PLATE 1. (FRONTISPIECE).

THE UNITED STATES COAST SURVEY STEAMER "G. S. BLAKE," 350 TONS, FITTED FOR DEEP-SEA SOUNDING AND DREDGING.

Heliotype Printing Co., 220 Devonshire St., Boston.

UNITED STATES
COAST AND GEODETIC SURVEY

CARLILE P. PATTERSON
SUPERINTENDENT

DEEP-SEA SOUNDING AND DREDGING

A DESCRIPTION AND DISCUSSION
OF THE
METHODS AND APPLIANCES USED ON BOARD
THE COAST AND GEODETIC SURVEY
STEAMER, "BLAKE"

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NOTE BY THE SUPERINTENDENT.

OFFICE OF THE
U. S. COAST AND GEODETIC SURVEY,
WASHINGTON, D. C., *March* 15, 1880.

This volume on Deep-Sea Sounding and Dredging has resulted from the work executed during the past few years, mostly in the Gulf of Mexico. To show the character of that work the following extract from my Annual Report of the Progress of the Coast and Geodetic Survey for the year ending June 30, 1879, is given.

* * * * * * * * * *

"The deep-sea soundings throughout the Gulf of Mexico, parts of the Caribbean Sea, and channels around Cuba, with serial temperature observations from surface to bottom and observations of currents, are beginning to yield valuable results towards a more definite conception of the flow, mass, and direction of the Gulf Stream.

"The problem of the Gulf Stream has been one of the principal studies of this Survey, but for several years before the war, during the war, and for several years after, the want of means and suitable vessels suspended its investigation. After the data previously secured, those to be obtained were:

I. Depths throughout the Gulf of Mexico and the Gulf of Florida.
II. Temperatures from surface to bottom over the same area.
III. Character of bottom throughout the same area.
IV. Specimens of water for analysis, from surface to bottom, throughout the same area.
V. Surface and under Currents.
VI. Animal life from surface to bottom, especially at the latter.

"After all the data have been obtained in reference to the waters forming the Gulf Stream, including those of the Gulf of Mexico and the Atlantic east of the Caribbean islands, the Stream is to be followed to its conclusions. Its oscillations of position, differences of velocity, monthly and annual, and increase of volume north of Cape Canaveral, if any, are also to be determined.

"Congress having partially provided means, the work of obtaining data under the first five heads was begun in 1872 in the Gulf of Mexico, by Commander J. A. Howell, U. S. N., Assistant Coast Survey, commanding successively the steamers 'Bache' and 'Blake.' Howell successfully ran seven hundred and forty miles of sounding lines from shore out to depths of 1,200 fathoms, by the old methods, obtaining the collateral data.

"Sir William Thomson's wire sounding apparatus having been successfully used, in the Pacific in depths to 4,655 fathoms, by Commander George E. Belknap, U. S. N., commanding steamer 'Tuscarora,' with improvements devised by that officer, one set was obtained for use in researches to be made by officers attached to the Coast Survey. At this time Commander Howell was transferred to other duty. He was succeeded in the command of the 'Blake' by Lieutenant-Commander C. D. Sigsbee, U. S. N., Assistant Coast Survey, and by that officer the deep-sea soundings (generally beyond one hundred fathoms and to the depths of 2,119 fathoms) of the whole of the Gulf of Mexico were completed. He obtained at the same time full data under the first five headings named. When Sigsbee saw the Thomson wire sounding apparatus, he at once suggested important improvements, and devised additional apparatus to relieve the strain on the wire during violent and rapid movements of the small vessel. He also made other improvements so greatly facilitating the work that in 2,000 fathoms' depth the 'Blake' (of three hundred and fifty tons N. M.) was enabled, in nearly all weathers, to sound and obtain serial temperatures continuously day and night, with a probable error in sounding not exceeding one-quarter of one per cent. of the depth, even during moderately severe gales.

"The number of nautical miles of sounding-lines run by Sigsbee in the Gulf, with serial temperatures, was 12,766.* This great work was, by the energy and unintermitting labor of Lieutenant Commander Sigsbee, earnestly supported by the officers and crew of the 'Blake,' completed early in the summer of 1878. The remaining part of the work; viz., collection of specimens of animal life from surface to bottom, was yet to be done.

"As naval officers are professionally neither naturalists nor geologists, I sought the services of Prof. Alexander Agassiz, who consented to take charge of this special part of the work, requiring only the outlay needful for his daily expenses. From his great experience with wire rope in mining operations, Professor Agassiz proposed its use for dredging purposes. Lieutenant-Commander Sigsbee, after conference with Professor Agassiz and myself, and to meet the requirements of the work in every way, thoroughly fitted the 'Blake' for dredging and other purposes.

"Professor Agassiz joined the 'Blake' at Havana in December, 1877, when Lieutenant-Commander Sigsbee at once began a series of dredgings in the Gulf of Mexico, over ground indicated by Professor Agassiz, who viewed as they came from the water, took charge of and preserved the 'finds' of each haul of the dredge and tangles. The nets, dredges, &c., had been made from the best models formerly used in researches abroad, but some, not proving entirely successful, were, at the first failure of each, made completely successful by suggestions from Lieutenant-Commander Sigsbee, Professor Agassiz, Lieutenant Ackley, Master Jacoby, and other officers of the vessel.

"Professor Agassiz was obliged to return home early in March, 1878. A few successful hauls of the dredge were made after his departure. Lieutenant-Commander Sigsbee in the 'Blake' continued, with his usual energy, until June, additional work of soundings, serial temperatures, &c., under my special instructions.

"The experience of that season suggested to Lieutenant-Commander Sigsbee many improvements of the machinery and facilities for dredging, and also an improved dredging accumulator of his own design for relieving the strain on the dredge rope. Under his special directions and in accordance with his plans the 'Blake' was completely refitted with new reeling-engine, dredging-engine, sounding apparatus, &c., for all the varied classes of work of deep-sea sounding, dredging, &c.

"The term of service of Lieutenant-Commander Sigsbee on the Survey having expired, he was relieved in the command of the 'Blake' by Commander J. R. Bartlett, U. S. N., Assistant Coast and Geodetic Survey, in November, 1878.

"The discovery by the 'Challenger' of submarine lakes, whose temperatures are constant to the greatest depths with that of the ocean at the depths of their rims, rendered it more than ever imperative to determine the depth of the rims separating the waters of the Gulf of Mexico from those of the Caribbean and its waters from those of the Atlantic, both to the eastward and northward. I assigned the 'Blake' for this development, and Professor Agassiz again accompanied the vessel to care for his own class of the work. As he was obliged to return home in March, 1879 (the 'Blake' having left Washington November 28, 1878), the first work done was, of course, the dredging. Commander Bartlett effected this with many successful hauls, at localities indicated by Professor Agassiz, in depths of from ten to 2,450 fathoms, all—officers, naturalists, men—working in harmony, with the necessary result—complete success. Of course the dredging operations of the vessel were conducted by

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* This is exclusive of 219 miles of inshore sounding-lines and 1,800 miles of dredging-lines in the Gulf of Mexico, and 2,065 miles of sounding-lines in the Gulf of Maine.

the officers and crew under the direction of Commander Bartlett. After the departure of Professor Agassiz. Commander Bartlett, under my instructions, completed all the required soundings and serial temperatures, &c., between all the islands in the series from Grenada to Cuba and Jamaica, making no soundings in the Gulf of Mexico. The 'Blake' arrived at New York on May 28, 1879.

* * * * * * * * * *

"Without specifying the great results obtained from this continuous research, I may be pardoned in referring with some gratification to the fact that in the small steamer 'Blake,' of only three hundred and fifty tons burthen, N. M., under the energetic and skillful commands of Lieutenant-Commander Sigsbee and Commander Bartlett, with a full complement of forty-five including officers and crew, more rapid work was done than had been accomplished with the old methods and appliances by the 'Challenger,' a vessel of over 2,000 tons burthen, with a complement of twenty-nine naval and civil officers and a correspondingly large crew."

* * * * * * * * * *

There being no special publications with detailed instructions on the systems and methods adopted for deep-sea sounding and dredging, although much attention is now paid by all maritime nations to the subject, it has been thought advisable to publish the methods used on board the "Blake." These methods, in even so small a vessel as the "Blake," have been prosecuted with celerity, ease, and precision, showing that deep-sea work has become nearly as ready of accomplishment as ordinary littoral soundings.

Carlile P. Patterson,
Superintendent U. S. Coast and Geodetic Survey.

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CHAPTER I.

INTRODUCTION.

THE AUTHOR'S CONNECTION WITH THE "BLAKE": CAUSES LEADING TO THE PUBLICATION OF THIS BOOK.

In August, 1874, the "Blake," commanded by Commander John A. Howell, U. S. N., Assistant in the Coast and Geodetic Survey, was provided with one of Sir William Thomson's sounding-machines for wire, modeled after the original service pattern (Plate 6), but, unfortunately, the nature of the work performed by the "Blake" thereafter, while under the command of Commander Howell, gave opportunity for only seven soundings with the wire. It is to be regretted that the machine did not reach Commander Howell at an earlier period of his work, as doubtless, had he seen more of it in actual use, many improvements would have resulted from his experience and well-known ingenuity.

In October, 1874, after four months of special work in the office of the Coast and Geodetic Survey, at Washington, during which the machine shown on Plate 7 was devised, draughted, and put in the hands of the mechanics, the Superintendent transferred me to the "Blake" as executive officer. The services of Commander Howell being needed in an important position at the Naval Academy, he was detached from the vessel at New Orleans in December, 1874, several months sooner than had been anticipated, and was succeeded in the command by the writer.

The adoption of wire for sounding purposes opened the way to more extended operations than had previously been attempted by the party.

For four years the vessel continued under my command, engaged in deep-sea work. When the time had arrived for my return to regular naval duty, the Superintendent of the Coast and Geodetic Survey was kind enough to express a belief that a description of the methods and appliances used on board the "Blake" would be worthy of publication, and under his direction this book has been written. The plan of the book involves a double purpose: first, to describe our methods and appliances, chiefly from a mechanical standpoint, in order that any deserving features may become generally known; and, secondly, to provide, in a measure, a guide for those who may hereafter have charge of the deep-sea work of the Coast Survey.

A question may naturally arise as to the considerations which would authorize a notice of the methods and appliances of the "Blake's" party. To this it is replied—

We were one of the first, after Sir William Thomson, and Capt. George E. Belknap, U. S. N., to use piano-forte wire for sounding purposes, and we probably continued its use for a longer time than any other organization.

The "Blake" is the only vessel that has ever been fitted out with wire rope (the suggestion of Prof. Alexander Agassiz) for deep-sea dredging and trawling.

But little has been published concerning the use of wire for sounding; and of wire rope for dredging, nothing, in fact, excepting in a general account of the "Blake's" dredging work by Professor Agassiz.

Nearly all the apparatus for sounding and dredging used on board the "Blake" is new or modified from previous forms, and is peculiar to that vessel, the water-cup (Plates 20 and 40) being the first and only instrument in the field for the performance of the complex work aimed at in its design.

These appliances, which are intended to effect an advance in accuracy or in celerity of operations, and to secure ultimate economy, have been well tested in actual service, and are believed to have accomplished, at least in some degree, the object sought.

Having had unusual facilities, in connection with continuous work, our methods were perhaps more systematic in certain directions than are generally followed by parties or organizations for the prosecution of deep-sea work.

Our navigation-record was comprehensive, and adapted to future revision or verification.

THE WORK OF THE "BLAKE."

The Coast and Geodetic Survey is entitled by law to the services of naval officers and men for its hydrographic parties. For the time being, naval officers on Coast Survey duty are as much a part of that organization, and as fully under the control of the Superintendent in all matters connected with the work, as the corps of civilian assistants. Excepting during the first two years of my command, when the surgeon and the engineer were civilians, the party on board the "Blake" was composed of naval officers, and of men enlisted under naval shipping-articles. In general terms, the work required of the party was to fulfill, in the Gulf of Mexico, a scheme of the Superintendent, having for its object the examination of certain physical conditions of that body of water throughout its whole extent, those of first importance being the depths and temperatures. Our operations in the Gulf of Maine were of similar intent, but on a smaller scale. The execution of the work, embracing observations for depths, serial water temperatures and densities, and for currents when possible, together with the collection of specimens of the bottom soil or deposit, and of surface, bottom and intermedial water specimens, was intrusted to the naval officers on board, under the direction of the Superintendent, who was cognizant of every important act of the party, and who, with much kindly interest, noticed its workings even to the smallest essential details. In this direction the Superintendent was assisted by Commander E. P. Lull, U. S. N., Hydrographic Inspector of the Coast and Geodetic Survey. Afterwards, during the first three months of my last season, we were most pleasantly associated with Prof. Alexander Agassiz and his assistant, Mr. S. W. Garman, for the dredging operations which then became part of our work.

A short sketch of the work performed by the "Blake's" party in each season will perhaps not be amiss.

During the winter season of 1874–'75, after two months of special work, we ran a number of lines of soundings radiating from the Passes of the Mississippi River and extending a distance of one hundred and twenty miles seaward. The work was brought to a close by running a line from the Southwest Pass of the Mississippi River to the mouth of the Rio Grande, four hundred and sixty miles, and thence another, nearly east, across the Gulf of Mexico, seven hundred and sixty miles, to Tortugas, the westernmost of the Florida Reefs. Total number of miles of sounding-lines in deep water run during the season, 2,505.

During the summer season of 1875 we ran a number of lines in and across the Gulf of Maine in various directions. Total number of miles of sounding-lines for the season, 2,065.

In the winter season of 1875–'76 we ran a system of east-and-west lines across the great bank west of the Florida Peninsula, and in the contiguous deep water. These were followed by others of less length on the northern portion of the bank, and by several extending well out to sea from points adjacent to the delta of the Mississippi River. The season was closed by running a line from the South Pass of the Mississippi River nearly due south to the Yucatan Bank, and another from Alacran Reef, on that bank, to Tortugas. Total number of miles of soundings for the season, 2,519.

We began the work of the winter season of 1876–'77 by running a line extending from Cape Romano, on the west coast of Florida, to a point two hundred and fifty miles due west, and thence another line due north, about an equal distance, to the coast not far east of Pensacola, Fla. Then followed an unbroken set of lines which, beginning near Pensacola and ending at Timbalier Island, formed nearly the three sides of a rectangle and crossed all the lines previously run on the slope of the Mississippi Delta. A continuation of the deep-sea work completed a system of east-and-west, north-and-south, and normal lines from the coasts of Texas and Louisiana. Before the end of March we had completed all that had been planned by the Superintendent for the whole season. Additional work was given us, as planned by the Superintendent, and, accordingly, we ran a set of sounding-lines from the Southwest Pass of the Mississippi River to the northwest edge of the Yucatan Bank; then, in irregular order with regard to locality, but according to the advantages to be derived from winds and currents, we ran a number of east-and-west lines, which sufficiently covered the ground from the southernmost part of the Gulf of Mexico to the completed lines off the coast of Texas and from the western shores of the Gulf to the Yucatan Bank, or to our finished work in the middle of the Gulf. Forty-six hundred miles of steaming on the additionally-prescribed work, much more than half on sounding-lines, brought us back to New Orleans, after an expenditure of one hundred and sixty-three tons of coal on the cruise; all of the work throughout that part of the Gulf of Mexico west of the meridian of 89° having been completed. A series of homeward-bound lines, in the east-middle part of the Gulf, brought the season's operations to a conclusion, and completed, as previously laid down by the Superintendent, the whole scheme of work for the Gulf of Mexico, exclusive of the Straits of Florida. Number of miles of sounding-lines run during the season, 6,426, with an average of one sounding to every six and one-fourth miles, over forty of the casts having been in depths exceeding 2,000 fathoms. In carrying out this season's work the "Blake" had encountered fifteen or more gales at sea.

