, of New York and San Francisco, for the erection of a modern substantial coal depot at Sangley Point, near the Cavite Naval Station.

In general terms this contract provides for the construction of the following:

A steel coaling pier, with cylindrical cast-iron supports, filled with concrete, which in turn are supported on wooden piles, 408 feet long and 75 feet wide.

An elevated steel coal pocket of a capacity of about 3,000 tons, located on the pier, so arranged that coal may be discharged by gravity into ships and lighters with great rapidity.

Two coal sheds of steel and concrete construction, each 192 by 144 feet. These sheds will be constructed with overhead automatic railway tracks in monitors for filling purposes, and with elevated concrete floors, through which coal will be discharged into cars by means of numerous valves for supplying ships and lighters.

Handling machinery, consisting of two steel discharging and loading towers, operated by steam and running on tracks along the pier, and 12 automatic railways for filling the sheds. In addition, 34 surface tracks for use in transporting coal from the sheds to the pocket on the pier or to ships and lighters.

A pumping plant with elevated tanks, for fire purposes.

A straight channel, 500 feet wide on the bottom and of a uniform depth of 20 feet at low water, to be dredged from deep water to a point 100 feet beyond the coal pier.

The contract provides that the depot shall be completed by August, 1903. It will have a capacity for storing under cover about 30,000 tons of coal. It is intended to provide for storing a large additional amount in the open.

In addition to the naval coal depot at Cavite, Manila Bay, the following subdepots have been established in the archipelago:

Polloc, Mindanao.	Olongapo, Luzon.
Port Isabela, Basilan.	Sual, Luzon.
Port Cebu, Cebu.	Port Salomague, Luzon.
Iloilo, Panay.	

The first four are of considerable importance and are being greatly improved. All are supplied with coal from Manila by the fleet colliers. Additional subdepots, particularly on the east side of the archipelago and near the Straits of San Bernardino, will probably be required in the near future.

The Bureau supplies all of the coal used by other bureaus at the naval station, Cavite.

Reference is made to Appendix VII[a] for interesting reports in connection with the establishment of a naval coal depot at Manila.

FOREIGN NAVAL COAL DEPOTS.

The establishment of naval coal depots in foreign waters involves diplomatic considerations of the highest order, and, manifestly, should not be discussed in a report of a public character.

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[a] Report of 1902.

COAL.

EQUIPMENT EXPENSES ABROAD, 1903.

[Extract from report of the Chief of the Bureau of Equipment to the Secretary of the Navy, 1903, pages 55–67.]

EQUIPMENT EXPENSES ABROAD.

There was expended during the fiscal year, under the direction of commanders in chief of fleets and commanders of ships, the sum of about $310,000 for supplies and services for equipment purposes, not including the amount expended for coal.

COAL.

A total of 487,036 tons of coal, costing $2,435,168.37, an average of $5 per ton, was purchased during the fiscal year.

The following table indicates the amount of coal purchased for steaming purposes since 1892 and the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.	Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.				*Tons.*		
1892	73,467	$550,451.35	$7.49	1898	452,551	$2,122,005.28	$4.68
1893	67,054	449,065.27	6.69	1899	281,169	1,679,510.55	5.97
1894	94,336	640,355.96	6.78	1900	228,395	1,572,652.97	6.88
1895	98,615	527,590.25	5.35	1901	324,108	2,273,111.81	7.01
1896	116,903	620,131.38	5.30	1902	382,040	2,220,211.09	5.81
1897	138,318	655,921.72	4.75	1903	487,036	2,435,168.37	5.00

DOMESTIC COAL.

Of the total amount purchased, viz, 487,036 tons, 385,017 tons, costing, with the transportation thereof, the sum of $1,731,064.69, at an average of $4.50 per ton, were purchased within the limits of the United States.

The following table indicates the amount of coal purchased within the United States for steaming purposes since 1892, and the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.	Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.				*Tons.*		
1892	38,450	$221,918.66	$5.77	1898	378,437	$1,520,119.75	$4.02
1893	33,257	147,999.04	4.45	1899	195,216	1,238,355.40	6.34
1894	42,190	178,163.58	4.22	1900	141,921	834,527.34	5.88
1895	50,630	181,985.89	3.59	1901	219,042	1,379,433.51	6.30
1896	55,162	196.795.40	3.57	1902	293,438	1,543,869.35	5.26
1897	82,051	280,091.09	3.41	1903	385,017	1,731,064.69	4.50

FOREIGN COAL.

The balance of the 487,036 tons, viz, 102,019 tons, were purchased by paymasters of ships, mostly abroad, costing the sum of $704,003, at an average of $6.90 per ton.

The following table indicates the amount of coal purchased by ships for steaming purposes since 1892, with the cost thereof:

Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.	Fiscal year ending June 30—	Quantity.	Total cost.	Average cost per ton.
	Tons.				*Tons.*		
1892	35,017	$298,948.55	$8.53	1898	74,111	$601,885.53	$8.12
1893	33,797	301,066.23	8.91	1899	85,953	441,155.15	5.13
1894	52,146	462,192.38	8.86	1900	86,476	738,125.63	8.53½
1895	47,985	336,183.47	7.00	1901	105,066	893,677.81	8.50
1896	61,741	423,335.98	6.85	1902	88,602	676,341.74	7.63
1897	56,268	375,840.63	6.68	1903	102,019	704,003.68	6.90

The amount of coal used during the fiscal year was 27 per cent greater than during the preceding year.

The cost of coal during the fiscal year was 81 cents, or 16 per cent less per ton than during the preceding year.

The average cost of coal purchased in the United States during the fiscal year was 76 cents per ton less than during the preceding year.

The average cost of coal purchased by ships during the fiscal year was 73 cents less per ton than during the preceding year.

While the total amount of coal purchased for the Navy during the fiscal year was 27 per cent greater than during the preceding year, the amount of foreign coal was 21 per cent as compared with 23 per cent the year before, and the amount of domestic coal correspondingly increased.

The following table indicates the price of the best Welsh coal f. o. b. at Cardiff, Wales, from May, 1899, to date:

Prices of best Cardiff coal at Cardiff, Wales.

Date.	Price per ton.	Date.	Price per ton.	Date.	Price per ton.	Date.	Price per ton.	Date.	Price per ton.
1899.		1900.		1901.		1902.		1903.	
May	$3.12 to $3.24	January	$6.48 to $7.20	January	$4.80 to $5.04	January	$4.14 to $4.26	January	$3.72 to $3.78
June	3.12	February	5.76 6.00	February	4.44 4.56	February	3.78 3.90	February	3.66 3.72
July	3.12 3.18	March	5.40 5.76	March	4.32 4.44	March	3.60 3.72	March	3.42 3.48
August	3.12 3.24	April	5.04 5.52	April	4.20 4.32	April	3.66 3.78	April	3.42 3.48
September	3.12 3.24	May	5.28 5.64	May	5.04 5.28	May	3.96 4.08	May	3.66 3.72
October	3.18 3.36	June	5.28 5.52	June	4.56 4.68	June	3.90 4.02	June	3.78 3.90
November	3.30 3.42	July	5.28 5.52	July	5.04 5.16	July	4.08 4.14	July	3.78 3.84
December	4.80 5.04	August	5.76 6.00	August	5.04 5.16	August	3.84 3.90	August	3.90 3.96
		September	6.48 6.96	September	4.80 4.92	September	3.96 4.02	September	3.84 3.90
		October	6.12 6.48	October	4.32 4.38	October	4.32 4.44		
		November	4.92 5.16	November	4.08 4.32	November	3.90 3.96		
		December	4.44 4.68	December	4.20 4.32	December	3.72 3.84		

CONSUMPTION OF COAL.

Of the total amount of coal used in ships of the Navy, viz, 346,587 tons, 30,116 tons were consumed on board of colliers, torpedo boats, tugs, etc., from which no reports are made of the specific object of expenditure.

Of the balance, 54 per cent was consumed for steaming purposes; 43 per cent for distilling, pumping, heating ventilating, and lighting; 2 per cent for cooking purposes, and 1 per cent for steam launches.

Notwithstanding the great scarcity of bituminous coal in the United States during the past fiscal year, frequently delaying the departure of trans-Atlantic mail steamers and otherwise paralyzing the business of the country, and the very great increase in cost, the Bureau was able to supply all the coal required by the fleet without exceeding the regular appropriation for this purpose, and at an average price per ton less than that of any year since 1898.