The first three months of our winter season of 1877–'78—December, January, and February—were devoted to dredging in localities indicated by Professor Agassiz; in the Straits of Florida to the westward of Havana and Key West, on the eastern and northern slopes of the Yucatan Bank, on the western slope of the Florida Bank, and on the southern slope of the Mississippi Delta. Early in March Professor Agassiz returned to his home, and shortly afterwards the systematic sounding and serial temperature work of the party, which we had not attempted while the naturalists were on board, was resumed. A number of lines of soundings were then run, to the westward of Havana and Key West, across the Straits of Florida and the Yucatan Channel in various directions, completing the Superintendent's scheme for the whole Gulf of Mexico. Number of miles on dredging-lines, 1,800; number of dredging-hauls, eighty-two; number of miles on sounding-lines, 1,316. During this season the longest piece of hemp rope on board the vessel, for sounding or dredging purposes, was an ordinary coasting lead-line. Soundings were made with piano-forte wire, serial water temperatures were taken with small steel rope, while hauls with the dredge and trawl were made with steel rope of a larger size.

On the arrival of the vessel at New York, after the winter season of 1877–'78, having performed four years of service on the Coast Survey, my detachment therefrom and return to regular naval duty became necessary; it being determined, however, that I should first superintend the preparation of the "Blake" for the work of another sounding and dredging season.

On November 1, 1878, the fitting of the "Blake" having been about completed, Commander John R. Bartlett, U. S. N., succeeded me in command of the vessel. Since then the party has executed another season's work, in the Caribbean Sea and Passages, the time having again been divided so as to permit several months of dredging in advance of the regular party work of deep-sea soundings, serial temperatures, &c. In the dredging operations, Prof. Alexander Agassiz and his assistant, Mr. S. W. Garman, were again associated with the party. For the second dredging cruise we concurred in a plan of fitting the vessel for dredging to accord with the experience gained on the previous dredging cruise. The plan was approved by the Superintendent, and under the management of Commander Bartlett and the officers of the "Blake," with the advice and suggestions of Professor Agassiz and Mr. Garman, the mechanical operations of the season have marked a definite advance in this kind of work. In addition to the new dredging arrangements, the vessel was supplied with a new sounding-machine, a later form of my modification of Sir William Thomson's deep-sea sounding-machine (Plate 8).

In the sounding and other party work, under Commander Bartlett, which succeeded the dredging operations, the success was equally marked. In the entire work of the season, comprehending two hundred and twenty-five hauls with the steel dredge-rope and six hundred and sixty-four soundings with wire, there were but few accidents of any kind, and none due to imperfect working of the appliances.

REMARKS ON THE UTILITY OF PIANO-FORTE WIRE FOR SOUNDING PURPOSES.

After the achievements of Captain Belknap, the success of Commanders Miller, Dewey, Schley, and Philip, and Lieutenant-Commanders Green and Gorringe, of the Navy, the continuous and successful work by Commander Bartlett and myself in the Coast Survey, and the work done under the auspices of foreign governments or companies, it would seem that no further evidence is required to demonstrate the superiority of wire over rope for deep-sea sounding; yet, as these results, however satisfactory, may not convince persistent doubters, some particulars are given that may seem more tangible.

First, it can be shown that the excess of iron for sinkers, thrown away in sounding with rope, if saved, would pay for all the probable losses of wire, sinkers, and instruments in sounding with wire. For the moment, let us take a view of rope so favorable as to assume that it will never part, hence will last indefinitely, and will never cause the loss of instruments.

Iron for sinkers expended in 20 soundings with rope, in depths of 2,000 fathoms (200 pounds each cast), 4,000 pounds, at 2½ cents per pound	$100 00

Again, let us take so very unfavorable a view of wire as to assume that it will part at every twentieth cast in depths of 2,000 fathoms, losing the wire, a sounding-rod, and a thermometer.

Iron for sinkers expended in 20 soundings with wire, in depths of 2,000 fathoms (60 pounds each cast), 1,200 pounds, at 2½ cents per pound	$30 00
Cost of 2,000 fathoms sounding-wire, 29 pounds, at 75 cents per pound	21 75
Cost of one elaborately finished sounding-rod	14 50
Cost of one thermometer	12 00
Total cash expenditure, should all this material be lost	$78 25

If, besides this, we were to lose an elaborately finished water-cup costing $25, the total cash expenditure would be $103.25.

If, in the above computations, we take the cost of the iron sinkers at three cents per pound, which is nearer the mark, we find the cost of iron expended in the rope soundings to be $120, and the total cash loss in the case of the wire $109.25, including the water-cup.

Contrary to the assumption, rope sounding-line does in reality part, much of it being lost in extended work, involving the loss of instruments. If not lost, rope will deteriorate in use.

In the six hundred and sixty-four casts with wire by Commander Bartlett, in depths varying from one hundred fathoms to 3,000 fathoms, the total losses of instruments and material, exclusive of iron sinkers, but including leads, could not have exceeded $150. At every cast a thermometer was used for bottom temperature, and in some cases a water-cup was sent down. The total loss of wire was 2,400 fathoms, due once to the rare accident of fouling on the vessel's copper sheathing, and once to the lead fouling on a coral bottom, on which everything fouled. Captain

Belknap, during the progress of his deep work in the Pacific, took one hundred and twenty consecutive casts without accident. Commander Schley lately ran a line of soundings across the South Atlantic, from St. Paul de Loando, Africa, to Cape Frio, Brazil, taking thirty-eight casts in depths from one hundred fathoms to 3,284 fathoms, without loss and nearly without accident. In a record of naval sounding work it is shown that Commander Philip recently took eighty-six consecutive casts in depths up to 3,000 fathoms without a case of parting the wire. On board the "Blake" we managed to keep the same piece of sounding-wire in use, as occasion presented, for a whole year, sounding day and night, and sometimes under circumstances in which the vessel rolled repeatedly 30° and even 35°, the machine being in charge of officers changed in regular sea watches. With wire we have hauled back a fifty-seven-pound shot-sinker from a depth of 1,800 fathoms by steam, and have sounded day and night, in seas three hundred feet from crest to crest, in depths of 1,200 fathoms, using and recovering a thirty-four-pound lead, and hauling back by steam.

It is believed that in point of accuracy and celerity the advantage of wire over rope has never been questioned.

Our casts in the swift current of the Gulf Stream were, to all appearance, as successful as elsewhere, and they presented no difficulties worthy the name.

DESCRIPTION OF THE "BLAKE": DUTIES OF OFFICERS AND CREW: ROUTINE.

The "Blake" was built for the special work on which she is employed. She is of three hundred and fifty tons O. M., one hundred and forty feet in length on the load line, twenty-six feet six inches beam, and has a deep draught of eleven feet. Her engine, which is compound, of about seventy nominal and two hundred and seventy actual horse-power, gives her a speed of eight knots, under ordinary circumstances, for an expenditure of four tons of coal in twenty-four hours; and she may be pushed to nine knots under steam alone. Under both sail and steam she has been known to maintain a speed of ten and a half knots. Her bunkers will accommodate coal for thirty-eight days' steaming, at a daily expenditure of four tons. The rig is that of a fore-and-aft schooner, and consists of foresail, mainsail, jib, fore-stay sail, and fore and main gaff-topsails. Aft on the main-deck are spacious and well-ventilated quarters for the officers. Forward of the wardroom, on the same deck, is a continuous line of midship houses, reaching nearly to the foremast and forming the engine-room, boiler-room, galley, pantry, draughting-room, lamp-room, and mechanics' sleeping-room. The arrangement of the main-deck houses leaves, on either side, a wide gangway, ventilated and lighted along its whole length through large square ports which can be kept open at sea in any ordinary weather. Beneath a sufficiently large berth-deck is a good-sized hold with tanks for holding 2,500 gallons of fresh water, while under the cabin and wardroom, and accessible only from those apartments, are large store-rooms. The upper-deck is flush, and gives ample room for the reception of all the necessary machinery and gear.

Plate 29 shows the upper-deck plan.

A.—Main hoisting or reeling engine.
B.—Dredge-reel.
C, C, C, &c.—Iron leading-blocks for dredge-rope.
D.—Dredge-boom.
E.—Small reeling-engine, connected with dredge-reel.
F.—Reel for steel-wire temperature-rope.
G.—Sounding-machine.
H.—Small reeling-engine for sounding-machine.
i.—Fore hatch.
j.—Foremast.
k.—Pilot-house.
l.—Draughting-room skylight.
m.—Galley skylight.
n.—Boiler-room skylight, and smokestack.
o.—Engine-room skylight.
p.—Mainmast.
q.—Wardroom skylight.
r.—Cabin and wardroom companion-way.
s.—Cabin skylight.
t.—Rudder-head.

The machinery will be explained hereafter.

The complement of officers, exclusive of the chief of the party, was as follows: One lieutenant as executive and navigator, one lieutenant or master as assistant navigator, three masters or ensigns as watch officers, one engineer, one surgeon, and one captain's clerk. The last two, in addition to their legitimate duties, acted as recorders on deck. The force of forward hands, all told, was thirty-six men, which gave for deck duty eight men in one watch and nine in the other;—the boatswain's mate being the odd man. The work required of each deck-watch at sea was to fill the stations for running the sounding-machine, getting temperatures and water specimens, making current observations, attending reeling-engines, making and reducing sail, steering, keeping lookout, &c. This force was adequate until the first dredging cruise, when six extra hands were shipped to turn the crank of the dredge-reel. For the second dredging cruise, steam having been applied to the dredge-reel, the regular complement did not need to be augmented, it being possible to haul in depths of 3,000 fathoms with three men, every detail, including steering, being executed. For working the main engines the "Blake" had three machinists and six firemen. The number of the latter was at one time reduced to three for part of a season, but this reduction providing for no substitutes in case of sickness, the original complement was afterwards restored. All the reeling-engines were managed by the deck-hands. Idlers were never called on to assist in any part of the hydrographic work.

Duties were divided among the officers as follows: The executive officer was charged with the care of the chronometers, compasses, and other delicate instruments. Besides having the usual navigating work to do, he plotted the lines of soundings and superintended the preparation of the records in every particular. The assistant navigator aided in the navigating work, took current observations at sea, and, on the arrival of the vessel in port, revised the computations of all observations for position. This officer and the three watch officers had each to care for certain appliances or gear, and to keep a record of data concerning them. The watch officers in rotation had charge of the deck, where they managed the vessel and directed the mechanical part of the hydrographic work.

The recorders assisted the officer of the deck in keeping the deck-record required by the several forms to be shown hereafter; they were unavoidably pushed to their utmost in prolonged work, their duties forcing them to stand watch and watch, which they divided, by choice, into six-hour intervals. The engineer helped greatly by draughting the profiles and temperature curves. No officer was excused from party work by other duties.

With two officers navigating, three doing deck duty, and two recording, the labor seemed fairly divided when the nature of the services to be performed was considered. Had the sounding-lines run by the "Blake" been of much greater length, a third recorder would have been necessary. With an increased complement of officers, from which to make the detail, a better plan, in one respect, would be to put all instruments, appliances, and gear, excepting chronometers, compasses, and the like, under the special charge of one officer, whose chief duty it would be to have them kept in good order and repair.

An overcast sky precluding observations for position, the proportion of favorable working weather during each season was not great, and we were sometimes compelled to remain in port many days together. Bearing this in mind, all hands cheerfully acquiesced in the demands made on them when at sea. The longest continuous run that we ever made on sounding-lines occupied eleven days, although that length of time was nearly equaled on several occasions. These long runs were sometimes executed under such trying circumstances of wind, weather, sea, and current as to impose much mental strain on the officers and to call forth all the endurance of the crew. At sea, everything had to give way to the work in hand. If the vessel did not look pretty, we concluded that we could not help it, and complacently looked forward to a higher standard on our arrival in port. It was generally understood and appreciated by all on board that mistakes through carelessness ought not to be tolerated, and that strictness should rule always in matters immediately connected with the special purpose of our party. In port, on the contrary, the fullest liberty of action, not at variance with good order and the interests of the work, was allowed.

The port duties were, in brief, to plot the work, to complete the record, and to "straighten up" the vessel. Whenever it was practicable we made fast to a wharf, with a view of lessening boat work and of affording facilities for recreation. The watch officers then went into "day's duty," but were not required to be continuously on deck unless something special or important made their presence necessary, the ordinary routine being under the immediate charge of the quartermaster.

Assuming early morning as a starting-point, the usual daily routine of sea duty on board the "Blake" was about as follows:

While the stars were still bright the navigators were up and ready, and, from the first well-defined appearance of the horizon until the disappearance of the stars, the best observations that could be had for the vessel's position were obtained. If a sounding was being taken at twilight, as frequently happened, we endeavored to time some of the observations, so that the position given by them might be coincident with that of the sounding. Then the navigators retired to the draughting-room to effect the computations, the result of which was anxiously awaited to find if the vessel had been drifted much away from the line during the night. The soundings, which had been carried on all night, were continued through the day at specified intervals of distance; and at occasional sounding stations, generally according to schedule, serial water temperatures and serial water densities were noted. When current observations were in order they came immediately after the sounding, unless serial temperatures were required also, in which case the latter took precedence. At every sounding the surface-water temperature, and certain other data, as shown on Form 3 in another chapter, were secured. A deck-board, having fastened to one side of it a General Record, Form No. 3, and to the other side a Supplementary Record, Form No. 4, for the reception of details relevant to the columns, was kept in the pilot-house under the care of the recorder. Although that officer made all the entries, excepting those requiring a nautical judgment, the officer of the deck was the responsible person, and as such was obliged to affix his initials to the record at each station. Usually at every sounding, when the run between soundings occupied an hour or more, observations for position were taken if possible, and at evening twilight the proceedings of the corresponding morning period were repeated. Favorable opportunities for finding the position afterwards were made the most of, but, as a matter of course, the work of the navigators was lessened at night by the comparative rarity of chances for accomplishing anything within the province of their office. In every other respect our operations, whether for depths, currents, or temperatures, went on the same at night as by day, there being no falling off in their amount or character on account of darkness. Dredging, when it became a part of the work, was likewise continued at night; but runs between the stations were made after dark rather than in the daytime, when our movements could be so managed.

The following is a specimen, given from memory, of the kind of general order that I issued at the beginning of the season's work, for the guidance of officers of the deck:

General Order.

In depths less than one hundred fathoms, sound with rope; in deeper water, sound with wire. For depths no greater than 1,000 fathoms, employ the thirty-four-pound lead and haul it back; for depths exceeding that, use shot-sinkers and detach them on the bottom. The sounding intervals will be as follows: In depths less than five hundred fathoms, five miles; between five hundred and 1,000 fathoms, seven miles; between 1,000 and 1,500 fathoms, ten miles; greater than 1,500 fathoms, fifteen miles. Make it a serial temperature station at the terminal soundings on all lines; also, at every fourth sounding when the interval is five or seven miles, and at every third sounding when it is ten or fifteen miles. At all temperature stations the usual party work, under the following heads, will be fully executed: Depth of water; serial temperatures and water specimens, including those at the surface and bottom; density and corresponding temperature of water specimens; bottom-soil specimen and all water specimens bottled and saved for examination. The appended table gives the serial depths from which temperatures and water specimens are required.

At every sounding the temperature of the surface water will be recorded, and that of the bottom water likewise when working in less than 1,000 fathoms over slopes. In getting the sub-surface water temperatures allow seven minutes after the final stoppage in which to let the thermometers register. Get the bottom temperatures and water specimens with the aid of the wire or rope that is being used for the sounding.