The Bureau also supplied, in numerous instances, other Bureaus of the Department at various naval stations, notably at the Naval Gun Factory, navy-yard, Washington, D. C. In several instances the shops at naval stations would have been obliged to cease work had it not been for equipment coal. The naval maneuvers in the West Indies proceeded as outlined and in no instance, so far as known, was the Department obliged to change its programme for want of coal.

The Bureau was greatly indebted during this emergency to Messrs. Castner, Curran & Bullitt, of Philadelphia, Pa., general agents for the sale of Pocahontas coal, and to the Consolidation Coal Company, of Baltimore, Md., miners of Georges Creek coal. Both of these firms continued to supply to the Navy a large percentage of their output of coal at the regular price named to the Bureau April 1, 1902, for the following year, viz, about $2.50 per ton f. o. b. at the tide-water outlets of their mines. These firms steadfastly adhered to their agreement with the Bureau, although constantly importuned for coal by powerful industrial companies. They were frequently threatened with legal proceedings and in some instances actually sued for damages. The ruling prices for coal were at this time three and four times the sum which they received from the Government.

The interests of these firms in the future are commended to your consideration.

The Bureau would not have been able to achieve the above-mentioned results had it not carried a large amount of coal in stock. There were 60,000 tons in store at Manila alone; this was reduced one-half before additional supplies could be sent there. Other coal depots were largely depleted, but are now, as a rule, well supplied.

On April 1, 1903, the large coal companies advanced the rate of coal from $2.50 to about $3.35 per ton. This rate can hardly be maintained any great length of time, and will prevent the export of American coal beyond the West Indies with the present price of Cardiff coal.

TRANSPORTATION OF COAL.

The Bureau has continued the policy of supplying the best domestic coal obtainable for use on shipboard when practicable.

During the past fiscal year 226,650 tons of coal have been shipped to foreign and domestic ports, the greater amount to the Asiatic Station. Of this amount 130,017 tons were sent in chartered vessels, mostly foreign, and 96,643 tons in navy colliers.

The following table will indicate the fluctuating rates of freight on coal from the Atlantic coast to the port of Manila.

Fiscal year.	Average rate per ton.	Fiscal year.	Average rate per ton.
1899	$6.99	1902	$5.83
1900	7.90	1903	4.84
1901	8.63		

TRANSPORTATION OF COAL BY NAVY COLLIERS.

There are fourteen navy colliers in commission, manned by merchant crews, as follows:

Ajax.	*Hannibal.*	*Marcellus.*	*Saturn.*
Alexander.	*Justin.*	*Nanshan.*	*Sterling.*
Brutus.	*Lebanon.*	*Nero.*	
Caesar.	*Leonidas.*	*Pompey.*	

The *Ajax, Alexander, Brutus, Nanshan,* and *Pompey* are attached to the Asiatic Station in attendance upon the fleet. The *Justin* has been continued as station collier at Guam.

The *Caesar, Sterling, Marcellus,* and *Lebanon* are in attendance upon the North Atlantic fleet.

The *Nero* and *Saturn* are in attendance upon the Pacific fleet.

Although the *Hannibal* and *Leonidas* are unassigned, they are frequently used to attend upon the fleet in home waters, but when not engaged on this duty are used by the Bureau for the purpose of transporting coal to various coaling stations. The greater part of coal transportation is now by chartered vessels.

The Bureau renews its recommendation for the construction of two large steam colliers, as indicated in the annual report of last year.

COAL TESTS.

Tests of coal have been continued during the fiscal year, the methods having been fully described in previous annual reports.

The following table contains the results of chemical analyses made of various samples received during the year. These samples are arranged in the order of amount of fixed carbon they contain:

Chemical analyses of samples of coal at the navy-yard, Washington, D. C.

[Arranged in order of percentage of fixed carbon. Sample selected officially is noted by an asterisk (*).]

BITUMINOUS COALS.

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.		Moisture.	Ash.	Sulphur.	Increase in weight at 250° F.
			Combustible.	Noncombustible.				
Eureka*	Clearfield County, Pa	82.04	11.50	0.657	0.843	4.96	0.676	0.076
Do.*	do	81.14	11.12	1.320	1.020	5.40	1.104	.198
Do.*	do	81.13	13.12	.334	.906	4.51	.429	.072
Thin-veined Pocahontas, Big Sandy mine.	McDowell County, W. Va	81.06	15.94	.500	.640	1.86	.653	.266
Eureka*	Clearfield County, Pa	80.56	11.16	1.720	1.040	5.52	.876	.140
Thin-veined Pocahontas, Tug River mine.	McDowell County, W. Va	80.52	13.34	1.760	.600	3.78	.590	.231
Eureka*	Clearfield County, Pa	80.42	11.53	1.650	.780	5.62	.627	.022
Do.*	do	80.34	10.82	2.720	.920	5.20	.963	.052
Do.*	do	80.19	12.32	1.270	.880	5.34	.407	.064
Do.*	do	79.56	11.26	1.920	.800	6.46	.632	.062
Do.*	do	79.06	9.56	2.570	1.710	7.14	1.560	.430
Do.*	do	78.19	9.16	3.020	1.020	8.61	.467	.072
Do.*	do	77.52	13.24	1.050	.630	7.56	.906	.122
Do.*	do	76.68	13	.810	1.080	8.43	2.390	.258
Yentai*	Moukden, Manchuria	74.56	9.03	.910	.820	14.68	.214	.048
None	Webster County, W. Va	65.16	28.74	1.170	1.250	3.68	Trace.	.....
Kanawha	Kanawha County, W. Va	59.35	30.93	2.650	2.150	4.92	.007	.....
Unknown	Graham Island	57.60	30.96	2.360	2.710	6.37	.107	.578
Sorachi*	Hokaido, Japan	56.60	34.60	3.340	2.540	2.92	.267	.524
Yubari*	do	53.10	39.20	1.860	1.640	4.20	.218	.352
Unknown	Near Zamboango, P. I	51.90	36.48	4.020	5.230	2.37	.082	.207
Yubari	Hokaido, Japan	51.42	40.60	2.050	1.350	4.58	Trace.	.....
Retchnoi*	West shore of Amur Bay, near Vladivostock	43.18	31.11	4.930	14.100	6.68	.074	.880

ANTHRACITE COALS.

None given	Graham Island	88.14	0.79	2.230	1.720	7.12	0.009	0.170
Do	Swansea, Wales	86.38	3.98	.850	1.830	6.96	.544	.149
Do	Pallasca Province, Peru	86.20	1.98	.630	3.170	8.02	.653	.116

ARRANGEMENTS FOR SUPPLYING COAL TO NAVAL SHIPS IN FOREIGN PORTS.

The Bureau has made agreements in sixty-six foreign ports to supply ships of the Navy with coal at below current rates. These agreements have been referred to in previous annual reports and have proved both convenient and economical.

COAL AND WATER BARGES.

Continuing its policy of providing, so far as possible, all necessary appliances for rapidly supplying ships with coal and water, the Bureau has increased the number of coal barges from 69 to 105 and water barges from 8 to 11.

NAVAL COAL DEPOTS.

The Bureau in its last annual report discussed extensively the subject of naval coal depots. The opinions of boards and officers were freely quoted, the necessity for their existence fully explained, and progress in the past illustrated and described. The previous reports of the Bureau also contain much information on this subject. In consideration of these facts the Bureau will confine itself in this report to a statement of progress during the last fiscal year.

Your attention is respectfully invited to the fact that no new depot has been authorized by the Department during the past year; also to the fact that an appropriation for coal depots was omitted in the last naval appropriation bill, after a yearly grant for a considerable period.

NAVAL COAL DEPOTS ON THE ATLANTIC AND GULF COASTS.

The location of these depots was illustrated in the last annual report of the Bureau. They consist of a total of fourteen, built, building, or projected.

Frenchman Bay, Me.—This depot is completed and has a capacity of about 10,000 tons. It has been improved during the past year by an ice breaker and a coal pocket; the latter has a capacity of 600 tons and is for coaling small craft rapidly. The water-supply system, including a standpipe containing 250,000 gallons, has also been completed. Four coal barges, carrying 250 tons each, have been added to the equipment of the depot.