Water-cups intended for use will be adjusted and in readiness before arriving at the station. Thermometers will be set the last moment before they are fastened to the rope or wire, and the readings noted at once when the instruments are removed from the rope on coming out of the water. The results of the serial temperature observations will be carefully scrutinized by the officer of the deck, and any readings that are apparently false, or are contrary to what was anticipated, will be at once reported to the commanding officer. At each temperature station the approximate highest point at which the temperature of 39½° occurs—the normal temperature of the deep Gulf water—must be ascertained in order to make the series complete. Record the character of the bottom-soil specimens at all soundings. Save the specimen for examination at serial temperature stations, and also whenever the appearance of it seems to be different from that taken at the previous sounding. In case of doubt, save it always. In general record, in addition to the usual data, at every sounding, all the information that can be got without delaying the vessel. Surface densities, however, need not be taken excepting at temperature stations. Current observations will be made under special orders. Reports will be made to the commanding officer when circumstances, of whatever nature, would seem to render adherence to any part of the foregoing instructions impracticable; when unexpected, important, or interesting results are obtained in any particular relating to the work, and when more complete information can be gained consistent with our system of operations.

TABLE SHOWING THE DEPTHS AT WHICH TO OBSERVE TEMPERATURES AND FROM WHICH TO SECURE WATER SPECIMENS, AT SERIAL TEMPERATURE STATIONS.

Depth of the sounding in fathoms.	Serial depths in fathoms.																
	Surface.	10.	25.	50.	75.	100.	150.	200.	300.	400.	500.	600.	700.	800.	900.	1,000.	Bottom.
Less than 10	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	......	2
10	2	2	....	....	....	....	....	....	....	....	....	....	....	....	....	......	2
25	2	2	1	....	....	....	....	....	....	....	....	....	....	....	....	......	2
50	2	2	1	2	....	....	....	....	....	....	....	....	....	....	....	......	2
75	2	2	1	2	1	....	....	....	....	....	....	....	....	....	....	......	2
100	2	2	1	2	1	2	....	....	....	....	....	....	....	....	....	......	2
150	2	2	1	2	1	2	1	....	....	....	....	....	....	....	....	......	2
200	2	2	1	2	1	2	1	1	....	....	....	....	....	....	....	......	2
300	2	2	1	2	1	2	1	1	2	....	....	....	....	....	....	......	2
400	2	2	1	2	1	2	1	1	2	1	....	....	....	....	....	......	2
500	2	2	1	2	1	2	1	1	2	1	1	....	....	....	....	......	2
600	2	2	1	2	1	2	1	1	2	1	1	2	....	....	....	......	2
700	2	2	1	2	1	2	1	1	2	1	1	2	1	....	....	......	2
800	2	2	1	2	1	2	1	1	2	1	1	2	1	1	....	......	2
900	2	2	1	2	1	2	1	1	2	1	1	2	1	1	1	......	2
1,000 or more	2	2	1	2	1	2	1	1	2	1	1	2	1	1	1	2	2
	Sur.	10.	25.	50.	75.	100.	150.	200.	300.	400.	500.	600.	700.	800.	900.	1,000.	Bot.

REMARKS.—To ascertain the serial depths from which temperatures and specimens of the water are required, find in the left-side column a depth next lower than that of the sounding. Opposite thereto will be found the figures 1 and 2, the former signifying temperatures and the latter both temperatures and specimens, which are to be referred, for the required depths, to the top or bottom row of figures denoting serial depths. Thus, in a depth of 250 fathoms, temperatures should be observed at the surface, at 10, 25, 50, 75, 100, 150, and 200 fathoms, and at the bottom, and water specimens should be secured from the surface, from 10, 50, and 100 fathoms, and from the bottom.

This table was too broad in its application to be strictly followed through a whole season, but it indicated in a general way what was expected of us, and it served as a guide to the officer of the deck, who, in the absence of special orders to the contrary, observed its directions without modification.

From the first, the quality of our work gradually became better. There was no year that we did not improve one or more of our appliances somewhat, and after the first season we trusted the wire to an extent not meditated at the outset.

OFFICERS OF THE "BLAKE" AND THEIR CIVILIAN ASSOCIATES.

Throughout the whole work I was singularly favored in having the assistance of intelligent and capable officers, and it is a source of regret that their services cannot be presented more prominently in this volume. The leading purpose of the volume may, perhaps, explain away any apparent neglect by me in the matter, when I state that the field of invention or adaptation in the party being occupied with so much evident interest by myself, the others—some of whom were ingenious in a marked degree—kindly accorded me the "right of way." The records of the Coast and Geodetic Survey bear testimony to their faithful service and to their high qualifications for the work required of them. The names of all the officers who have served with me on board the "Blake" will be found in the table of statistics accompanying this Introduction.

My association with Prof. Alexander Agassiz and Mr. S. W. Garman, though short, was very pleasant. Professor Agassiz and I were shipmates and messmates for but little over two months, during which time we gave ourselves up heartily to the work in hand. To these gentlemen belongs all the credit, pertaining to the province of the naturalist, which was gained on the dredging cruises.

STATISTICS OF WORK DONE BY THE HYDRO

Season.	General locality.	Miles of sounding-lines.	Soundings.			Water temperatures observed.				Water densities observed.			
			With rope.	With wire.	Total	Surface.	Intermedial.	Bottom.	Total.	Surface.	Intermedial.	Bottom.	Total.
Winter, 1874–'75.	Off mouth of Mississippi River, Gulf of Mexico.	219	347	0	347	348	132	4	484	369	129	4	502
Do.	Gulf of Mexico	2,505	280	134	414	378	50	223	651	130	32	125	287
Summer, 1875.	Gulf of Maine.	2,065	649	15	664	664	64	133	861	133	64	133	330
Winter, 1875–'76.	Gulf of Mexico	2,519	338	100	438	403	456	91	950	108	176	82	366
Winter, 1876–'77.	....do........	6,426	616	418	1,034	287	1,232	273	1,792	185	350	137	672
Winter, 1877–'78.	Straits of Florida, Gulf of Mexico.	1,316	3	193	196	192	678	138	1,008	157	24	25	206
Do.	....do........	1,800	4	98	102	91	0	50	141	(*)	(*)	(*)	(*)
	Grand total.	16,850	2,237	958	3,195	2,363	2,612	912	5,887	1,082	775	506	2,363
Winter, 1878–'79.	Caribbean Sea and Passages.	......	0	664	664	670	547	553	1,770	437	60	19	516

* Perhaps some observed by naturalists.

GRAPHIC PARTY ON BOARD THE "BLAKE."

Water specimens saved for examination.				Soil specimens saved for examination.	Current observations.	Remarks.	List of Officers.
Surface.	Intermedial.	Bottom.	Total.				
....	....	....	......	....	....	Special work near shore.	Lieutenant-commander, C. D. Sigsbee; lieutenants, C. T. Hutchins, J. W. Hagenman, and J. M. Grimes; master, R. G. Peck; ensign, W. E. Sewell; medical officer, M. L. Crawford, M. D.; engineer, T. L. Churchill; captain's clerk and recorder, J. B. Howell.
170	100	185	455	211	20		
....	....	....	......	....	....	Deep work.	
127	55	126	308	131	65	....	Lieutenant-commander, C. D. Sigsbee; lieutenants, J. E. Pillsbury and W. O. Sharrer; masters, R. G. Peck and M. F. Wright; ensign, W. E. Sewell; assistant paymaster, O. C. Tiffany; medical officer, M. L. Crawford, M. D.; engineer, T. L. Churchill; captain's clerk and recorder, L. P. Sigsbee.
102	157	79	338	77	68	....	Lieutenant-commander, C. D. Sigsbee; lieutenants, J. E. Pillsbury and W. O. Sharrer; masters, R. G. Peck and M. F. Wright; ensign, W. E. Sewell; medical officer, S. W. McJunkin, M. D.; engineer, T. L. Churchill; captain's clerk and recorder, L. P. Sigsbee.
185	353	183	721	332	71	....	Lieutenant-commander, C. D. Sigsbee; lieutenants, J. E. Pillsbury (for half the season, then invalided), S. M. Ackley (half the season), and W. O. Sharrer; masters, M. F. Wright, W. E. Sewell, and Henry McCrea; passed assistant engineer, W. S. Moore; medical officer, S. W. McJunkin, M. D.; captain's clerk and recorder, L. P. Sigsbee.
33	28	25	86	68	0	Regular party work.	Lieutenant-commander, C. D. Sigsbee; lieutenants, S. M. Ackley and W. O. Sharrer; masters, H. M. Jacoby and Henry McCrea; ensign, G. H. Peters; passed assistant engineer, W. S. Moore; assistant surgeon, C. J. Nourse; recorder, L. P. Sigsbee.
(†)	(†)	(†)	(†)	61	0	Dredging work; made 82 hauls.	For the dredging season: Naturalists, Prof. Alexander Agassiz and Mr. S. W. Garman.
617	693	598	1,908	880	224		
40	64	10	114	328	0	Hauls— With dredge.. 71 With trawl... 109 With tangles . 45 Total..... 225	Commander, J. R. Bartlett; lieutenants, W. O. Sharrer and J. P. Wallis; master, H. M. Jacoby; ensigns, G. H. Peters and E. L. Reynolds; passed assistant engineer, John Pemberton; assistant surgeon, C. J. Nourse; recorder, L. P. Sigsbee. For the dredging season: Naturalists, Prof. Alexander Agassiz and Mr. S. W. Garman.

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† A large number saved by naturalists.

CHAPTER II.

SOUNDING-WIRE, CORRECTION-CURVE, SOUNDING-RODS AND SINKERS.

ROPE FOR SOUNDING PURPOSES.

The principal drawback to deep-sea sounding with rope is the large area which rope offers to resistance in its passage through the water, and to the action of currents tending to deflect it from a vertical direction. This resistance is increased by the rough and grooved surface which all ropes have to a greater or less degree. Their weight, if made of hemp or manilla, is reduced to about one-fourth in water, and thus there is but little weight in the material itself to cause it to sink rapidly. "The resistance upon the line varies, first, as the square of the velocity; second, as the diameter of the line; third, as the length of line immersed."*

Since the weight of the sinker remains invariable, and the resistance upon the line continually increases as the length of the immersed portion becomes greater, it follows that the rate of paying out will gradually lessen and must become very slow if the whole resistance approximate to the weight of the sinker. With the weights and ropes formerly used it came about, in deep casts, that the resistance of the line would so nearly equal the weight of the sinker that, before bottom had been reached, the line would be sinking almost wholly by its own weight, and the rate of paying out after bottom had been reached would, therefore, remain about the same as for some time previously, giving no indication of the time when the sinker had landed. The invention by Brooke, permitting the sinker to be detached on striking bottom, made it practicable to use much heavier weights than it would be possible to haul back with any rope suitable for sounding purposes. Since then the use of small line with very heavy sinkers, and the taking of time-intervals when paying out, have made rope soundings acceptable in general, yet, in strong currents the most experienced and accomplished hydrographers have been known to fail

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*Appendix No. 37, Coast Survey Report for 1858. Investigation of the laws of motion governing the descent of the weight and line in deep-sea soundings; by Prof. W. P. Trowbridge, Assistant in the Coast Survey.

completely in its use, and attempts in heavy seas would probably prove ineffectual also. The latest and most trustworthy deep-sea soundings with rope have been taken with stuff from 0.8 inch to 1 inch in circumference (0.255-inch to 0.318-inch diameter), the sinker weighing one hundred pounds for a depth of 1,000 fathoms, with one hundred pounds added for each additional 1,000 fathoms of anticipated depth.

WIRE FOR SOUNDING PURPOSES.

Attempts were made to sound with wire from time to time, but there was no encouraging measure of success until 1872, when Sir William Thomson invented a machine for the purpose. With machines constructed on his principle we are now able to make the deepest cast with a percentage of probable error as small as pertains to ordinary in-shore soundings with the hand-lead. His original apparatus has since been improved by himself and by others, but not in point of accuracy, this having been attained by Sir William Thomson in his first efforts in sounding with wire. The kind of wire that he originally recommended was adopted on board the "Blake," and, so far as I am aware, no other is employed for sounding purposes. A piece may be seen pictured on Plate 2, where it is contrasted with a rope of one-quarter of an inch diameter to which the thermometer case is attached.

Fig. 1. Fig. 2. Fig. 3.

A.—Comparative size of hemp rope and steel wire for sounding purposes.

Figs. 1 and 2. Hemp sounding-line. Fig. 3. Piano-forte sounding-wire.

DESCRIPTION OF PIANO-FORTE WIRE USED FOR SOUNDING PURPOSES.

The material used is steel piano-forte wire of No. 22 Birmingham (Stubbs) gauge, which corresponds nearly to No. 21 American wire-gauge (0.028 of an inch in diameter); it weighs fourteen and one-half pounds to the nautical mile (1,000 fathoms approximately) in air, and consequently about twelve pounds in water. We purchased ours either of Messrs. Webster & Horsfall, Birmingham, England, or of the Washburn & Moen Manufacturing Company, of Worcester, Mass. The English wire has a tensile strength from two hundred to two hundred and forty pounds, and costs about seventy-five cents per pound.* It is provided in lengths from one hundred fathoms to four hundred fathoms, and is made up in eighteen-inch coils, weighing about sixty pounds each, and wrapped with oiled paper. The American wire, which is called music-wire No. 13 by the Washburn & Moen Manufacturing Company, has a tensile strength somewhat less than that of the English wire, and costs about $1.50 per pound. It seems to have a higher polish than the English wire, and is made up in nine or ten inch coils, stowed neatly within sealed tin cases. The method of protecting the English wire for transportation is not a good one, for it is often found that a piece of the paper has become stripped off by careless handling, leaving many layers of the metal exposed; but this is a matter which would doubtless receive attention if brought to the notice of the manufacturers. M. Poehlman, of Nuremburg, Germany, exhibited some of his piano-forte wire at the Centennial Exhibition, which wire, by the official test, proved to possess a strength of about ten per cent. over the English wire on exhibition; but Messrs. Webster & Horsfall may not have been exhibitors.

METHODS OF SPLICING THE WIRE.

Splicing seems to have given Sir William Thomson considerable trouble in his first experiments, for the reason that an abrupt change of section from a thick splice to the single part of wire made a point of weakness, and in his earlier tests the wire always broke just at the splice. He finally settled on a method described by him as follows:

> "A splice of two feet long I have found quite sufficient, but three feet may be safer. The two pieces of wire are first prepared by warming them slightly and melting on a coating of marine glue to promote surface friction. About three feet of the ends so prepared are laid together and held between the finger and thumb at the middle of the portions thus overlapping. Then the free foot and a half of wire on one side is bent close around the other in a long spiral, with a lay of about one turn per inch, and the same is done for the free foot and a half on the other side. The ends are then served round firmly with twine, and the splice is complete."

In connection with the above I give one of Haswell's recipes for marine glue, although the mixture is probably a commercial article:

> "Dissolve india-rubber, 4 parts, into 34 parts of coal-tar naphtha; add powdered shellac, 64 parts. While the mixture is hot it is poured upon metallic plates in sheets. When required for use it is heated and then applied with a brush."

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* Three lengths of English wire were recently tested on board the "Blake" and broke at the following strains: 204, 210, and 202 pounds. Occasionally a piece will break at a strain less than 200 pounds.

PLATE 2.

FIG. 1.

FIG. 2.

FIG. 1. MILLER-CASELLA THERMOMETER CASE FITTED WITH SIGSBEE'S SPRING CLAMP. ABOVE IS SHOWN A PIECE OF THE SOUNDING WIRE.