During the naval maneuvers of the past summer the ships of the fleet coaled at this station and were also supplied with water. The fleet required 19,000 tons of coal, indicating that the capacity of the depot should be increased.

The Bureau has been much gratified at the praise bestowed upon this depot by the officers of the fleet. A captain of one of the battle ships, in writing of the depot, says, "It is the best I have ever seen." Again, "I went to the station in company with ten other ships, and all were coaling within an hour after arrival."

Naval station, Portsmouth, N. H.—The construction of the coal storage and handling plant at this station, appropriated for March 3, 1899, is under the cognizance of the Bureau of Yards and Docks. It is now in process of erection and about 40 per cent completed. Its capacity will be about 10,000 tons.

Naval station, Boston, Mass.—The construction of the coal storage and handling plant at this station, appropriated for under the acts of July 9, 1898, March 3, 1899, and March 3, 1901, is under the cognizance of the Bureau of Yards and Docks. The foundations have been completed and the material has all been delivered. The process of erection has just commenced. Its capacity when completed will be about 12,800 tons. Six coal barges are under construction for this station.

The Bureau renews its recommendation of last year that a coal depot in the near vicinity of Boston, inside the fortifications, with a capacity of 50,000 tons, be established; the reasons for this recommendation are fully stated in the above-mentioned report.

Narragansett Bay, R. I.—The coal depot on this bay was fully described in the last annual report of the Bureau, and is nearing completion. A water-supply service, with a standpipe of 260,000 gallons capacity, located sufficiently high to supply water for fire purposes, has been completed. Twelve coal barges are under construction for this depot.

During the fiscal year the Bureau advertised for bids for an increase in the storage capacity of this plant to a total of 40,000 tons. Mr. Augustus Smith, the contractor for the plant nearing completion, being the lowest bidder, was awarded the contract. It is anticipated that the extension will be completed in about two years' time. When finished it will probably be one of the most complete coal depots, for its capacity, in the world.

Naval station, New London, Conn.—The coal depot at this station has done efficient service during the past year. No changes or extensive repairs have been made.

Naval station, New York, N. Y.—The acts of March 3, 1899, March 3, 1901, and July 1, 1902, appropriated a total of $260,000, under the cognizance of the Bureau of Yards and Docks, for the construction of a coal storage and handling plant at this station.

The pier on which the coal shed is to be erected has been completed. The shed itself is in process of construction, and it is hoped that it will be ready for use by November 1; its capacity will be about 9,000 tons, an amount totally inadequate for a first-class naval station. About 30,000 tons are used for yard purposes every year, and as battle ships and first-class cruisers now carry from 1,500 to 2,000 tons of coal in their bunkers, and as a reserve supply should always be on hand, it will readily be seen that a much larger depot should be constructed.

In this connection, the Bureau renews its recommendation of last year, that at some point in the lower bay or in the Hudson River a large depot capable of storing not less than 50,000 tons of coal be established.

Naval station, League Island, Pa.—There are no facilities for storing coal under cover or for handling coal rapidly at this station. The Bureau renews its recommendation of last year that facilities be provided at this station for storing a large reserve supply of coal for shipment.

Naval station, Washington, D. C.—The small storage shed of 3,000 tons capacity at this station, referred to in the last annual report of the Bureau, has been of much service during the past year. The appliances for handling coal have been used for unloading and transporting to cars many thousands of tons of coal for the shops of the gun factory.

Naval station, Norfolk, Va.—No improvements in storing or handling coal have been made at Norfolk or its vicinity during the year. The recommendations in the last annual report of the Bureau are renewed. Some attention has been paid to selecting a favorable site for a large storage of coal in this general locality. It is believed that York River furnishes the most favorable conditions for this purpose; it is considered expedient that a storage of at least 50,000 tons should be provided for in the vicinity of Yorktown with as little delay as possible.

Naval station, Port Royal, S. C.—Attention is invited to the recommendations of the Bureau in connection with this station in the report of last year. These recommendations are renewed. There is an excellent wharf at the Port Royal Naval Station, which may be utilized for coaling purposes, and with other appliances already constructed, accommodations for a large amount of coal can be established at small expense. Of the two ports, Port Royal and Charleston, the former is considered more desirable for a coal depot.

Naval station, Charleston, S. C.—As coal is always required for yard use and for ships at a navy-yard, it is recommended that appliances for handling and storing 10,000 tons be established at this station as soon as practicable.

The distinction intended to be made between Charleston and Port Royal is, that the latter shall be used to supply ships in need of coal while in this locality and the former to provide for local consumption only.

Naval station, Key West, and Dry Tortugas, Fla.—A large amount of coal has been supplied from Key West to ships of the Navy and vessels belonging to other departments of the Government during the year. Pier A of this depot, built in 1881, is in need of repairs, but there are funds available under the cognizance of the Bureau of Yards and Docks for this purpose. A depth of 26 feet alongside of pier B has been obtained by dredging. The coal-handling appliances are in good condition and very efficient.

The coal storage and handling plant at Dry Tortugas, which has been fully described in preceding reports, is nearing completion, under the supervision of the Bureau of Yards and Docks. It will probably be ready to receive coal in November, 1903. Dry Tortugas having been placed under the cognizance of the Bureau of Equipment by the Department for a coal depot, the Bureau has from time to time made small repairs upon the quarters, in order to make them habitable and sanitary for the marine guard and others stationed there.

Naval station, Pensacola, Fla.—No change has taken place at this station during the past year in reference to accommodations for handling and storing coal. The presence of the fleet in Pensacola Bay during the past winter emphasized the necessity of greatly improved conditions for rapidly supplying ships of war with coal, and attention is invited to the statements of the Bureau in preceding reports on this subject.

Naval station, New Orleans, La.—The act of March 3, 1901, appropriated $150,000, under the cognizance of the Bureau of Yards and Docks, for a coal-storage plant at this station. So far as the Bureau is aware, no steps have been taken to erect the necessary appliances for the above-mentioned purpose. It is understood that the matter has been delayed in order that additional land may be obtained.

The coal found in the market at New Orleans is, as a rule, of an inferior quality, hardly suitable for use by ships of war. The best coal can only be obtained by carrying it in stock, and the necessary appliances for so doing should be erected as soon as practicable.

The distance of New Orleans from the mouth of the Mississippi River, and the difficult navigation of the latter, render it desirable that a coal depot should be established near the sea, but inside the line of fortifications.

The Mississippi River and the harbor of Pensacola are the only two ports in the Gulf of Mexico that can be entered by heavy ships under any circumstances. Both may be easily closed by obstructions. It is therefore desirable to have ample appliances at both places for supplying ships with coal, water, ammunition, waste, and such other stores as are constantly needed by ships in time of war.

NAVAL COAL DEPOTS ON THE PACIFIC COAST.

Reference is made to a chart in the last annual report of the Bureau showing the location of Pacific coast naval coal depots, consisting of a total of five, either built, building, or projected.

Dutch Harbor, Amaknak Island, Alaska.—As stated in the last annual report of the Bureau, a site for a coal depot at this port has been obtained and is now the property of the Navy Department. No progress, however, has been made during the past year toward establishing the depot thereon. In the opinion of the Bureau Dutch Harbor should be fortified, not only as a means of defense of naval supplies, but in order that it may be used as a place of refuge for American merchant ships. This harbor is located on a commercial route, over which treasure and valuable cargoes are constantly passing to and fro.

The Alaska Commercial Fur Company has offered its extensive plant at Dutch Harbor, including a coal wharf, coal-storage houses, and other buildings, for sale to the Government for $150,000. The Bureau has asked for an inventory of this property, and is of the opinion that the offer is worthy of serious consideration.

Sitka, Alaska.—Since the last annual report of the Bureau a contract has been awarded for the construction of an additional coal-storage house at this port, with a capacity of 2,500 tons. This will give a total capacity of 5,000 tons for the depot. The work is being done by Mr. George E. James, who built the original plant, which has proved satisfactory. In addition to doubling the storage capacity of the depot, the small lighter wharf formerly used is now being widened and lengthened sufficiently to permit vessels of considerable size to discharge cargo or take coal on board alongside.

The construction and custody of the above-mentioned coal depot have been in charge of Capt. J. H. Pendleton, U. S. Marine Corps. All work at the depot is done by the marine guard, without expense to the Department. This duty has been performed in a manner highly satisfactory to the Bureau.

Naval station, Puget Sound, Washington.—The coal-storage and coal-handling plant located at this station is under construction by the Bureau of Yards and Docks, and is nearing completion. It will have a capacity of 20,000 tons, and should be ready for use by January 1, 1904. Arrangements have already been made to stock this depot with the best coal obtainable.

Naval station, Mare Island, Cal.—Coal sheds have been constructed at this station with a capacity of 20,000 tons, when stored at a depth of 12 feet. By increasing the latter additional supplies may be accommodated. These sheds are constructed with transverse axes parallel to the water front, and the coal is handled by Brown conveyors. Four wooden barges of 250 tons capacity each and two steel barges of 550 tons capacity each have been added during the year to the coal-handling appliances.

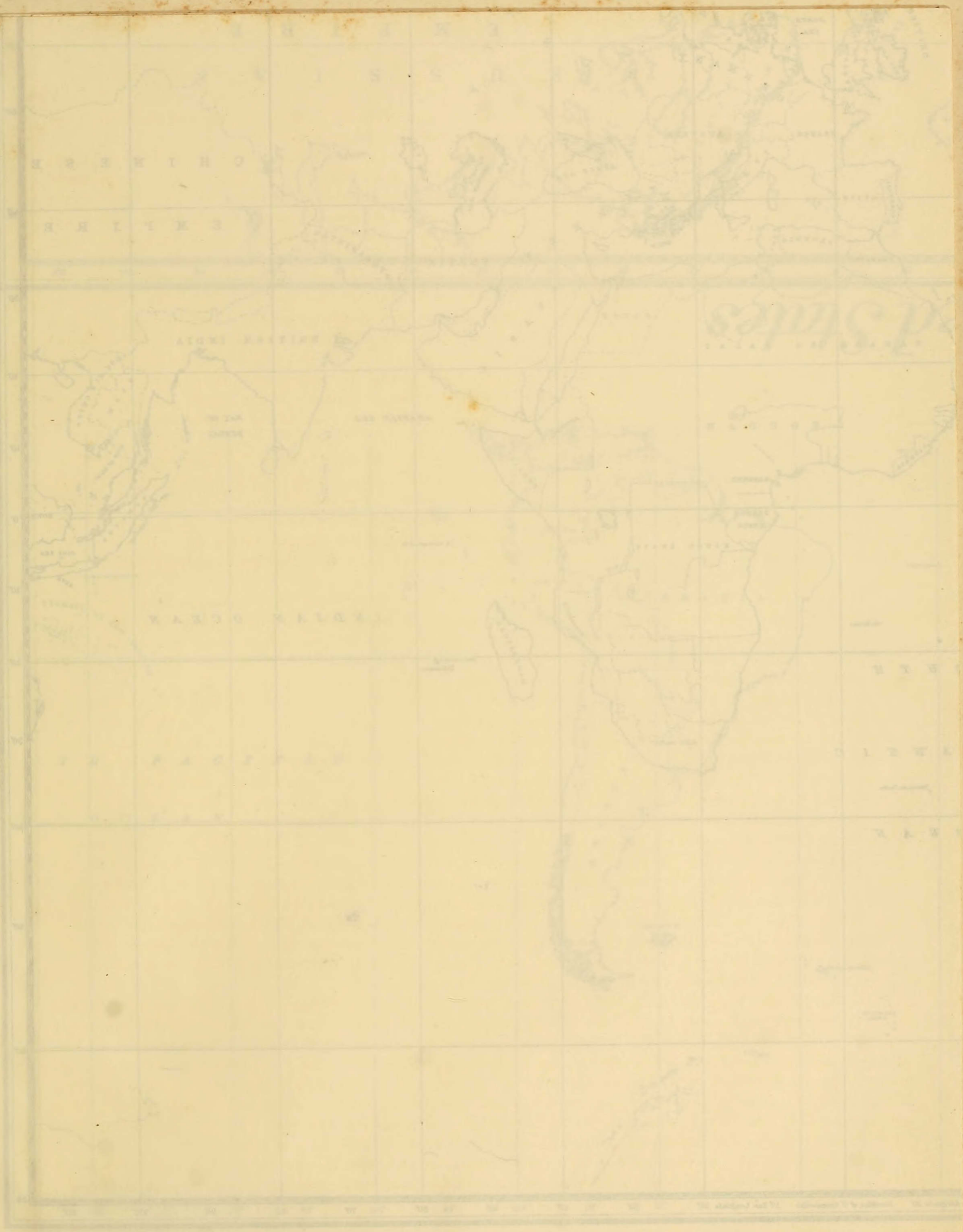
San Francisco Bay, California.—Reference is made to former reports of the Bureau for a full description of the efforts made by the Department to establish a naval coal depot of large dimensions at this port.

In this connection especial attention is invited to the question of title to Mission Rock Island, which has been recommended in the past by various officers, boards, and the Bureau as a site for the large depot above mentioned. This matter has been in litigation for a number of years, and was appealed by the company in possession to the Supreme Court. Since the last annual report this court has rendered a decision to the effect that the original land above water is the property of the Department, and that the surrounding area made by filling in is the property of the company; in other words, that title is divided. The superficial area given to the Department, however, is small. The company offers to quitclaim its right and title to the island for the sum of $250,000, a sum $50,000 greater than its former price when claiming ownership to the entire property.

The warehouses on the islands owned by the company are dilapidated wooden structures, and are practically of no value to the Department; there is remaining, therefore, only the land on which they are situated, amounting to about 4 acres. It is located along the fairway of the water front of the harbor; nearby are dangers to navigation, and the tidal currents in this vicinity are very strong. Owing to the nature of the bottom and sloping sides of the island, the construction of a depot there will be very expensive.

Having in mind these facts, the Chief of Bureau recently visited San Francisco Bay with a view of finding some other locality that was acceptable. A site consisting of 50 acres, located in Marin County, commonly known as California City Point, was offered for sale to the Department for $100,000. The anchorage off this site is excellent, the currents are moderate, the depth of water desirable, and the holding ground good. An entire fleet can anchor there in formation. Coal can be taken on board rapidly from piers, lighters, or from both. The Bureau is at present investigating the character of the bottom, water supply, and other matters necessary before reaching a decision as to the advisability of acquiring this site. At present the Bureau is very favorably disposed to substituting the California City Point site for the Mission Rock site.

San Diego, Cal.—No progress has been made during the past year in establishing a naval coal depot at this port. The former reports of the Bureau give a complete history of previous attempts, and the present status of the matter may be described as follows, viz: That the desirable portion of the land obtained by the