FIG. 2. SOUNDING ROD; A SLIGHT MODIFICATION OF CAPTAIN BELKNAP'S SOUNDING CYLINDER NO. 2, WITH SIGSBEE'S DETACHER. THE CONSTRUCTION IS SHOWN ON PLATE 39.

Heliotype Printing Co., 220 Devonshire St., Boston.

The New York Rubber Belting Company advertise "pure rubber cement," which is pure rubber gum dissolved in naphtha.

Capt. George E. Belknap, U. S. N., who has taken the deepest casts ever made, explains his splices in this manner:

> "Long-jawed twist two feet in length; soldered at ends and two or three places in middle, and served with fine waxed twine."

All anxiety about our splices on board the "Blake" was saved us by Commander Howell. The kind that he had used in his initiatory soundings from the "Blake" was found to answer perfectly. Experience shows that with these the wire rarely, if ever, breaks at the point where the single part joins the splice. While we have not sounded in the deepest water, we have nevertheless many times, when reeling in by steam, subjected these splices to as much strain as would be brought upon them in the deepest cast ever taken; in fact, we have parted the wire a number of times by direct strain through one cause or another. While, from the shape of the splice, it is probable that the theoretical point of weakness is retained in a small degree, yet it may be presumed that in every great length of wire there will be other comparatively weak spots, removed from the splices, which would not sustain so strong a pull as the points in question. We always regarded our splices as entirely satisfactory, and they appear to have decided advantages over those heretofore described, the chief of which are that they need less attention and repair and are less liable to get stripped; they are but three inches long, which makes them stow compactly upon the reel; are neat and smooth; are easily made and renewed, and need not be served with twine or other material. They are shown on Plate 41. In making them caution should be observed not to give the lay at the cross or middle of the splice so short a nip that it will afterwards be straightened out under strong tension. The form shown on the plate is correct. In soldering, the ends should be given as long a taper as quick soldering will allow, for it will not do to keep the hot iron very long on the single part of the wire for fear of altering the temper of the steel. We were in the habit of having them made always by the same machinist, on the principle that "practice makes perfect," but almost any person who is handy with tools could make them well enough. Their shape is so regular that a simple machine might be devised to make the twist. The outfit necessary for making splices consists of the following: a small charcoal stove, such as is used by tinsmiths, two soldering-irons, some soft-solder, nippers, plyers, and a bottle of soldering-fluid. For the last mentioned, Haswell gives this recipe, which is the same, or nearly the same, as that by which we made our soldering-fluid:

> "To two fluid ounces of muriatic acid add small pieces of zinc until bubbles cease to rise; add one-half teaspoonful of sal ammoniac and two fluid ounces of water."

For the purpose in view this fluid is more useful than resin, because more searching. It should be applied sparingly with a feather or a brush, immediately before the soldering-iron is used.*

PRESERVATION OF THE WIRE WHEN NOT IN USE.

When wire was received in sealed tin cans the latter were painted and stowed below in a dry place, after which only an occasional inspection or touching up of the outside of the cans was necessary. When it was supplied to us in coils wrapped with oiled paper we would parcel each coil with soft canvas, and then apply several coats of paint before stowing them below. Once when we wished to stow away a spare reel containing several thousand fathoms of wire, and had no tank available, we left the coil upon the reel, covered the upper layers with old washed flannel saturated with sperm-oil, spread tallow over the flannel to a depth of half an inch,

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* I have noticed in one of the late reports from the United States Steamer "Tuscarora," Commander J. W. Philip, regarding the work of that vessel, that they had been unfortunate with some splices made after the "Blake's" method. The wire used had been received from the United States Steamer "Alaska," where it had been in service. On board the "Alaska" was Master W. E. Sewell, formerly of the "Blake," a most efficient worker with sounding-wire, and one who knew perfectly the "Blake's" method of splicing. I have no knowledge of the length of time that these splices were used by the "Alaska;" how long they were in stowage thereafter; in what fluid they were stowed, or if they were examined and repaired preparatory to use by the "Tuscarora." I imagine, however, that they were not repaired, as our naval vessels are not usually given more than one reel, and have, therefore, no facilities for winding off wire for examination.

Later, the United States Ship "Saratoga," sailing training-ship, Commander R. D. Evans, has used our splices with entire satisfaction. Lieut. W. M. Wood, who had charge of the sounding-machine, practiced such a neat way of applying the solder, in order to avoid burning the wire with the soldering-iron, that I give his method here: Across a strip of board, about six inches wide, a narrow score or groove was made, which was deepened in the middle for a length somewhat greater than that of the splice. With the hot iron the solder was melted so as to fill the deep part of the score. The splice was then run backwards and forwards through the melted solder, lengthwise in the score, until the soldering was complete. Afterwards the roughness was smoothed down with a knife. I cannot help thinking, after my experience with them, that these splices are sufficiently strong, and in every other respect they have the advantage over the other splices.

and then wrapped the whole reel in old canvas and stowed it below in a cool place. Our methods in this respect answered the purpose for which they were intended.

WINDING OFF WIRE FOR USE OR TRANSFER.

Plate 41 shows our method of mounting the coils for winding upon the sounding-reel; the second reel—that nearest the turn-table—being unnecessary after the correction-curve, shortly to be described, has once been obtained. The turn-table may be made of a circular disk of wood, perforated with auger-holes, arranged in radial lines and on concentric circles, into which pegs may be inserted to suit the coil; the disk being centered and mounted upon any stable pedestal or standard, the apparatus is complete.

When wire is passed from one reel to another a slight resistance should be placed upon the losing-reel—by securing the friction-line by one end and laying it loosely over the friction-score of the reel—in order to keep the wire taut and thus avoid kinking. A friction-score may be turned around the turn-table disk for the same purpose.

To take wire from a sounding-reel, where it has been in use, and make it up again in close coils is not easily done. The difficulty lies in getting an equal strain on each convolution: failing in this, the coil may spring into a figure-of-eight shape when released from support, particularly if the coil be not made as nearly as possible of the same size as when wrapped upon the reel. Before being removed, if wound on a turn-table, the coil may be lashed to transverse strips of wood or iron should a tendency to twist be noticed.

STOWAGE AND SUPPLY OF WIRE: A SUGGESTION.

A simple method of stowage and supply of wire would be to transfer the commercial coils, as soon as they are received, to special cast-iron reels or drums capable of holding four or five times as much as the ordinary sounding-reels. In winding the wire to the supply-drums the splices might be completed at once, which would give the advantage of always having the supply in very long lengths, from which losses could be quickly replaced at sea or in port. These drums, when wound with wire, might be kept in tanks of oil or lime-water.

Something like the following would perhaps suffice for merely containing and transferring wire. A cheap cast-iron drum, one foot in diameter and two and a half inches wide inside the flanges, with side flanges nine inches deep and friction-score at the side; center bored for the reception of an axle of a sounding-reel for mounting on standards. Such a drum would hold more than 20,000 fathoms of wire of No. 22 Birmingham gauge, wound with ordinary care. The register on the gaining-reel would give the measure of the wire reeled off and that remaining on the supply-drum, if used in connection with the correction-curve.

The winding of wire from a turn-table is a slow operation and can best be done in port.

GUIDING THE WIRE IN REELING UP AND UNREELING.

The even winding of the wire, which would, at first, seem to present difficulties, in reality gives little or no trouble under careful management. Accurate guiding is necessary, but this may easily and successfully be done. If ridges are allowed to form when reeling up, in the subsequent operation of paying out they will slip and loosen some of the turns, which is certain to bring about kinking if the paying out be continued.

This mishap came to us but once, and then when we had more than a thousand fathoms of wire in the water. The annoyance and delay that it caused made us guard carefully against a recurrence of similar accidents. Neither swabs nor soft rags should be used for guiding, as they catch in the splices when least expected. The best thing for the purpose, according to our experience, is a piece of stiff canvas folded several times; the rounded fold being pressed against the wire with both hands. This can be managed by one man; is adapted to any change of direction that the wire may take; is always available, and presents a smooth surface, which, if chafed, may be quickly renewed by refolding the canvas.

PRESERVATION OF THE WIRE IN USE: THE TANK.

The preservation of the wire when on the working-reel is an important point, but presents no serious obstacle to the use of wire for sounding. That we should have been able to keep the same length in use for a year is proof of this. When not on our lines the sounding-reel and its wire were kept in a cylindrical tank of galvanized sheet-iron, containing sperm-oil. The tank is built up inside, so that, as nearly as possible, there is but a film of oil beneath and at the sides of the reel, while on top it is covered to a depth of about one or two inches. The cover is a flat, circular piece of sheet-iron, riveted all around its edge to the under side of a wrought-iron ring, the latter being perforated to receive screws projecting at regular intervals through a second wrought-iron ring or flange fastened around the inside of the top edge of the tank. In the center of the cover is a square hole, through which the axle of the reel is allowed to project. A sheet-iron, cylindrical, water-tight cap, to fit over this hole, is a desideratum. It should be about six inches in diameter and four inches high, so as to cover the stray-line, which, being connected with the wire, is rove up through the central hole and coiled down upon the tank when the reel is stowed.*

The cover of the tank, when in place, is set up firm by means of thumb-screws, and between the two wrought-iron rings, already mentioned, which form the joint, a washer of rubber or sennit is interposed to prevent leakage of the oil in a sea-way. In the foreground of Plate 7 the top of the tank is shown, covered with a canvas hood.

Sir William Thomson at first suggested that the wire be kept in a solution of caustic soda when not in actual use. This mixture being found by Captain Belknap to slightly affect the solder of his splices, that officer substituted sperm-oil in its stead. Since then Sir William Thomson has advised that lime-water be used in the tank, and kept up to full strength by occasionally dropping in a lump of burnt lime. Lime-water is certainly recommended by its cheapness, and would probably answer well to preserve the wire in the tank, but sperm-oil, although expensive, has been shown by long experience with it to be a thoroughly trustworthy preservative. For preserving the working wire, when the reel was mounted for use, we always had in store a few cans of concentrated lye, such as may be bought at any ship-chandlery. From this stuff we made an alkaline mixture, which was kept near the sounding-machine in an iron bucket. We never used

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* The stray-line is a piece of small rope, from 10 to 15 fathoms in length, connecting the sinker or sounding-rod with the outer end of the wire. It will be described in the next chapter.

drip-pans, thinking them cumbersome. The alkaline water was frequently but sparingly applied to the wire on the reel, in winding or unwinding, by means of a swab fitted with a wooden handle. If used too freely it flies into the faces of the men working at the machine, causing much annoyance. When the wire had been long exposed, and was noticed to have taken on a rusty color, the surface-layers were scrubbed with lye-water, then rinsed with fresh water and oiled. It is a good practice to perform the same operation when the sinker has reached bottom and a stoppage is made to let the bottom thermometer register. Before a reel is stowed in sperm-oil it should be carefully scrubbed and washed with fresh water to avoid fouling and thickening the oil. A litmus-paper test would show at any time if the oil were getting acid from any cause, and oil should be tested before it is purchased.

KINKING.

Chief in importance of all things to be guarded against when sounding with wire is "*kinking*." By the emphasis which I attach to kinking, I do not mean to imply that it is necessarily an accompaniment of sounding with wire, or that there is a frequent appearance of parts or spots showing a tendency to kink and demanding special presence of mind in the person having charge of the machine. On the contrary, I think a kink is less likely to happen in the wire than undue chafe in a sounding-rope, but there is this difference: a rope may sustain considerable chafe and yet be in no immediate danger of parting in ordinary work, while if the wire kink it is almost certain to break under a light strain.* In no case should even an incipient kink be trusted. By not losing sight of the qualities of the wire in connection with the character of the sounding-machine, the watch-officers of the "Blake" would not for months together, or even for a whole season or more, encounter a single kink. As long as the wire is taut it is safe; but if allowed to slack it will have a tendency to assume the shape of the convolution in which it has been wrapped under strong tension, either upon the reel or in the coil. From this tendency we have bights or loops, which, if not cleared by hand, form kinks when the wire is again subjected to tension.

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* In recent tests of the strength of English wire in kinks, the wire parted at the following strains, each time in a kink: 46, 54, 46 pounds.

WIRE TESTS AND WORKING STRAIN.

Several pieces of the working wire should be tested for strength from time to time, with a view of finding the limit of strain which it would be safe to put upon it. I would suggest, as a safe rule for beginners, that the wire be worked to no more than one-half its breaking strain. With us discarded wire was kept upon a spare reel, to be used for the outer lengths in case the better material should give out. Such stuff might be made up into coils, each coil being tallied with a record of its length, tensile strength, and history, when it could be made to serve for make-shifts. When wire which has lost much in uniformity of strength is used with the sounding-machine, it is prudent to keep a memorandum of the working strain of each length, that the person who superintends the working of the machine may be able to exercise a correct judgment when reeling in. The risk of losing rods, water-cups, and thermometers is too great with weak wire, however, to sanction the use of any but the best material if it can be had.

THE CORRECTION-CURVE.

All deep-sea sounding-reels that I have seen are of such a size that their drums will exactly accommodate one fathom of the sounding-wire as a single turn (Plate 17 and others). While each turn of the first layer wound about one of them is, therefore, one fathom in length, those that are above measure more, according to their distance from the drum. Each reel is rigidly attached to an axle, on which is a worm to connect with the train of a register for recording the number of revolutions of the reel (Plates 36–38). It is evident that the readings of the register show the number of *turns* of wire paid out or reeled in, but not the number of *fathoms*, and, since the turns are almost constantly varying in length, it becomes necessary to have some ready means of reducing them to fathoms in order to arrive at the depth of the sounding. For this purpose the correction-curve (Plate 41) was devised on board the "Blake" at the commencement of our first season, and its use was continued thereafter throughout the whole four years of our work.

To get the data for constructing a correction-curve like that on Plate 41, the commercial coil of wire is mounted upon a turn-table and two empty reels are placed as shown on the plate. The wire is led from the coil five or six times around the first, or spare reel, and the end is secured to the drum of the second, or working reel. Then, as it winds in accumulating turns on the working reel, it only passes on and off the spare reel in non-riding terms of one fathom each. A register being applied to each axle, that placed on the working reel will record *turns* as they occur in actual sounding, while that on the spare, or measuring reel, will give the corresponding *fathoms*. From this it follows that, at any stage of the transfer, the difference between their readings is a correction which, if added to the reading of the register connected with the axle of the working reel, will give the number of fathoms of wire reeled off. As the operation progresses a table is prepared like that on Plate 41, from which the curve may be constructed in a few minutes.

I have known misapprehension to exist in the minds of a few persons who have given this curve only a hasty notice. Some have understood that we used a spare reel at every sounding to measure the length of wire paid out; others have thought that each vessel would require a curve at the outset, and a new one whenever wire was added to the working reel or lost from it thereafter. I will attempt to make it clear by stating that only the working reel is used at soundings; the spare one serves the sole purpose of getting the data, so far as any connection with the curve or the other reel is concerned. A curve once obtained is always applicable to the same kind of reel and wire that was used to get it, and this without regard to losses or gains of wire within the limit of the extension of the curve; for example, if made out for only 3,000 turns the curve will not suffice for 4,000 turns, but if carried forward in the first instance to include the figures of the greatest possible depth of water, there will then be no limit to its use with the original size of reel and gauge of wire. From this it will be seen that if all the sounding-reels, supplied from any source, be made with drums of equal dimensions, and the same gauge of wire be used with all, then the parties issuing the reels, by constructing a curve in a single instance, and extending it for the total amount of wire that a reel is capable of containing, may provide a photolithograph, engraving, or other copy of the original curve with each machine as part of its outfit, in which case no future measurements nor preparation of tables will be necessary with those machines.