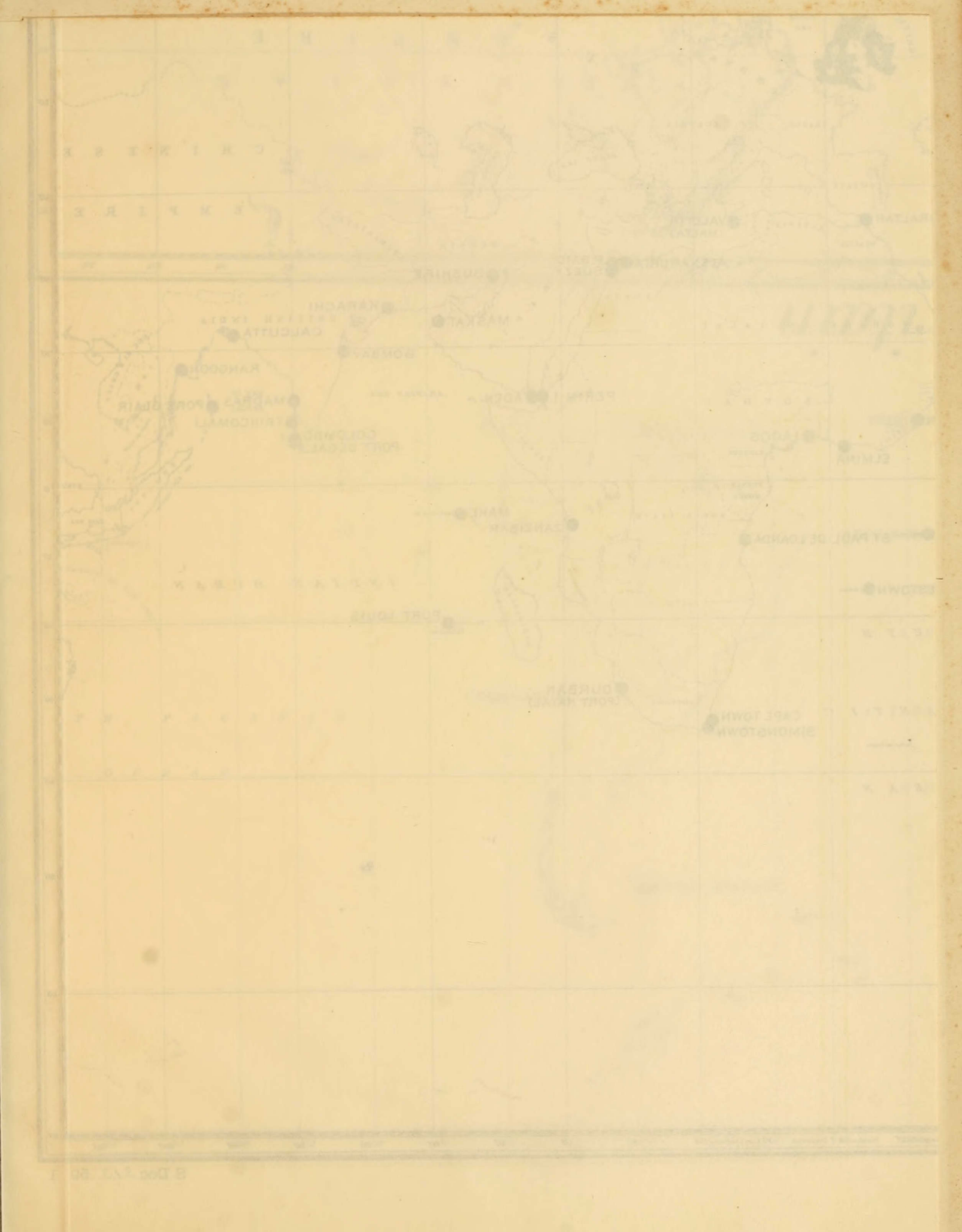


Coaling Stations of the United States

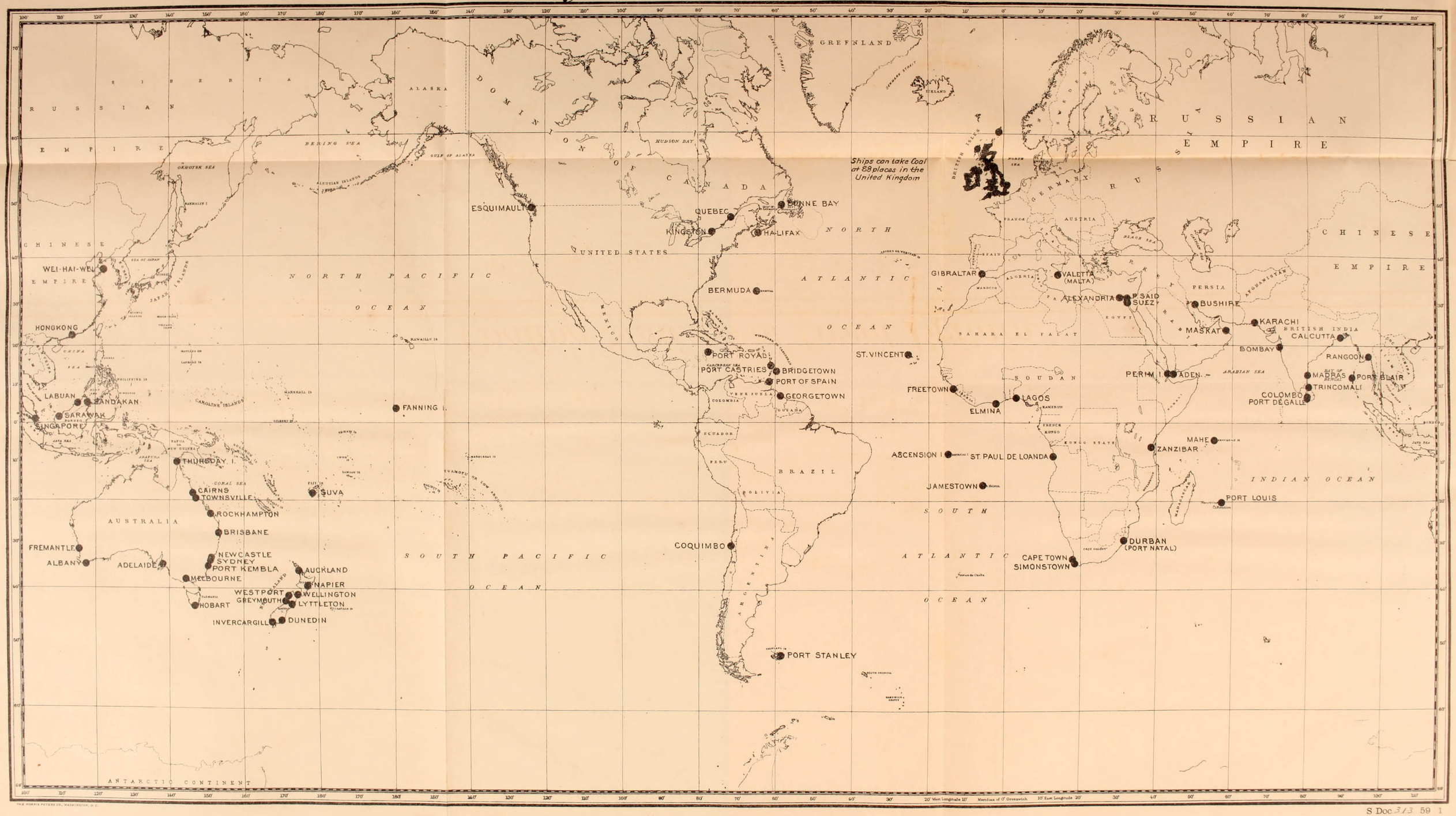


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Coaling Stations of Great Britain



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Navy Department from the War Department for this purpose having been transferred by act of Congress to the Treasury Department, for use as a quarantine station, the entire matter is held in abeyance for further action of Congress.

The work accomplished thus far in establishing naval coal depots on the Pacific coast may be summarized as follows:

At Sitka, Alaska, storage built and building for 5,000 tons; at Puget Sound Navy-Yard, storage building for 20,000 tons; at Mare Island Navy-Yard, storage practically completed for 20,000 tons; total storage, built and building, for 45,000 tons, where there should be at all times in stock not less than 200,000 tons.

INSULAR NAVAL COAL DEPOTS.

Attention is invited to a chart appended to the last annual report of the Bureau showing the relative locations of the insular naval coal depots built, building, or projected for the use of ships of the Navy.

NAVAL STATION, SAN JUAN, P. R.—This depot has been used constantly during the past year, having supplied a large amount of coal to ships of the Navy. No change has occurred in this station since the last annual report, with the exception that the Bureau has concreted a large portion of the open space where the coal is stored in order to prevent foreign substances from being taken up with the coal when it is supplied to ships.

GUANTANAMO, CUBA.—A naval coal depot is projected at this port, but no steps have yet been taken toward its construction.

BAHIA HONDA, CUBA.—A naval coal depot is projected in this harbor. It is necessary to make a thorough hydrographic survey of the port before a suitable site can be selected or other steps taken toward its construction.

NAVAL STATION, HAWAII, HAWAII.—This coal depot is in excellent condition and has performed efficient service during the past year. No changes or repairs of any extent have been made during the year.

NAVAL STATION, TUTUILA, SAMOA.—Reference is made to the last annual report of the Bureau for a full statement concerning the naval coal depot now existing at this port. No change has taken place in its status during the past year.

NAVAL STATION, ISLAND OF GUAM.—During the past year the purchase of the necessary land for a naval coal depot in the harbor of San Luis d'Apra has been consummated. A report of the land obtained and its cost has not yet been received. The latter will, however, be considerably less than anticipated.

Attention is invited to the full statements in previous reports in connection with the island of Guam. Immediate action with a view of establishing at this island a fortified base and coal depot is respectfully urged.

NAVAL STATION, CAVITE, P. I.—The Bureau continues to supply American coal for the use of the Asiatic fleet. A coal depot with a capacity of 30,000 tons is now under construction at Sangley Point, near the naval station, Cavite, and was fully described in the last annual report. At present this depot is about 85 per cent completed.

Coal is also kept stored at the following Philippine ports, viz:

Isabela de Basilan.	Cebu, Cebu.
Polloc, Mindanao.	Olongapo, Luzon.

These small depots and ships are supplied from Cavite by navy colliers.

Upon completion of the depot under construction, the facilities for supplying coal to the fleet will be greatly improved and the expense of handling much reduced. The capacity of the coal storage houses, however, should be doubled as soon as practicable. It is necessary to carry at least 50,000 tons in stock at this station.

Of the seven insular naval coal depots, four are now provided with indifferent facilities for storing a very moderate amount of coal. The remaining three have no facilities whatever.

FOREIGN NAVAL COAL DEPOTS.

The establishment of United States coal depots for naval use in foreign waters, owing to diplomatic considerations, is not discussed in this report on account of its publicity. The Bureau will add, however, for the information of the Department, that no progress whatever in this direction has been made during the past year.

There are submitted herewith, in connection with the subject of naval coal depots, two maps of the world.

On the first is shown, by a heavy black border, the seacoast of the continental limits of the United States, and by black dots the coal depots built, building, or projected of the United States located outside of these limits.

On the second map the same information is depicted in connection with the United Kingdom of Great Britain.

A comparison of the two is instructive.

CHEMICAL ANALYSES OF COAL AT NAVY-YARD, WASHINGTON, D. C.

CHEMICAL ANALYSES OF COAL AT NAVY-YARD, WASHINGTON, D. C.

NAVY DEPARTMENT,
Washington, March 6, 1906.

SIR: Referring to your letter of the 23d ultimo, requesting copies of reports of analyses of coal made under the direction of the Bureau of Equipment since those given in its annual report of 1902, and to this Department's letter of the 1st instant, advising you that steps had been taken by the Bureau concerned to prepare the desired data, I have the honor to forward herewith a copy of the Annual Report of the Bureau of Equipment for 1903, which contains, on page 59, a number of analyses made under the direction of that Bureau, together with a typewritten list of analyses made since the publication of the 1903 report, which have not yet been published by the Bureau.

It is requested that, if practicable, 500 copies of the document which it is proposed to have published by the Committee on Interoceanic Canals, be furnished this Department for distribution.

Very respectfully,

CHARLES J. BONAPARTE, *Secretary.*

The Hon. JOHN T. MORGAN,
United States Senate, Washington, D. C.

(Inclosures.)

Chemical analysis of samples of coal at the Washington Navy-Yard, Washington, D. C.

[Arranged in order of percentage of fixed carbon. Sample selected officially is noted by an asterisk (*).]

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur.	Increase in weight.
Nixon's Navigation	Wales	*87.00	10.98	0.62	1.40	0.72	0.20
Banff Smokeless Semi-Anthracite	Banff, Alberta, British Columbia	86.20	8.23	.83	4.74	.42	.17
Nixon's Navigation	Wales	*85.96	11.86	.60	1.58	.94	.30
Do	do	*84.72	12.90	.80	4.60	.89	.10
Pocahontas (Miltrena, sample No. 5)	West Virginia	84.56	13.58	.56	1.30	.35	.28
Nixon's Navigation	Wales	*84.56	10.29	.65	4.50	.93	.064
Do	do	*84.44	11.44	.60	3.52	.85	.15
Do	do	*84.28	11.42	.71	3.59	.90	.27
Pocahontas	Virginia and West Virginia	*84.12	13.45	.19	2.24	.60	.18
Pocahontas (Miltrena, sample No. 3)	West Virginia	84.02	13.62	.74	1.62	.52	.51
Nixon's Navigation	Wales	*83.32	11.26	.82	1.58	.84	.34
Pocahontas	Virginia and West Virginia	*83.14	12.96	.46	3.44	.65	.20
Do	do	*82.48	12.76	.62	4.14	.49	.14
New River	Fayette County, W. Va	*82.44	14.65	.57	2.34	.71	.32
Pocahontas	Virginia and West Virginia	*82.38	13.70	.48	3.44	.88	.04
Do	do	*82.36	14.14	.54	2.96	.64	.13
Pocahontas (Miltrena, sample No. 4)	West Virginia	82.31	15.46	.61	1.62	.60	.22
Pocahontas	Virginia and West Virginia	*82.24	14.22	.74	2.80	.60	.14
Eureka	Somerset and Cambria counties, Pa	*82.18	13.67	1.03	3.12	.72	.14
Pocahontas	Virginia and West Virginia	*82.06	13.38	.54	4.02	.69	.16
Do	do	*81.98	12.37	.33	5.32	.74	.06
Do	do	*81.96	14.48	.42	3.14	.59	.21
Miller Seam	South Fork, Pa	81.64	14.37	.51	3.48	.90	.28
Pocahontas	Virginia and West Virginia	*81.60	14.81	.63	2.96	1.14	.08
Do	do	*81.54	13.70	.36	4.40	.81	.30
Eureka	Somerset and Cambria counties, Pa	*81.44	13.96	1.04	3.56	.71	.10
Do	do	*81.40	12.84	.50	5.26	.82	.60
Do	do	*81.34	12.92	.80	4.94	.68	.10
Tug River Thin Vein Pocahontas	McDowell County, W. Va	81.24	15.98	.52	2.26	.55	(a)
Pocahontas	do	81.18	16.21	.27	2.34	.67	.20
Do	do	*81.14	14.19	.56	4.11	.56	.15
New River	West Virginia	*81.12	14.62	.32	3.94	.81	.43
Pocahontas	Virginia and West Virginia	*81.08	14.11	.45	4.36	.56	.20
Thin Vein Pocahontas, Big Sandy Mine	McDowell County, W. Va	81.06	15.94	.64	1.86	.653	.266
Pocahontas	Virginia and West Virginia	*81.00	14.46	.66	3.88	.63	.05
Elk Garden Big Vein, Georges Creek	Mineral County, W. Va	*80.92	14.85	.21	4.02	.95	.12
Pocahontas	Virginia and West Virginia	*80.76	14.56	.80	3.88	.80	.05
Do	do	*80.73	14.80	.49	3.98	.70	.10
Do	do	*80.70	16.22	.50	2.58	.71	.30
Eureka	Somerset and Cambria counties, Pa	*80.62	13.64	.76	4.98	.85	.02
Pocahontas Steam	West Virginia	80.58	15.10	.38	3.94	.65	.35
Pocahontas	Virginia and West Virginia	*80.52	14.81	.73	3.94	.53	.25
Thin Vein Pocahontas, Tug River Mine	McDowell County, W. Va	80.52	13.34	.60	3.78	.59	.231
Pocahontas	Virginia and West Virginia	*80.50	15.34	.82	3.34	.69	.10
Georges Creek	Allegany County, Md	*80.42	15.85	.47	3.26	.85	.13
Pocahontas	Virginia and West Virginia	80.38	15.86	.40	3.36	.56	.25
Eureka	Somerset and Cambria counties, Pa	*80.38	14.83	.41	4.38	.72	.22
Do	do	*80.38	14.28	1.02	4.32	.81	.17
Do	do	*80.34	14.65	.91	4.10	.68	.40
Do	do	*80.32	14.53	.27	4.88	.68	.11
Pocahontas	Virginia and West Virginia	*80.30	15.56	.40	3.74	.68	.30
Do	do	*80.24	13.57	.57	5.62	.53	.16
Eureka	Somerset and Cambria counties, Pa	*80.22	14.14	.70	4.94	.92	.10

[a] Far below permitted limit.

Chemical analysis of samples of coal at the Washington Navy-Yard, Washington, D. C.—Continued.