It has been stated that winding the wire smoothly is a simple matter and need not be classed amongst the difficulties. In reeling back, after a sounding, the index of the register nearly always returns to precisely the same point whence it started, and I have never known, even in depths as great as 2,000 fathoms, a discrepancy amounting to as much as three turns. Should any considerable difference occur, and should equal dependence be placed in the register record of paying out and that of reeling in, then a correction may be found for a *mean* of the two readings of the register. If wire be lost from the reel or added to it, a new constant, *c*, corresponding to the altered number of turns, *t*, in actual use, must be sought, and the rule applied just as before. The "Blake's" curve, framed and hung in the pilot-house, was always at hand, and to effect a reduction after a sounding was the work of but a few seconds.

In the Sigsbee sounding-machines (Plates 7 and 8), the wire after leaving the reel passes over a pulley above, which is one yard in circumference less the allowance for the thickness of the wire. An odometer (Plate 38) was at first attached to the axle of this pulley, and by its reading showed at once the number of yards of wire paid out at a sounding. We could, therefore, work independently of the correction-curve or of any other measurement than that of the pulley, but the position and size of the register on the axle of the reel was so convenient that we preferred the use of the register. We found the two measuring-instruments to agree after the usual correction, it being necessary in each case to make a small allowance for the four or five revolutions that the pulley always gave after bottom had been reached.

SOUNDING-RODS.

An instrument made fast to the outer end of a sounding wire or rope, and which, being inserted within the sinker and projecting through it, serves to retain the sinker in the descent and to detach it when bottom has been reached, is usually called a sounding-rod.

A single rod is sometimes made to perform three separate offices; viz, to bear the sinker to the bottom and leave it there; to bring up a specimen of the bottom soil; and to bring up a specimen of the bottom water.

There are objections to the employment of a sounding-rod for bringing up water-specimens. To adapt them to this purpose involves the application of an arrangement of valves, more or less expensive, and, since bottom water is not wanted at every sounding on a connected line such as ours were, it does not seem economical to risk costly accessories unless something is to be gained. In regard to this, only a certain number of rods in any outfit might be supplied with valves, the others being without them; but there is a more weighty objection than that mentioned above.

It is doubtful if a genuine bottom-water specimen is always secured by means of a combined rod and water-cup when the rod has returned from soft bottom; for, owing to mud entering and fouling the valves and their seats, or from a deposit upon these parts of particles held in temporary suspense on account of the agitation caused by the impact of the sinker, the valves may not seat perfectly at the moment of beginning to haul back. This contingency should be all the more carefully guarded against, because, during the ascent, the reverse current of water through the rod, allowed by the non-seating of the valves, would probably clear away the obstructions, and thus the rod might come to the surface with every appearance of having worked well, when in reality the specimen of water within would be of no value whatever.

On board the "Blake," when we wanted bottom water, a water-cup was used and fastened two or three fathoms, according to depth, above the sinker or rod. The water-cups will be described hereafter.

During our first three years we used the rod known as Capt. George E. Belknap's sounding-cylinder No. 3, with the difference that the Sigsbee detacher was added in place of the single hook, and that a device was applied to overcome the objections to a flat-headed cylinder for use with sinkers fitted with iron bails or slings, of which more will be said hereafter.*

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* For description and drawing of the original cylinder No. 3, see "Deep-sea soundings in the Pacific Ocean, obtained in the United States Steamer 'Tuscarora' by Commander George E. Belkuap, U. S. N." U. S. Hydrographic Office Publication, No. 54.

PLATE 3.

FIG. 1.

FIG. 2.

FIG. 1. MILLER-CASLELA THERMOMETER CASE FITTED WITH SIGSBEE'S SPRING CLAMP.
FIG. 2. SOUNDING ROD; A SLIGHT MODIFICATION OF CAPTAIN BELKNAP'S SOUNDING CYLINDER NO. 2, WITH SIGSBEE'S DETACHER. THE CONSTRUCTION IS SHOWN ON PLATE 39.

Heliotype Printing Co., 220 Devonshire St., Boston.

In this rod the arrangement for getting a bottom-soil specimen consisted of an auger-shaped spindle terminating in a conoidal cup. A cylinder which was kept above the auger in the descent fell down and inclosed it on detaching the sinker. This did remarkably well for bringing a specimen from soft bottoms, which was all that Captain Belknap claimed for it, but as our expectation for finding sand, shells, or coral increased, something different appeared to be necessary.

It is not always possible to foretell the consistency of bottom-soil specimens, and when, therefore, it is surmised that it will be varied over the locality to be sounded, a rod should be used which will probably give at least slight evidence of any bottom composed of fine loose material. In order to determine on some good shape for a specimen-cup—that part of the rod which gets the specimen—I supplemented my experience by experimenting with a number of devices in wet sand, which is one of the most difficult of bottom materials to bring up with a sounding-rod.*

The result of my experiments showed that a simple cylindrical pipe, open at both ends, could be plunged far into the sand, which, however, resisted the blunter forms to a degree that precluded their adoption. Here was a suggestion—to shape the specimen-cup as nearly as possible like an open cylindrical pipe; to drive it into the bottom material, and to retain the inclosed specimen. Captain Belknap's sounding-cylinder No. 2 seemed to answer the demands better than anything else, the poppet-valve being, to my mind, preferable to the butterfly-valve which is sometimes used. Accordingly, cylinder No. 2 was modified by me in some respects, and fitted with the Sigsbee detacher, after which it was brought into service on board the "Blake" (Plates 2 and 3). The spring, the cone top, and the fittings for permitting the escape of water are changed somewhat from Captain Belknap's plan, but their operation is, in effect, about the same. It is not intended that this rod shall get a specimen of the bottom water.

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*I have sometimes seen repeated trials with a fifty-pound lead, armed with a Stellwagen cup (Plate 5), fail to get a single grain of material from bottom known to be only of sand, the depth being only four or five fathoms.

DESCRIPTION OF THE MODIFIED BELKNAP'S SOUNDING-CYLINDER NO. 2, FITTED WITH SIGSBEE'S DETACHER.

(Plate 39.)

The cylinder A (Figs. I, II, III, and VI), with a screw-joint at B (Figs. I, III).

A casting, composed of the upper and lower cylindrical guide-stems C, C (Figs. I, III, IV, V, VI) and the perforated plate J (Figs. I, V, VI), rigidly attached to the upper part of the cylinder A.

The valve-seat E (Fig. I).

The poppet-valve F (Figs. I, II, and III), rigidly connected with the pipe G (Fig. I) which travels loosely on the lower guide-stem C (Fig. I).

The weak spiral spring H (Fig. I).

The hollow cone I (Figs. I, II, III, IV, VI), to the bottom of which is soldered the smooth cylindrical ring D (Figs. I, V, VI).

The apertures P, P, &c., for the escape of water (Figs. I, II, III, V, and VI).

A detacher composed of the swivel K, the pawl L, the tumbler M; and the spring N, of No. 14 American gauge—or No. 15 Stubbs's gauge—*spring-brass* wire (Figs. I, II, III, IV). Every part of the rod and detacher is of brass.*

In connection with the above is used the iron shot-sinker Q, fitted with the iron-wire bail R (Figs. I, II).

WORKING OF THE SOUNDING-ROD.

(Plate 39.)

During the descent, the cone I is kept up by the shot as shown in Figs. I and II (see also Plate 2), and on striking bottom the bail is prevented from getting over the top of the detacher by the bearing which the shot has under the cone.

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* The idea of leaving the sinker on bottom in deep casts was first put in acceptable mechanical shape by Passed Midshipman John M. Brooke, U. S. N., now Professor Brooke, of the Virginia Military Institute. The leading feature of his device was a rotating hook. Since writing the above it has been claimed for him that my detacher is a modification of his, a point which I willingly concede. Although in designing my form of detacher I had no thought of modifying that of Brooke, yet, had I not been familiar with the latter, the peculiar

On reaching bottom the slacking of the wire—or, more strictly, its diminished tension—allows the tumbler of the detacher to trip, and the shot is then free to slide off the cylinder. The tumbler is kept back by the spring wire N, and cannot rehook the bail, Fig. III (see also Plate 3). The resistance of the bottom material raises the poppet-valve, thus allowing the specimen to pass into the cylinder, a free escape of the water from

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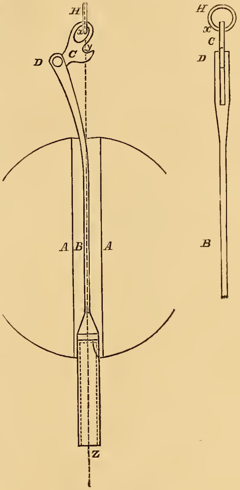
shape of the former might not have suggested itself to me. In fact, there is no sounding-rod—as I have defined the term—that is not a modification of Brooke's rod in one respect or another.

I give here a wood-cut of Brooke's apparatus. By comparing the cut with Plate 39 the extent of my modification may be seen, while the explanation on this page will show how carefully the form of the Brooke detacher was studied by the inventor in order to adapt it to the requirements of sounding with rope. The explanation is taken almost *verbatim* from a pamphlet published by the Bureau of Navigation, Navy Department, in 1868, entitled "General Instructions for Hydrographic Surveyors," &c.

"A is a shot, cast with a hole through it, and slight grooves on its sides to receive and steady the slings. B is a rod to which is attached an arm, C, moving vertically about the pin D, and from which the shot A is suspended by slings. The lower end of the rod B is tubular, receiving the barrels of several goose-quills open at both ends, with the cut downward, retaining their places by their elasticity. At the top of the tube is a valve of thin leather opening outward; it permits the water to flow through the quills as the rod descends, but, closing as it is drawn up, preserves the specimens intact.

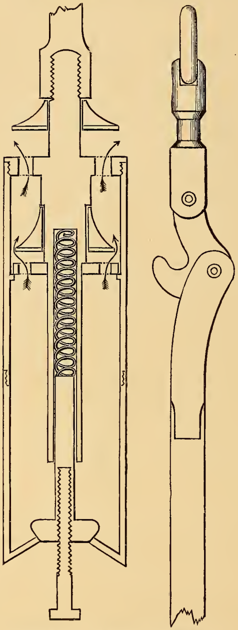
"The proportions of this instrument are such that when the shot is suspended from the arm C, the point of contact x, the point of suspension y, and the point of resistance Z, all lie in the same vertical line; the weight of the rod B will then give the arm C a slight inclination, which, with the friction of the water on the line holding it back, guards against premature detachment.

"It is obvious that the sensitiveness of this detaching apparatus will depend upon the relative position of these three points; for the arm C may be regarded as a lever of the second order with its fulcrum at D; the gravity of the shot as the power acting upon the resistance of the line. So that by increasing or diminishing the distance of the ring H from the pin D the detachment is rendered more or less difficult. In order that change of position in the arm C, as it yields to the pull of the shot in the act of detaching, may not interfere, it is so made as to permit the ring to slip back as the arm inclines."



B.—Brooke's Sounding-rod and Detacher.

This detacher, I think, would be too sensitive for use with wire. I purposely gave mine a form to insure against premature detachment and to permit the rod to penetrate well into soft-bottom material. Commander Bartlett reports that in the 250 casts taken by him with shot, using the Sigsbee detacher, there was not a single failure the latter being provided for by the apertures P, P, &c.* On hauling back, the valve drops to its seat, or is forced back by the spiral spring H, and the cone falls, closing the upper apertures against a current of water through the cup. When the rod is recovered the specimen-cup may be unscrewed for extracting the bottom material (Plate 3).†



C.—BELKNAP SOUNDING-CYLINDER NO. 2.

* Experiment has shown of late that it would be an improvement to do away with the stud which projects from the lower part of the poppet-valve, leaving the under surface of the valve smooth.

† I give herewith a wood-cut showing, in section, the original cylinder No. 2 by Captain Belknap. Although the use of a poppet-valve in a specimen-cup is not original with Captain Belknap, my intention was directly to modify his cylinder. The description already given of the modified rod will suffice to explain the original. I had at first only referred to a publication wherein a drawing of the original No. 2 might be found, but since Captain Belknap has stated that he does not think my changes improvements, it seems due to him that his cylinder should be given a graphic representation on these pages. It is also proper that the alterations should stand or fall according to their merit.

The changes made by me in the rod proper or cylinder are, briefly, as follows: Substituting a cone top for that shown in the wood-cut; dispensing with the inside water-valve; enlarging the specimen-aperture and poppet-valve; giving the bottom of the cup a sharper bevel; employing a spring of greater diameter in order to get more elastic movement; making provision for the escape of water at the moment of impact.

In the original there is no escape for water from the small cylindrical chamber in which the stem of the poppet-valve is guided, excepting what may take place around the valve-stem. In deep water, owing to pressure, the valve-stem has above it, in its chamber, a practically incompressible column of water and a highly compressed column of air resisting the lifting of the valve; hence an escape must be provided. This may be done by perforating the guide-cylinder, or by slightly filing away a side of the valve-stem; but I have changed the form of the apparatus considerably in this respect, chiefly to get a more effective spring.

The testimony of records is in favor of the modified rod, but with the wood-cut available it would be easy to construct either rod that might be preferred.

NOTES ON THE CONSTRUCTION OF THE SOUNDING-ROD.

(Plate 39.)

The Sigsbee detacher was used by us for nearly all soundings in which the sinker was left on bottom, the few exceptions occurring during the early part of our first season and in experimental trials with other devices. It was so highly appreciated by the officers who used it that most of them would appeal from instructions to use any other. When properly made it is, perhaps, as little liable to fail as an ordinary pedestrian is to stumble, but the drawing should be followed strictly in the construction. The following points should receive attention in the manufacture of the detacher and cylinder:

I. The pawl and tumbler are made to fit each other in such a manner that, when connected and under strain, they are held undeviatingly as shown in Figs. I and II; that is, the wire is in the prolongation of the axis of the rod. If this be not observed the relation of the leverages of the pawl and tumbler will be destroyed, and the detacher may be too sensitive, besides which the rod may incline to a degree that will act somewhat against a vertical descent.

II. That part of the lip of the tumbler on which the bail of the shot rests should have the edges beveled or rounded, otherwise the edges may be broken up and spread, thus preventing the tumbler from being thrown back between the side pieces. Thin washers put on either side of the tumbler and pawl would probably be an improvement.

III. All parts should work freely.

IV. The bottom of the specimen-cup should have the proper bevel; if too sharp it may retain but a small specimen, and if too blunt the rod may not penetrate firm material.

V. The spiral spring H should not be so strong as to prevent soft bottom material entering the cup; *its strength should be sufficient, when the rod is lying flat, to force the valve smartly to its seat when the valve is pushed inward and released, and yet not strong enough to seat it by about one inch when the rod is held bottom upwards.* The springs for the "Blake's" rods are of No. 17 American or No. 18 Stubbs's gauge *spring-brass* wire; they are three inches in length when not under compression, and have twelve coils each. Any spring thus made could easily be adapted to the requirements.

VI. If desired, the rod might be made considerably lighter for very deep work, the present size of the detacher being retained. On the scale of Plate 39 the rod and detacher are strong and handy, weighing five and one-quarter pounds. The size of the specimen sought should have much influence in determining the size of the rod. If only an *indication* of the bottom material were wanted, no specimen for careful examination being needed, a rod weighing only two or three pounds would suffice.

REQUIREMENTS FOR A PERFECT SOUNDING-ROD.

The following might be added to the list of requirements for a perfect sounding-rod:

I. Certainty of not detaching the sinker during the descent.

II. Certainty of detaching on striking any character of bottom.

III. Certainty of not rehooking or of fouling with the sinker, in any way, after the same has once been tripped.

IV. Adaptability to getting a specimen from the various kinds of bottom material.

V. Certainty of not grappling irretrievably with the bottom.

VI. Certainty of retaining the specimen against the wash of water in the ascent.

VII. Handiness for extracting the specimen and for cleaning the parts.

VIII. Freedom from changing its form under the severe pressure in deep water.

IX, &c. Strength, simplicity, cheapness, light weight, and freedom from corrosion.

GENERAL REMARKS ON SOUNDING-RODS AND DETACHERS.

In general there are two ways of effecting the detachment of a sinker from its rod:

I. By the actual or partial slacking of the sounding wire or rope.

II. Directly by the impact of the rod against the bottom.

Of these two methods the former is regarded as the safer, but sometimes both are involved in one detaching apparatus.

A detacher which depends for tripping solely on the resistance of the bottom material is usually more sensitive on hard than on soft bottom; also, should the sinker glance on the side of a rock or ledge, the trigger or other appliance might not be presented fairly to the blow necessary to upset the connection which holds the sinker in place.

The action of the original detacher by Brooke was based on the diminution of the tension on the line. This is the principle applied in the Sigsbee detacher, and, indeed, in almost all others approved by persons of experience in deep-sea sounding.

That detacher must be very objectionable which will drop the sinker before bottom has been reached. In tests made with the Sigsbee detacher and a fifty-seven-pound shot-sinker it was found that the latter did not fall until the wire had been released from all but eight pounds of the weight of the sinker, yet this result always follows when the wire is slacked or "rendered" less than one inch. This shows the right kind of sensitiveness and gives assurance that the rod will find an entrance into most sea-bottoms.

In sounding with wire it is so important that there should be no failure of the sinker to detach on deep-water bottoms, that I am constrained to dwell still longer on this subject. In order to show how accidents in this regard may be brought about, Plate 4 has been prepared. By taking various other rods in consideration the cases might be much extended. It must be understood that I have in mind the use of the iron bails or slings adopted by the Navy and by the Coast and Geodetic Survey.

Fig. 1 shows an assumed case wherein the sinker and rod are imbedded in mud. The bail has been tripped by the single-hook detacher, but the resistance of the mud holds it in an upright position. The sinker, supported by the mud, does not drop clear, and on hauling taut the sounding-wire the detacher rehooks the bail. The case applies to a number of forms of detachers, but this accident would be much less liable to happen were the sinker suspended from the hook by a rope-sling composed of two independent legs, each going over the hook with a ring.

In Fig. 2 the sinker and rod are supposed to be wholly covered with mud and at rest in the position shown. Although the sounding-wire is slack the pawl of the detacher does not fall because of the resistance of the mud; and there is no pull from the sinker to force it down. This applies to a number of rods. In the Sigsbee detacher the spring N, Plate 39, is intended to meet this contingency as one of its functions.

Fig. 3 shows what has often occurred with us, experimentally and in actual work, when there was a flat top to the cylinder of the sounding-rod. The bail has tripped, but has fouled on the cylinder-head.

Fig. 4 shows what may happen when there is no provision for preventing the cylinder from getting further within the sinker than is desirable. That this is possible has been proved experimentally. It could not come about with projecting heads or caps like those shown in Figs. 3 and 5.

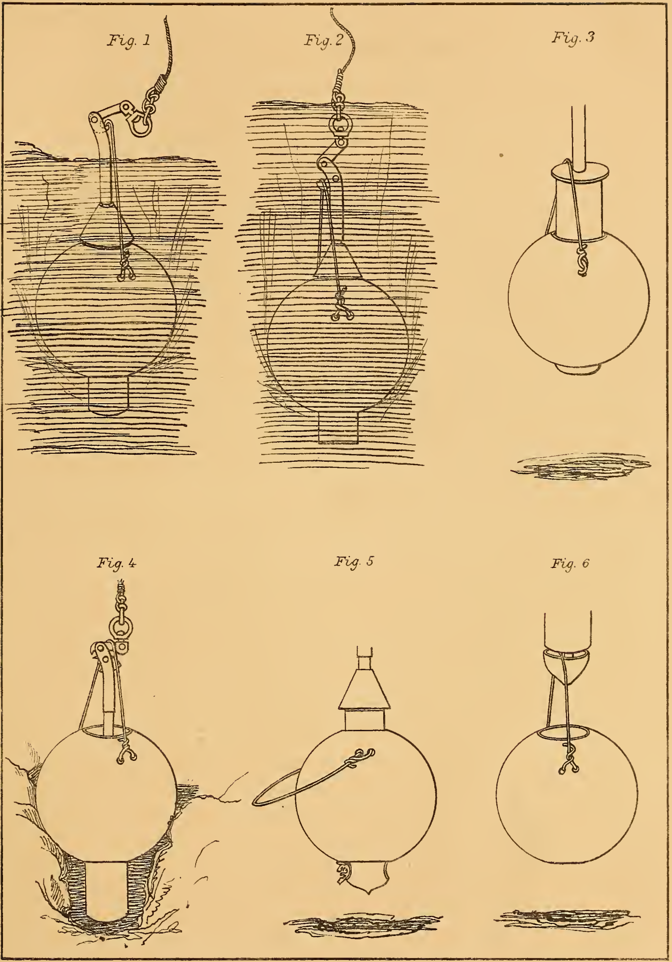
Fig. 5.—This accident is possible when the rod is constructed to admit the specimen from the side. The sinker has tripped, but has fouled on pieces of coral, rock, or gravel protruding from the specimen chamber. This has been proved by experiment.

Fig. 6.—The sinker has tripped, but has fouled on a specimen-cup. The accident shown in Fig. 5 may also happen with this arrangement. Both cases have been proved.

Some of the contingencies illustrated are very remote, it is true; but by providing against as many as occur to the mind, we not only narrow down the list of possible failures, but when accidents then happen we are better able to find the real cause by having previously limited the field of investigation.

HEAVY SINKERS FOR DETACHING.

The sinkers now used on board the "Blake," in connection with sounding-rods, are cast-iron eight-inch shot, with a hole of sufficient size to give a clearance of one-sixteenth of an inch all around the rod, and weighing about sixty pounds each (Plate 39). They are cast at the Washington Navy-Yard of old scrap material not suitable for ordinary purposes, and cost \$1.75 each. On those sent us were small lugs or loops—for securing the iron-wire bail, or sling—in place of the side holes shown in the plate. The



SHOWING SOME OF THE CAUSES—PROBABLE AND REAL—OF THE OCCASIONAL FAILURES OF SINKERS TO DETACH.

lugs being cast with the shot, the brittleness of the metal was such that after a few months of stowage many of the lugs were found to be broken. In order to avoid trouble of that kind, I proposed holes in which to make fast the ends of the bails. To replace the wire bails that came adrift through the breaking of the lugs, we at first used single rope slings as a make-shift, but this causing accidents like that illustrated in Fig. 6, Plate 4—for at the time we were using a specimen-cup of the pattern shown in the figure—we improvised wire bails, which did well. An advantage with a stiff-wire bail is that it will keep its shape from the surface to the bottom and after tripping, while with a rope sling in one piece we may expect shrinkage when it becomes wet, and possibly dangerous twisting when it is released from tension on striking bottom. In Plate 39 we will suppose the rope sling to exactly fit over the tumbler when the shot and cone top of the cylinder are up as far as they will go. This is the state of things when the rope is dry, but when the sinker is lowered into the water the sling shrinks and bears down on the tumbler in a way not provided for. From this it will be seen that rope slings when employed with a cylinder having a projecting top should be of a length to allow for shrinkage, and should be made wet before they are hooked to the detacher. All seamen know, at least in a general way, the power developed by the shrinkage of rope after being made wet. In securing the ends of bails to side holes in the shot, as shown on Plate 39, care should be taken that the fit be loose enough to allow the bail to fall clear by its own weight on tripping. Although this is not necessary with the Sigsbee-Belknap detacher and cylinder, it is a very proper precaution. A double rope sling is much less liable to foul than a single one of the same material. There has been some objection made to the use of iron-wire bails, because they do not always fall clear in soft mud or clay (Fig. 1, Plate 4). The trouble is not with the iron bail, but lies in using it with a rod not adapted to it. We used these bails for four years and approved them highly—in fact, we regarded their adoption as a decided advance.

While on the subject of detaching, it is well to mention that the edges of the metal, around the cylindrical hole in the shot, sometimes become bent inward by rough usage in stowage or transportation; hence an additional need of a large clearance. Every shot taken from the locker for use should be examined and fitted to the rod immediately after being brought to the upper-deck. A slight beveling of the metal at the exposed edges, in the manufacture, would prevent mishaps in this respect.

Should heavier sinkers than those used by us become desirable, the rod (Plate 39) has ample length to admit of carrying a much larger shot. Probably the deepest cast with wire might be taken with a sixty-pound shot, excepting in very strong currents or heavy seas, when a heavier weight would give results more trustworthy. Certainly seventy-five pounds of metal should suffice for any possible case. With a steamer, economy of time might effect a great saving of coal and of general outlay which could not be offset by an occasional gain of a few pounds of old iron, hence considerations of economy might vary the plan of operations for different vessels. As a rule, a sixty-pound sinker may be pronounced a heavy one for wire sounding, and one that will give rapid work up to 3,000 fathoms or 3,500 fathoms. In fitting out with heavier sinkers it should be remembered that the proportion of depths to be sounded exceeding 4,000 fathoms is small in comparison with the lesser ocean-depths requiring examination.

THE GAS-PIPE SOUNDING-ROD.

There were occasions, in deep water, when we did not wish to save a specimen of the bottom soil. At such times we often used a simple rod made from a length of ½-inch or ¾-inch gas-pipe, to which was screwed a Sigsbee detacher. This would bring up a few particles of bottom material, just enough to show the color. It presented very little surface to resistance in hauling back, and was of such light weight that we gained time by its use. If the wire parted, we lost nothing of value but the submerged wire and the detacher. With a rod of this kind, to make sure of tripping at once on striking bottom, the lower end of the gas-pipe should project through the shot at least a foot; an arrangement which will also provide against the bail or sling getting above the detacher. The lower end of the pipe may be plugged and armed with tallow, or a ball of rubber or metal being slipped inside the pipe the edges of the metal at that end may be rounded inwards so as to retain the ball as a valve. In the latter case a

FIG. 1.

FIG. 2.

FIG. 1. CANS FOR OBSERVING CURRENTS. FIG. 2. SOUNDING LEAD FITTED WITH THE STELLWAGEN SPECIMEN CUP.

couple of small holes for water-escape should be bored through the pipe just below the detacher. With a similar instrument, when falling short of shot-sinkers, we have sounded successfully with old grate-bars, an old ash-bucket filled with fire-bricks, &c., leaving these weights on bottom. Almost any piece of old scrap-iron, of elongated form, may be made to serve as a sinker by fitting a rope grommet transversely around it at each end, like the single strap of a block, and leaving a free eye or becket in each grommet through which to pass the rod. For the sling or bail, wire would be best.

LIGHT-WEIGHT SOUNDING-LEAD FOR RECOVERY.

When, in sounding with wire, circumstances were favorable to the recovery of a sinker, we used a sounding-lead of the common commercial pattern, to which we fitted a Stellwagen specimen-cup (Fig. 2, Plate 5). The combined weight of the lead and cup was about thirty-four pounds. With this kind of sinker we took the greater number of our soundings with wire, especially after getting on board a sounding-machine giving us the advantage of an accumulator (Plate 7). The hauling back was always done by steam. The lead and Stellwagen cup are not the best that could be devised for the purpose, as the specimen is sometimes washed out in the ascent and the lead is not of the best shape possible. Fig. 2, Plate 5, gives a clear representation of the apparatus, which may be described as follows: A wrought-iron spindle, sunk for a part of its length into the sounding-lead, has a detachable conoidal cup screwed to its lower end. Sliding freely on the spindle, between the lead and the cup, is a leather washer, which is raised by the resistance of the water in the descent or by the resistance of the soil on striking bottom. On the ascent, the washer falls by its own weight, or by the resistance of the water is forced down upon the cup, thus inclosing the specimen. We generally used a second washer, of lead or iron, above the leather, and sometimes adopted a suggestion by Lieut. R. D. Hitchcock, U. S. N., which was to gather and seize a piece of muslin around the spindle above the washers, allowing its folds to drape down around the washers and cup nearly to the bottom of the latter. This was intended to prevent a current of water between the spindle and the washer.

While much ingenuity has been displayed in designing combined leads and specimen-cups that may be operated when it is intended to recover the sinker, there is nothing known to me that I think altogether acceptable for use with wire, and on all bottoms. It should be remembered, when considering the requirements for such a device, that it would be the one most often used in depths varying from 100 fathoms to 1,000 fathoms, between which depths all characters of bottoms are met with—such as sand, shells, gravel, coral, rock, clay, and mud or ooze; also that by retaining the sinker the whole force of impact due to the weight and velocity of the sinker at the instant of striking bottom is brought to bear on the specimen-cup, and unless this crushing-force be provided against the cup may become injured by a blow on rock or other hard material.

More will be said hereafter about hauling back the sinker.

CHAPTER III

THE SOUNDING-MACHINE AND ITS USE.

DESCRIPTION OF THE ORIGINAL SERVICE MACHINE FOR SOUNDING WITH PIANO-FORTE WIRE.

To illustrate in what respect changes were made by me in the sounding apparatus, an explanation will be given of the machine we first used, which was practically the same as those originally issued for general use with the sanction of Sir William Thomson (Plate 6).

A reel having a drum one fathom in circumference (less the small allowance for the diameter of the wire) and with a **V**-shaped friction-score at the side is rigidly attached to its axle and mounted upon standards. On the axle is a worm which engages a counter or register, to mark the revolutions of the reel. The wire, which is wound about the drum, pays out directly from the reel—through a fairleader or clamp on the forward end of the bed-board—into the water. In rear of the reel, and on the same side as the friction-score, is a dynamometer-pulley or wheel having two scores, which we will call the wide score and the narrow score, respectively. This is mounted in a special standard, from which it may be removed at will. For paying out wire, an endless rope-belt, called the brake-cord or the friction-rope, is passed somewhat more than half around the friction-score of the reel, thence one whole turn around the wide score of the dynamometer-pulley, and through a tail-block to the rear. The pendant of the tail-block—or, more strictly, pulley—being rove through a standing block, supports weights to tighten the friction-rope.* The narrow score of

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* Captain Belknap introduced the use of weights for putting strain upon the friction-line, a tackle having previously been employed for that purpose.

the dynamometer-pulley is connected with a spring-scales by a tangent wire or cord in such a way that the traveling of the belt can turn the pulley on its axle only to the extent permitted by the resistance of the spring-scales. When the reel is set in motion, the retardation of the belt on the dynamometer-pulley places a resistance upon the reel that can be regulated by weights at the tail-block. The scales are intended to show, approximately, the amount of resistance applied to the reel by means of the belt.