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur.	Increase in weight.
Pocahontas	Virginia and West Virginia	*80.20	14.14	0.44	5.22	0.70	0.05
Do	do	*80.08	16.62	.35	2.95	.58	.28
Do	Bluefields, W. Va	80.06	14.96	1.10	3.88	.50	.61
Miller Seam	South Fork, Pa	80.04	13.32	.88	5.76	1.20	.06
Pocahontas	Bluefields, W. Va	79.96	12.75	.79	6.50	.63	.55
Do	Virginia and West Virginia	*79.92	16.26	.80	3.02	.54	.36
Do	do	*79.80	17.28	.58	2.34	1.41	.52
New River	Fayette County, W. Va	*79.76	17.58	.60	2.06	.66	.18
Pocahontas	Virginia and West Virginia	*79.72	17.67	.95	1.66	1.09	.71
New River Smokeless, Sugar Creek	Fayette County, W. Va	79.66	17.35	1.27	1.72	.53	.72
Pocahontas	Virginia and West Virginia	*79.60	17.68	1.02	1.70	.55	.17
Pocahontas, Greenbrier-Louisville Mines	McDowell County, W. Va	*79.55	13.49	.88	6.08	.49	.09
Eureka	Somerset and Cambria counties, Pa	*79.52	14.62	.62	5.24	.93	.17
Standard Eureka	do	*79.51	12.49	.21	7.79	1.68	.41
Not named	Republic of Panama	79.48	11.90	1.04	7.58	.67	.....
Elk Garden, Big Vein Cumberland	Elk Garden, W. Va	79.44	15.46	.80	4.30	.91	.17
Pocahontas	Virginia and West Virginia	*79.40	16.56	.82	3.22	.71	.26
Georges Creek	Allegany County, Md	*79.38	14.90	1.02	4.70	.81	.07
Pocahontas	Virginia and West Virginia	*79.30	18.24	.60	1.86	1.56	.13
Nomparlel	Cambria County, Pa	79.24	16.74	.58	3.44	1.21	.39
South Fork	South Fork, Pa	*79.20	13.64	.94	6.22	1.85	.05
New River Smokeless, Macdonald	Fayette County, W. Va	79.18	18.58	1.20	1.04	.42	.61
Pocahontas	Virginia and West Virginia	*79.12	15.88	.38	4.62	.70	.16
Georges Creek, Washington Mine No. 2	Allegany County, Md	79.06	15.81	.91	4.22	1.05	.05
Eureka	Somerset and Cambria counties, Pa	*79.06	13.70	1.20	6.04	1.13	.18
Pocahontas	Virginia and West Virginia	*79.04	16.46	.66	3.84	.65	.17
Do	do	*79.02	16.60	.92	3.46	.47	.11
New River	Fayette County, W. Va	*78.98	17.47	.25	3.30	.69	.29
Pocahontas	Virginia and West Virginia	*78.96	16.44	1.08	3.56	.47	.21
Do	do	*78.86	16.82	.42	3.90	.58	.30
Georges Creek	Allegany County, Md	*78.80	14.84	.68	5.68	.88	.08
Pocahontas	Virginia and West Virginia	*78.78	16.65	1.36	3.22	1.26	.36
Eureka	Somerset and Cambria counties, Pa	*78.74	14.02	.60	6.64	1.13	.10
Georges Creek	Allegany County, Md	*78.70	16.00	.52	4.78	.83	.20
Do	do	*78.62	15.47	.63	5.28	.87	.07
Rocky Ridge	Huntingdon County, Pa	78.60	16.00	.50	4.90	1.03	.06
Eureka	Somerset and Cambria counties, Pa	*78.58	14.70	.94	5.78	1.15	.40
Do	do	*78.58	14.60	1.04	5.78	1.57	.18
Do	do	*78.40	14.32	1.04	6.24	.81	.12
Pocahontas	Virginia and West Virginia	*78.36	15.55	.47	5.62	.65	.13
South Fork	South Fork, Pa	*78.34	15.66	.66	5.34	1.13	.16
Eureka	Somerset and Cambria counties, Pa	*78.28	14.65	.75	6.32	1.16	.10
Standard Eureka	do	*78.28	13.63	1.03	7.06	.62	.25
Georges Creek	Allegany County, Md	*78.26	15.19	.83	5.72	.78	.28
Do	do	*78.08	15.58	.32	6.02	.88	.25
New River Smokeless, Scarbro	Fayette County, W. Va	78.06	19.48	1.24	1.22	.48	.64
Georges Creek	Allegany County, Md	*78.06	13.80	.90	7.24	1.07	.07
Eureka	Somerset and Cambria counties, Pa	*78.02	13.48	1.04	7.46	1.26	.17
Georges Creek	Allegany County, Md	*77.96	14.42	.50	7.12	.94	.36
New River (Rend Mines)	Fayette County, W. Va	*77.80	20.06	.44	1.70	.54	.52
Pocahontas	Virginia and West Virginia	*77.74	15.56	.44	6.26	.52	.15
Georges Creek	Allegany County, Md	*77.70	16.01	.41	5.88	1.22	.16
Georges Creek, Elk Garden	Elk Garden, W. Va	77.64	15.56	.64	6.16	1.20	.20
Elk Garden, Big Vein George's Creek	Mineral County, W. Va	*77.62	16.16	.84	5.38	.93	.22
Pocahontas	Virginia and West Virginia	*77.50	14.96	.68	6.86	.65	.10
Georges Creek	Allegany County, Md	*77.48	15.51	1.09	5.92	.82	.12
South Fork	South Fork, Pa	*77.48	14.23	1.27	7.02	1.06	.07
Pocahontas	Virginia and West Virginia	*77.32	20.97	.83	.88	.70	.20
Georges Creek	Allegany County, Md	*77.30	16.62	1.00	5.08	.99	.12
Pocahontas	Virginia and West Virginia	*77.28	16.07	.61	6.04	.69	.20
New River (Miltrena, Collins' Colliery)	Fayette County, W. Va	77.26	19.94	.82	1.98	.70	.52
New River	do	*77.18	18.68	.76	3.38	.71	.42
Eureka	Somerset and Cambria counties, Pa	*77.10	17.54	.40	4.96	.75	.40
Pocahontas	Virginia and West Virginia	*77.06	16.37	.69	5.88	.68	.27
South Fork	South Fork, Pa	*77.04	18.37	.51	4.08	.59	.45
Pocahontas	Virginia and West Virginia	*76.86	16.48	1.08	5.58	.51	.12
New River	Fayette County, W. Va	*76.84	20.50	.66	2.00	.66	.34
New River (Rend mines)	do	*76.83	20.29	.40	2.48	.58	.50
New River (Miltrena, Whipple Colliery)	do	76.82	20.59	.81	1.78	.69	.77
Eureka	Somerset and Cambria counties, Pa	*76.76	14.28	1.10	7.86	.90	.12
Elk Garden, Big Vein, George's Creek	Mineral County, W. Va	*76.74	15.05	.61	7.60	.92	.25
New River (Rend mines)	Fayette County, W. Va	*76.70	20.58	.48	2.24	.88	.18
Georges Creek	Allegany County, Md	*76.68	16.16	.64	6.52	.74	.21
New River	Fayette County, W. Va	*76.66	20.26	.18	2.90	.55	.15
Do	do	*76.66	19.32	.76	3.26	.62	.25
New River Smokeless, Stuart Colliery	do	76.64	21.00	.76	1.60	.56	.66
South Fork	South Fork, Pa	*76.62	16.86	.54	5.98	2.08	.34
New River	Fayette County, W. Va	*76.60	18.35	.73	4.32	.52	.31
Do	do	*76.56	16.48	.50	6.46	.90	.14
Georges Creek	Allegany County, Md	*76.56	15.95	.99	6.50	1.19	.07
Elk Garden	Mineral County, W. Va	*76.56	14.92	.66	7.86	1.01	.07
Georges Creek, Washington Mine No. 3	Allegany County, Md	76.44	13.31	.87	9.38	1.16	.44
Georges Creek	do	*76.42	16.31	.83	6.44	1.04	.21
Do	do	*76.42	16.15	.85	6.58	.86	.14
New River (Peerless)	Fayette County, W. Va	*76.32	18.34	.74	4.60	1.33	.32
Georges Creek	Allegany County, Md	*76.32	16.12	.50	7.06	.92	.21
Do	do	*76.26	15.33	1.07	7.34	1.20	.10
New River (Rend mines)	Fayette County, W. Va	*76.24	20.47	.83	2.46	.79	.66
New River Steam	do	*76.20	16.82	.96	6.02	.94	.58
Georges Creek	Allegany County, Md	*76.18	16.56	.90	6.36	1.18	.33
Pocahontas	Virginia and West Virginia	*76.08	17.12	.66	6.14	.72	.21
South Fork	South Fork, Pa	*76.08	14.95	1.05	7.92	1.29	.11
Do	do	*76.00	18.58	.50	4.92	.89	.60
New River (Peerless)	Fayette County, W. Va	*75.92	20.19	1.09	2.80	6.87	.40
New River	do	*75.84	20.38	.98	2.80	.56	.34
Eureka	Somerset and Cambria counties, Pa	*75.84	17.68	.84	5.64	1.18	.17
Georges Creek	Allegany County, Md	*75.84	16.70	.70	6.76	.96	.38
Do	do	*75.82	15.56	.94	7.68	1.57	.07
Do	do	*75.78	16.87	.99	6.36	1.07	.32
South Fork	South Fork, Pa	*75.76	18.53	.37	5.34	1.59	.52
New River (Rend mines)	Fayette County, W. Va	*75.68	19.65	.95	3.72	.67	.50
Georges Creek	Allegany County, Md	*75.68	18.75	.51	5.06	1.30	.19
Georges Creek, Big Vein Cumberland	do	*75.66	14.08	.86	9.40	.85	.40
South Fork	South Fork, Pa	*75.60	16.71	1.37	6.32	1.89	.05
Not given	Sample furnished by Bureau of Equipment	75.60	15.58	1.10	7.72	.87	.11