The words of the inventor are quoted to explain the action of the machine:

> "The wire is coiled on a large wheel (of very thin sheet-iron galvanized) which is made as light as possible, so that when the weight reaches the bottom the inertia of the wheel may not shoot the wire out so far as to let it coil on the bottom. The avoidance of such coiling of the wire on the bottom is the chief condition requisite to provide against the possibility of kinks; and for this reason a short piece of hemp line, about five fathoms in length, is interposed between the wire and the sounding-weight; so that, although a little of the hemp line may coil on the bottom, the wire may be quite prevented from reaching the bottom. A galvanized-iron ring, of about half a pound weight, is attached to the lower end of the wire, so as to form the coupling or junction between the wire and the hemp line, and to keep the wire tight when the lead is on the bottom and the hemp line is slackened. The art of deep-sea sounding is to put such a resistance on the wheel as shall secure that the moment the weight reaches the bottom the wheel will stop. By 'the moment' I mean within one second of time. Lightness of the wheel is necessary for this.
>
> "A measured resistance is applied systematically to the wheel, always more than enough to balance the weight of wire out. The only failure in deep-sea soundings with piano-forte wire, hitherto made, has been owing to neglect of this essential condition. The rule adopted in practice is to apply resistance, always exceeding by 10 pounds the weight of the wire out. Then the sinker being 34 pounds, we have 24 pounds weight left for a moving force. That, I have found, is amply sufficient to give a very rapid descent—a descent so rapid that in the course of half an hour or fifty minutes the bottom will be reached at a depth of 2,000 or 3,000 fathoms. The person in charge watches a counter, and for every 250 fathoms (that is, every 250 turns of the wheel) he adds such weight to the brake-cord as shall add 3 pounds to the force with which the sounding-wheel resists the egress of the wire. That makes 12 pounds added to the brake resistance for every 1,000 fathoms of wire run out. The weight of every 1,000 fathoms of the wire in the air is 14½ pounds. In water, therefore, the weight is about 12 pounds; so that, if the weight is added at the rate I have indicated, the rule stated will be fulfilled. So it is arranged that when the 34-pound weight reaches the bottom, instead of there being a pull, or a moving force, of 24 pounds on the wire tending to draw it through the water, there will suddenly come to be a resistance of 10 pounds against its motion. A slight running on of the wheel—one turn at the most—and the motion is stopped."*

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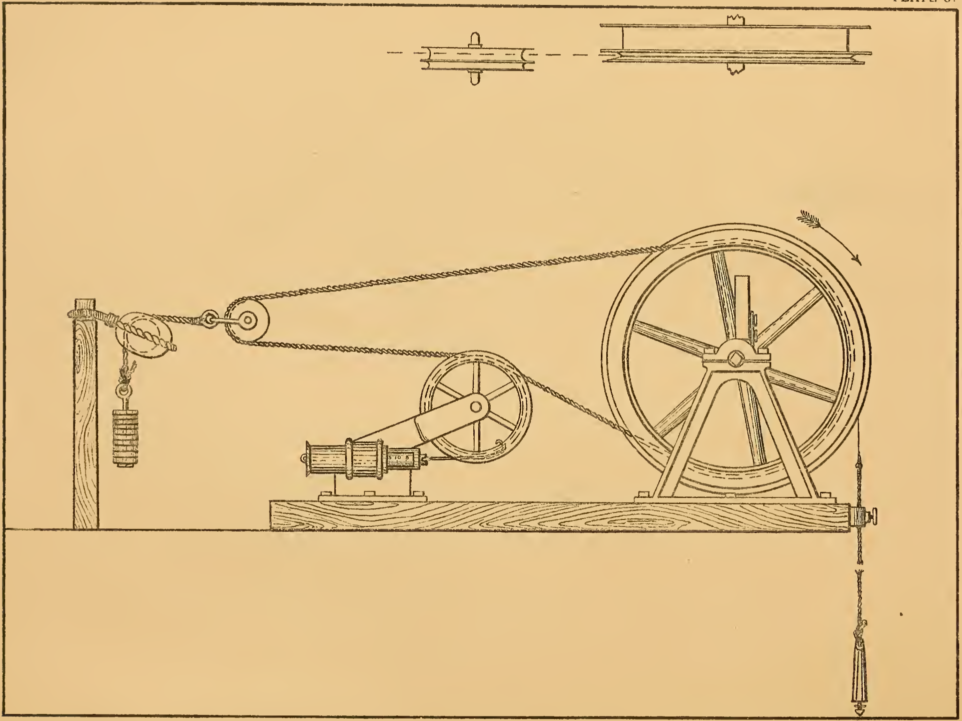
* Sir William Thomson was the first to discard the method, already described, of weighing the resistance upon the reel. In Captain Belknap's Pacific work a record was kept of the dynamometer readings, and a number of cases are found wherein the sinker struck bottom, when, *according to the dynamometer*, the resistance upon the reel was less than the weight of the submerged wire. The dynamometer readings in such cases must have been erroneous, otherwise the reel would not have stopped; but since the reel, in fact, did give immediate evidence of the arrival of the sinker on bottom, it must have been that there was resistance upon the reel not shown by the dynamometer. The resistance upon the reel not indicated by this dynamometer arrangement is probably due to the following causes: Friction of axles or pivots; friction of the working parts of the scales on account of the horizontal position of the latter; stiffness of the brake-cord at the several changes of direction; and the occasional chafing against each other of the two parts of the cord moving in different directions on top of the dynamometer-wheel. On board the "Tuscarora" the error was somewhat increased perhaps by taking

PLATE 6.



SHOWING THE GENERAL FORM AND WORKING OF SIR WILLIAM THOMSON'S SOUNDING MACHINE AS USED ON BOARD THE "BLAKE" DURING HER FIRST SEASON IN THE GULF OF MEXICO. (RIGGED FOR PAYING OUT)

Notwithstanding its immediate success under the supervision of the inventor, and its complete triumph over rope under the management of Captain Belknap, in his great Pacific work, when used for the first time in actual service, it is not surprising that even this simple and admirable machine should have been thought open to modification or improvement, to suit the varying conditions of prolonged work at sea. Sir William Thomson cordially invited improvement, and he, himself, gave it quite a different form, with additional parts to prevent the crushing of the reel and to admit of the vessel steaming ahead while hauling in the wire. In describing his experience when reeling in at his first sounding with the original machine, he says:

> "After about 1,000 fathoms of wire had been got in, the wheel began to show signs of distress. I then perceived for the first time (and I felt much ashamed that I had not perceived it sooner) that every turn of wire under a pull of 50 pounds must press the wheel on the two sides of any diameter with opposing forces of 100 pounds, and that, therefore, 2,240 turns, with an average pull on the wire of 50 pounds, must press the wheel together with a force of 100 tons, or else something must give way. In fact, the wheel did give way, and its yielding went on to such an extent that when 500 fathoms of wire were still out, the endless cord which had been used for hauling would no longer work on its groove."

ATTEMPTS TENDING TOWARDS THE IMPROVEMENT OF THE SOUNDING-REEL.

The galvanized sheet-iron reel was soon abandoned by Americans because of its weakness, and because Captain Belknap had given the opinion that a heavier reel might be employed. The Navy at first made a brass reel, weighing, when equipped with worm and ratchet-wheel, about eighty-seven pounds. That proved to be too weak for depths as great as 2,000 fathoms, and it was also supposed that a galvanic action was set up between the brass reel and the steel wire. The Navy then made a reel in which a cast-steel drum and friction-score in one piece were shrunk upon a cast-iron wheel of twelve spokes. This reel is still in use, but, in my opinion, is much heavier than it need be. It weighs about one hundred and fifty-five pounds when equipped, whereas the original galvanized sheet-iron reel weighed, when similarly fitted with worm and ratchet-wheel, but twenty-seven pounds. When the "Blake" was provided with the Navy steel

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the tail-block a long distance to the rear. The scales used may have been graduated when the axis of the spring was vertical; if so, the scales would have registered a trifle too low with the axis horizontal. I thus notice the imperfections of this dynamometer, because there still exists a mistaken opinion that it is very accurate, notwithstanding its abandonment by Sir William Thomson.

reel, we at once removed every alternate spoke and turned down other parts, reducing the whole weight about thirty pounds. For paying out in a heavy sea the advantage of speed, combined with safety, was obviously with the lighter but weaker brass reel. From our experience I was convinced that a reel could be devised which would combine lightness for paying out with enough strength to resist the accumulated crushing force of reeling in, thus permitting the abandonment of accessories for relieving the reel from a part of the strain when reeling in from great depths. In a late form of the apparatus, by Sir William Thomson himself, this dangerous accumulated strain is avoided by taking a number of turns of the wire around an auxiliary or strain pulley, from which it is passed to the reel with the tension very much reduced.

The new steel reel, Plates 16 and 17, was designed with a view of testing the practicability of my views, and the very severe test which it has withstood seems to indicate that it will suffice for the purpose intended. The new reel will be fully described in this chapter. When we consider that the reel and its coil of wire really constitute a fly-wheel, which by its weight and rapid revolution gathers considerable momentum, we can readily see why a light reel possesses an advantage over a heavy one for paying out wire in deep-sea sounding. The momentum of a heavy reel becomes an antagonistic feature of much importance at the instant the sinker strikes bottom, when the reel should stop quickly; and likewise at times when the sudden downward motion of the vessel towards the side where the machine is set up is liable to admit, for a second, of a more rapid paying out of the wire than the submerged weights will take off the reel under tension. If the wire slack, several turns of it may fly from the drum, causing kinks and involving delay, if not loss. Since we cannot divest the drum of the weight of wire that it contains—which, however, becomes lighter as the process of paying out continues—and since the drum itself must have considerable weight that strength may be secured, it seems probable that a *governor* to control the motion of the reel may be employed to advantage. In the Sigsbee improved form of the sounding-machine for wire, herein shortly to be described, it will be shown that the accumulator operates as a *governor* to check the momentum of the reel at the right time when paying out wire, and that it performs the same function at the instant the sinker has reached bottom.

THE STRAY-LINE AND THE METHOD OF SPLICING IT TO THE WIRE.

The piece of rope mentioned by Sir William Thomson, as connecting the sinker with the wire to prevent the latter from coiling on bottom, is called the "*stray-line.*" We usually made our stray-line ten or twelve fathoms long and from any small stuff slightly less than one-quarter of an inch in diameter. The iron ring for joining it to the wire, mentioned by Sir William Thomson, proved a failure on board the "Blake." As the ring passed through the fairleader, on the forward part of the bed-board of the original machine, it was necessary to slow down the reel in order to avoid fouling the ring and thus parting the stray-line. At such a time there would be only about eighteen inches of wire off the reel to sustain the tension and torsion caused by the resistance and gyration of the sinker in the water, and the consequence was the loss of the rod and sinker on several occasions by the parting of the wire. In sounding from a large vessel this might not happen, but the rolling and pitching motions of the "Blake" were so quick that we found it necessary to make a change, and we hit upon the method of splicing the wire directly into the stray-line, as shown on Plate 41. This permitted a rapid unreeling from the first; no slowing down nor stoppage being needed as before. The objection to the ring in our case applied equally to reeling in. We used no weight at the end of the wire, although to do so certainly seems a proper precaution. I recommend the use of a small weight for the purpose stated by Sir William Thomson, and suggest that several small pieces of lead, weighing in the aggregate one pound, be strung upon the stray-line as upon the roping of a seine, and that they be fastened at a distance of four or five fathoms from the end of the wire. Disposed in this way there will still be one or two fathoms of the stray-line upon the drum when the leads are passing through the fairleader, and then, should the reel be slowed down for the moment, any torsion, as found in our experience, will come upon the rope. Once the leads are through the fairleader the wire may be allowed to pass off quickly, and torsion will be of no account after several fathoms of wire have been unwound.*

To splice the wire into the stray-line (Plate 41) make a single-wall knot in the latter, and whip the rope with twine for a half inch below the knot; tuck the end of the wire down through the middle of the single-wall, and complete the knot by jamming the strands, working close down to the whipping. Beginning close up under the knot take ten or twelve turns of the wire around the rope against the lay, then tuck it through under a strand and make another set of turns below the first set, this time with the lay of the rope; then tuck and repeat against the lay, and expend the end of the wire. Taper and whip the ends of the strands about the wire above the knot and the splice will be complete. These we used for nearly four years, and they are still used on board the "Blake." They have to bear only the weight and resistance of the rod, sinker, stray-line, and instruments fastened to the latter, and since one of them well made withstands the test of a heavy man's weight, they are strong enough. I think it well that they should not be so strong as the wire itself, for should the rod or lead foul irretrievably on bottom, if all parts of the stray-line and wire were equally strong the latter would part just at the machine, where the greatest strain comes, while with one of these splices there would be a chance of parting at the stray-line. In fact, our wire was several times saved in this manner.

REMARKS ON THE SIGSBEE MACHINE FOR SOUNDING WITH WIRE.

The remarks and description which follow, concerning the Sigsbee sounding-machine, are taken mainly from a letter written by me to the Superintendent of the Coast and Geodetic Survey in 1876, which was afterwards published as a Bulletin of the Museum of Comparative Zoology of Cambridge, Mass. (vol. v, No. 8), at the instance of Prof. Alexander Agassiz.

In June and July, 1874, I read the reports made by Captain Belknap to the Bureau of Navigation, Navy Department, detailing the working of the original Thomson sounding apparatus in the operations in the Pacific with the "Tuscarora," in 1873-'74. While it was evident that this machine for sounding by means of wire gave remarkable results as compared with

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* With the Sigsbee sounding-machine no slowing down for the purpose stated is necessary, although the reel should not be allowed much speed until the weights are clear.

PLATE 7.

EXPERIMENTAL FORM OF THE SIGSBEE MACHINE FOR SOUNDING WITH WIRE. USED FOR THREE YEARS ON BOARD THE "BLAKE."
RIGGED FOR PAYING OUT.

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rope-sounding, its mechanical success was apparently due in a great degree to the intelligence, patience, and skill of Captain Belknap and the officers who assisted him. A study of Captain Belknap's reports suggested to me the idea of improving the machine in order that it might be worked with fewer demands on the watchfulness and ingenuity of those having it in charge. Captain Belknap having been forced to reel in by hand, it occurred to me that if the wire were connected with an accumulator, interposed between the reel and the sinker, to show the strain upon the wire at all times when reeling in, and to ease the sudden jerks caused by the oscillating motion of the ship, steam might be applied for reeling in, and thus the labor and difficulty attending this operation by hand might be obviated. My views were communicated to the Superintendent, who at once approved them. Under instructions from him, a machine having an accumulator was designed during the summer of 1874, and, as the drawings advanced, other ideas were incorporated with the original plan. From my drawings, a machine for experimental purposes was made in the winter of 1874–'75 (Plate 7). This was used for three years on board the "Blake," and, as we had previously used the original Thomson machine (Plate 6) for six months, opportunity was afforded for comparing the relative merits of the two. Some faults arising from bad mechanical arrangement had first to be corrected in the Sigsbee experimental machine, after which, even under the most unfavorable circumstances of wind, sea, and current, it performed as had been anticipated. This machine being experimental and open to such improvements as experience might suggest, it was always intended, if successful, to replace it by one embracing these improvements. Accordingly, drawings were prepared during the summer of 1876 to this end (Plates 36, 37, 38), but, for various reasons not necessary to be recited, the machine was not made until just before my detachment from the survey, so that I have never seen it at work (Plates 8 to 15, inclusive).

Since this book was commenced Commander Bartlett, my successor on board the "Blake," has used the new machine for six hundred and sixty-four casts, in depths from one hundred to 3,000 fathoms, many times under trying circumstances in trade-wind seas about the Windward Islands of the Caribbean Sea. Commander Bartlett and others on board the "Blake" agree in representing its working as wholly satisfactory. Among the "Blake's" officers who have rendered these favorable opinions are those who have operated the Sigsbee experimental machine also, and one who has worked both the original Thomson machine and the Sigsbee experimental machine. It is highly probable that so small a vessel as the "Blake" must have been very lively in the seas she encountered during her recent cruise; hence if a governor on the motions of the sounding-reel possesses any advantage, it must then have been needful on board the "Blake," particularly as most of the work was done with a reduced Navy-steel reel weighing, independently of the wire, at least one hundred and twenty-five pounds. Of the governing action of the new or latest form of the Sigsbee machine the opinions cited were most favorable.