Chemical analysis of samples of coal at the Washington Navy-Yard, Washington, D. C.—Continued.

Commercial name.	Location of mines.	Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur.	Increase in weight.
South Fork (Miller Vein)	South Fork, Pa	*75.54	19.70	0.86	3.90	0.79	0.30
Georges Creek	Allegany County, Md	*75.50	16.71	.87	6.92	1.10	.10
New River Admiralty, Caperton Colliery.	New River district	75.46	21.25	1.25	2.04	.50	1.20
New River	Fayette County, W. Va	*75.42	22.06	1.02	1.50	.71	.10
New River (Rend mines)	New River district	75.38	21.76	.72	2.14	.45	.27
New River	Fayette County, W. Va	*75.36	19.26	1.00	4.38	.79	.24
Do	do	*75.24	20.00	.62	4.14	.54	.15
New River (Rend mines)	do	*75.22	21.19	1.31	2.28	.71	.24
Georges Creek	Allegany County, Md	*75.18	16.81	.65	7.36	1.28	.17
South Fork	South Fork, Pa	*75.12	19.51	.51	4.86	1.16	.37
Elk Lick	Somerset County, Pa	75.04	15.83	.93	8.20	.96	.14
New River Smokeless, Stuart Colliery, Shaft No. 2, middle.	Fayette County, W. Va	75.02	22.03	1.37	1.58	.50	.60
New River (Rend mines)	do	*75.02	21.27	1.20	2.51	.68	.15
South Fork	South Fork, Pa	*74.94	20.19	.33	4.54	1.14	.21
Georges Creek	Allegany County, Md	*74.80	21.66	.88	2.66	.62	.39
New River (Rend mines)	Fayette County, W. Va	*74.66	20.60	.74	4.00	.55	.18
New River	do	*74.62	22.56	.80	2.02	.70	.49
New River Smokeless, Stuart Colliery, Shaft No. 2, top.	do	74.58	22.36	1.50	1.56	.57	.75
Standard Eureka	Somerset and Cambria counties, Pa	*74.50	18.56	.22	6.72	1.31	.41
Big Vein Cumberland	Thomas, W. Va	74.42	17.78	1.20	6.60	.74	.27
South Fork, Miller Seam	South Fork, Pa	*74.36	19.04	.60	6.00	1.63	.27
New River (Rend mines)	Fayette County, W. Va	*74.16	22.57	.77	2.50	.67	.28
New River	do	*74.06	22.34	1.00	2.60	.70	.47
Georges Creek	Allegany County, Md	*74.04	17.06	.60	8.30	.94	.20
New River	Fayette County, W. Va	*73.94	21.03	.41	4.62	.60	.27
Georges Creek	Allegany County, Md	*73.94	16.10	.42	9.54	.78	.31
South Fork	South Fork, Pa	*73.92	19.15	.61	6.32	1.09	.26
New River	Fayette County, W. Va	*73.86	20.98	.76	4.40	.72	.40
New River Smokeless, Stuart Colliery, Shaft 2, bottom.	do	73.84	22.03	1.41	2.72	.66	.30
New River	do	*73.72	12.90	.36	3.02	.65	.40
South Fork	South Fork, Pa	*73.62	20.03	.57	5.78	1.07	.27
Georges Creek	Allegany County, Md	*73.36	18.96	.66	7.02	1.00	.13
New River	Fayette County, W. Va	*73.16	24.22	1.00	1.62	.62	.20
Davis Big Vein Cumberland	Thomas, W. Va	*73.16	18.36	1.02	7.46	2.66	.05
Georges Creek	Allegany County, Md	*73.10	19.20	.83	6.87	1.15	.22
Davis Big Vein Cumberland	Thomas, W. Va	*73.06	16.46	1.20	9.28	2.23	.30
Do	do	*73.04	18.24	1.40	7.52	2.18	.06
New River (Rend mines)	Fayette County, W. Va	*72.98	23.07	.71	3.24	.77	.55
Pocahontas	Virginia and West Virginia	*72.92	16.14	1.18	2.76	.68	.30
New River	Fayette County, W. Va	*72.72	22.27	1.05	3.96	.72	.12
Somerset Southern	Somerset County, Pa	72.72	17.51	.84	8.93	2.86	.54
South Fork, Miller Seam	South Fork, Pa	*72.60	20.38	.82	6.20	.84	.30
South Fork	do	*72.50	20.88	.76	5.86	.89	.24
Do	do	*72.44	22.82	.70	4.04	1.29	.16
New River	Fayette County, W. Va	*72.34	22.26	1.00	4.40	.65	.20
Do	do	*71.74	21.40	.60	6.26	1.27	.55
South Fork, Miller Vein	South Fork, Pa	*71.34	23.28	.80	4.58	.93	.32
Empire	Clearfield County, Pa	70.86	23.62	.52	5.00	.90	.18
War Eagle	War Eagle, Mingo County, W. Va	69.76	27.88	.90	1.46	.61	.53
New River (Rend mines)	Fayette County, W. Va	*69.50	20.18	.70	9.62	.94	.50
Comox, Mine No. 7	Union, Vancouver Island, British Columbia	68.24	24.12	1.30	6.34	.61	.30
South Fork	South Fork, Pa	*67.70	24.10	1.30	6.90	.70	.38
Do	do	*67.68	24.41	1.14	6.77	1.48	.08
Greensburg	Westmoreland County, Pa	67.50	25.75	1.11	5.64	.83	.22
Greenwich, Mines No. 4 and No. 5	do	67.36	26.19	.81	5.64	2.04	.13
War Eagle (Pappoose Mine)	Mingo County, W. Va	66.90	29.06	1.14	2.90	.76	.42
Imboden Steam	Tacoma, W. Va	64.78	29.22	.82	5.18	.708	.301
Delagua, No. 4 Mine	Colorado	63.74	27.94	1.54	6.78	.77	.62
Low Banner	Stonega, W. Va	63.27	32.91	.92	2.94	1.66	.252
Greensburg	Westmoreland County, Pa	62.46	30.81	1.37	5.36	.88	.13
Hastings, No. 2 Mine	Colorado	60.53	30.77	1.25	7.45	.81	.68
Granite Creek	Buller County, province of Nelson, New Zealand	60.46	38.78	.50	.26	5.06	.17
Do	do	60.16	39.20	.54	.10	5.02	.11
Delagua, No. 5 Mine	Colorado	59.58	31.11	1.55	7.76	.55	.77
Mill Run	Leslie County, Ky	58.32	36.88	2.30	2.50	.84	.96
Kenova	do	57.06	38.48	2.44	2.02	.90	.98
Carbonado	Pierce County, Wash	53.18	38.10	2.40	6.32	.97	.64
Richmond, Pelew Main	New South Wales, Australia	51.22	42.08	2.10	4.60	1.15	.45
Black Diamond	Kings County, Wash	50.26	41.05	4.75	3.94	.57	.47
Franklin	do	50.08	40.80	4.06	5.06	.52	.28
Lawson	do	48.52	42.60	2.76	6.12	.52	.18
Improved Block Fuel	Manufactured in Wilkes-Barre, Pa	35.34	16.94	4.48	43.24	1.36	.....

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