I will state briefly that the experimental machine was the same in principle as the new one, shortly to be described, but in the latter spiral springs have been substituted for the helical springs used in the former; there has also been added to the new machine a strain-pulley to prevent the crushing of the reel, and a swivel-pulley to admit of the vessel steaming ahead on her course when reeling in the wire. The idea of using these two pulleys was obtained from Sir William Thomson's machine in its form as improved by him after Captain Belknap's cruise, but Sir William Thomson's mode of construction was departed from in order to suit the different shape of my apparatus. The modification or improvement made by me on the original Thomson sounding-machine lies chiefly in the employment of a peculiar kind of accumulator, and its adaptation to the various uses of accumulator, dynamometer, brake, correct register, and governor. The accumulator eases the jerks that may be brought upon the wire while reeling in, and as a dynamometer it shows the strain upon the wire at each instant during the same operation. The brake gives a handy means of applying resistance to the reel without weights, and, with its attachment of spring scales, provides a second dynamometer, which, during the operation of paying out, shows the tension upon the wire and the resistance which the reel suffers. The brake, in connection with the accumulator, operates as a governor on the motions of the reel when paying out wire. The odometer, used as a register in a special place, gives, without interpolation, the amount of wire played out.

PLATE 8.

THE LATEST FORM OF THE SIGSBEE SOUNDING MACHINE, AS NOW USED ON BOARD THE "BLAKE." RIGGED FOR PAYING OUT.
N B THE CHALK LINE DEFINES THE PROPER LIMIT OF THE MACHINE, THE ADDITIONAL LENGTH OF THE BED-BOARD BEING SPECIAL FOR THE "BLAKE." THE CONSTRUCTION IS SHOWN ON PLATES 36. 37 AND 38.

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It may be stated, after four years' experience in deep-sea sounding with wire in a small steamer, that these changes and additions, excepting, perhaps, the use of the odometer as cited, are desirable and of sufficient value in prolonged work to warrant their extra cost. With the experimental machine (Plate 7), eight hundred and twenty-four soundings were taken in weather varying from calms to gales, and with scarcely any annoyance whatever. The latest form of the Sigsbee machine (Plate 8), being more compact and having less friction in its working parts, has been found to be more convenient.

In comparing the original Thomson sounding-machine for wire (Plate 6) with the Sigsbee form of the machine (Plate 8) the following points have been established.

I. For reeling in the latter has the advantage at all times.

II. For paying out when there is no distinctly perceptible rolling or pitching motion on the vessel, there is no gain worth mentioning, excepting at the instant of striking bottom.

III. When there is such motion the advantage is largely in favor of the new machine—greater in degree as the motion becomes excessive.

IV. In handiness the comparison is always in favor of the latter.

Before passing to a detailed description of the new machine it is proper to state that my efforts to improve the sounding-machine have been made in the interest of good work, and that the kind manner in which Sir William Thomson has been willing to receive co-operation in improving the apparatus has been very encouraging and gratifying, although nothing less could have been expected from that distinguished scientist. I have already stated that, in point of accuracy, the original form of the machine by Sir William Thomson was successful from the first, and it is particularly to be understood that the sufficiency of the original machine in that respect is fully recognized.

DESCRIPTION OF THE LATEST FORM OF THE SIGSBEE SOUNDING-MACHINE.

(Plates 36, 37, 38.)

The Reel (A, Figs. I, II, III, IV, and V) is, for convenience, one fathom in circumference of drum, less an allowance for the thickness of the wire; that is, the initial turn of wire taken around the bare drum measures exactly one fathom in length. At the side is a score, which is **V**-shaped in cross-section, for receiving the friction-line. The reel is rigidly attached to its axle by a key, and for each end of the axle a crank should be provided. The drawing was made from the Navy brass reel, the form of which is not now approved. (For another style of reel see Plates 16 and 17.)

If the key by which the reel is attached to its axle be made to admit of easy removal, the axle may be withdrawn when the reel is to be stowed in the tank of oil or lime-water. In this way a smaller tank may be used. For a description of the tank ordinarily used see Chapter II. In the machine made for the "Blake" the axle rests on friction-rollers. This is not necessary, but it gives a very smooth movement, and, by lessening the friction of the axle, a more accurate indication of the amount of resistance upon the reel, when paying out, is given by the readings of the two scales to be described hereafter.

The Register for the Axle of the Reel (B, Fig. 1).—This is the same in construction as the register used by Sir William Thomson on the original machine, but it is marked differently. (See drawing, Plate 38, on which, however, the thousands dial has been marked in tens where it should have been marked in units.) A worm on the axle of the reel engages the gearing of the register. Since the record of the instrument gives only the revolutions of the reel—turns, not fathoms—a correction-curve (Plate 41) or other means of reduction must be employed in order to ascertain the true length of wire payed out at a sounding. For a ready method of measurement see *Odometer* in the course of this description.

The Reeling-in or Strain Pulley (C, D, E, Figs. I, IV, V).—Composed of three separate pulleys, C, D, and E; the score E, for the wire; the score C, for a rope belt to connect with the friction score of the reel, if desired; and the score D, for a rope belt to connect with a hoisting-engine. The two belts are shown "brought to" on Plate 13. For each end of the axle a crank should be provided. The axle is made in two parts, squared and slotted to clutch each other. That part which sustains the pulleys is free only to revolve in its bearings, while the other, besides revolving, slides in its bearing in the line of its axis to admit of unclutching, that the wire and belts may be "brought to" on the strain-pulley. (Fig. V.)

The scores C and D should be **V**-shaped in cross-section. The score E should be rounded like the barrel of a capstan or of a winch-head. I do not fully believe in the necessity for a strain pulley. Since its use is only auxiliary, it being intended to relieve the reel of some of the crushing force which otherwise must be brought upon it when hauling in from great depths, its retention would be without object if we had a reel satisfactorily answering the conditions of weight and strength. As indicated by our experience on board the "Blake," one hundred pounds may be fixed upon as the weight beyond which it is not advisable to amplify the parts of a reel. This includes the axle and fittings and assumes a well-proportioned reel, but does not include the weight of the coil of wire. Within this limit great strength may be secured, probably enough for the deepest casts; but since the latter is not yet *entirely* certain, and to increase the weight of the reel beyond one hundred pounds is of doubtful expediency, it is, perhaps, not safe to advise that the use of the strain-pulley be wholly relinquished. The strain-pulley placed upon the "Blake's" new sounding-machine was added more for experiment than for any supposed necessity. In the light of my present knowledge of the requirements in extreme cases and of the devices which are available, it is recommended concerning the Sigsbee machine that the reel shown on Plates 16 and 17 be used; that the strain-pulley now used be discarded, and in its stead be added, on the same standards, a spur fly-wheel equal in diameter to the sounding-reel, weighing several hundred pounds, and having turned into its rim three grooves corresponding to those of the present strain-pulley; or, economy permitting, the substitution for the present strain-pulley of a steam-engine, similar to that shown on Plate 18, of which a description will be given in this chapter. If the fly-wheel of this engine were given the three grooves mentioned, either of the above modifications would possess all the advantage of an independent strain-pulley, and either might be employed with equal facility for the same purpose.

The Accumulator.—Composed of the tubes F, F, F, &c. (Figs. I, II, III, IV, V), containing the spiral extension-springs G, G (Fig. III) which connect with the movable cross-head H (Figs. II, VII, VIII, IX) by means of the chain, or wire rope, I, I (Figs. I, II, III) passing over the pulleys J, J (Figs. I, II, XII). The tubes are hinged at K, K (Figs. I, II, III, IV) that the upper sections may be lowered for convenient stowage; they may be graduated for the number of pounds pull on the wire, either the upper or the lower arm of the cross-head being made the index. There are three sections to each tube, the lower section of each, beneath the bed-board, unscrewing for stowage or transportation (Plate 12). The cross-head H, containing the pulley L (Figs. I, VII, VIII, IX), moves on the steel guides M, M (Figs. II, III, V, XI), which are fastened by screws to the tubes. The pulley L is rigidly attached to its axle by a key. To the axle is attached an odometer, N (Fig. II, Plate 37, and drawing on Plate 38). This pulley is exactly one yard (one-half fathom) in circumference on its drum, less the allowance for thickness of wire. One-half the number of revolutions of the pulley, as shown by the odometer, will, therefore, give at once the number of fathoms of wire payed out or reeled in. The action by which the accumulator operates as a governor will be explained when the method of taking a sounding is described.

The extension-springs used in the accumulator are each twenty-eight and a half inches long and two and an eighth inches outside diameter; they are made of No. 4 (American gauge) steel wire; each weighs eight and a quarter pounds, and has a movement of four feet (approximately) for a strain of one hundred and fifty pounds directly applied. When the purchase is considered, it is seen that a pull of one hundred and fifty pounds on the wire will move the cross-head four feet, which will correspond to a rendering or cushioning of the wire a distance of eight feet. Thinking that these springs might be found too stiff, a couple of spare sets were provided the "Blake," which were made from smaller wire but on the same mandril used in the manufacture of the first set. A single spring from one of the spare sets gave a movement of four feet for one hundred pounds strain, and from the other spare set an equal movement for eighty pounds strain. The original pair seem to have done well, however. The springs were made by John Chatillon & Son, 91 Cliff street, New York, at a cost of about $12 each.

The upper section of each tube is of two and a half inches inside diameter and an eighth of an inch thickness of metal. The two lower sections are the same as the others in inside diameter but are a quarter of an inch thick.

Within the limit of its elasticity the movement of a spring varies as the strain; hence the tubes of the sounding-machine may be graduated for the number of pounds of strain upon the wire as follows: Reeve the end of the wire from the reel over the cross-head pulley and pawl the reel. Hang a weight of twenty-five pounds from the end of wire, the and mark the point on one of the tubes opposite which the upper arm of the cross-head comes to rest, which point we will call A. Increase the weight to one hundred pounds and mark the corresponding point on the tube indicated by the upper arm of the cross-head, which second point we will call B. Lay off on a thin strip of wood or metal the distance A B, and divide this distance into seventy-five equal parts. Each division will correspond to a strain of one pound on the wire. Continue the same scale above the point A and below the point B. Lash the strip of wood to the tube so that the point A on the former will coincide with the point A on the latter. The upper arm of the cross-head will be the index.

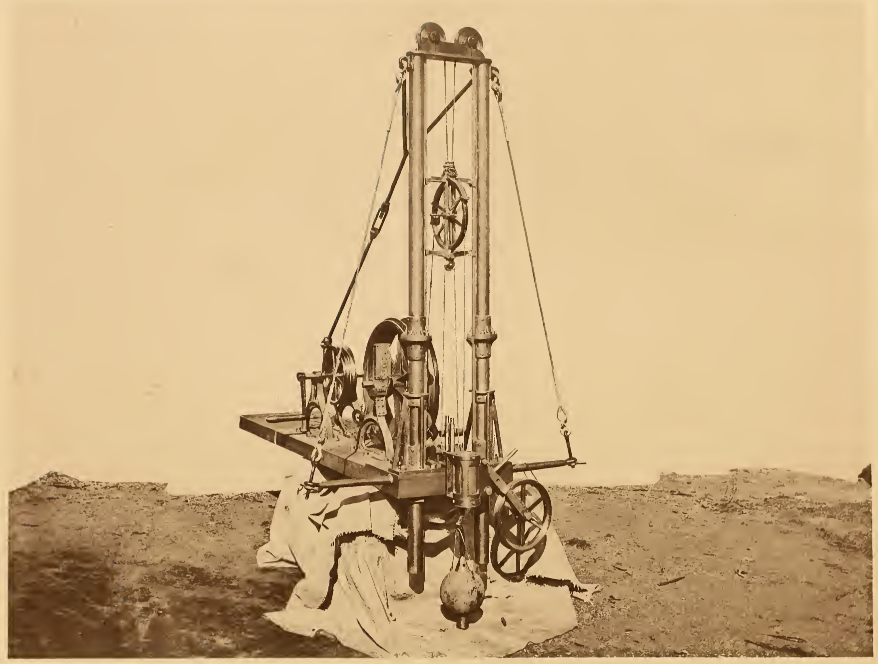
Should the rope by which the cross-head is suspended stretch or shrink thereafter, add twenty-five pounds to the wire as before, and determine the position to which the point A of the tube has shifted. Having determined the new point A on the tube, bring the point A on the strip of wood to a coincidence therewith, and the graduation will have been corrected.

It is obvious that to get a sensitive accumulator dynamometer, or governor, it is necessary to keep the weight of the cross-head and its pulley as light as strength will permit. There will be very little lateral strain upon the cross-head other than that due to its own weight when the vessel is heeled.

The cross-head pulley should be so made as to permit its removal from the cross-head without unshipping the latter from the guides. Figs. VII and IX show an arrangement to prevent the wire from flying off the pulley, in which the small spiral springs should be very supple.

O, O (Figs. II, VII, VIII) are shoulders, to guard against the bending of the cross-head in the event of parting the chains or ropes I, I, or of parting the wire. Should the chains part the cross-head would fall, the lower shoulders striking on the studs P, P (Figs. II, III, V, and also Plates 8 to 11 inclusive). Should the wire part while reeling in, the cross-head on flying up would receive the blow against the upper shoulders, the latter striking against the cross-piece upon which rest the pulleys J, J. On the "Blake's" machine a piece of rubber is fastened under the cross-piece to ease the shock. On the latest machine—on board the "Blake"—the studs P, P constitute buffers. A hole is bored in the upper end of each stud in the line of the axis of the stud, into which a spiral compression-spring is placed. A simple piston cut from a cylindrical steel or iron rod, of a size to fit loose in the hole, is allowed to rest on the spring and project above the stud. Perhaps the plain stud capped with rubber or padded canvas would do as well.

The Swivel Pulley.—The object of this pulley, S (Figs. I, II, V), is to allow the wire to be reeled in while the vessel is steaming ahead. A sleeve



THE SIGSBEE SOUNDING MACHINE RIGGED FOR PAYING OUT.

Heliotype Printing Co., 220 Devonshire St., Boston

of steel, or case-hardened iron pipe, is fastened to a casting that is bolted to the bed-board. This sleeve, which is a fairleader for the wire, has, sliding freely around it, a brass or iron collar to which is bolted the arm holding the pulley. In the positions shown in Figs. I and V the pulley is ready for reeling in, and it may be swung latterly to any desired angle (see also Plates 11 and 13). The score will always be in the same line with the score of the cross-head pulley. Before paying out the wire—or before reeling it in if it be not intended to steam ahead during the operation—the arm T, which holds the swivel pulley, is released from the bolt U, when the arm will pivot on the bolt V. The pulley should then be lifted clear of the wire, turned to one side, and secured (see also Plates 9 and 10).

The Spring-Scales (W and X, Figs. I and IV).—In paying out the wire, the difference between the readings of the scales W and X gives the number of pounds of resistance imposed upon the reel by the friction-rope at the instant of taking the readings.

The scales should be of the kind that have a long movement of the index, or pointer, for a small extension of the contained spring, and they should be strong enough to withstand the sudden pulls that may be brought upon them by the governing action of the accumulator in heavy seas. In the manner of attaching the friction-line to them, as shown in the drawing, the scales might slew so as to present the dials of the two instruments in different planes; it would, therefore, be well to use braided stuff for friction-line, at least for that part of the friction-line which rests in the score of the reel. Any seaman could attach the line to suit the circumstances of the case.

Excepting during our first season, we used no means of measuring the resistance placed upon the reel. This would seem to have been taking a great risk, but we never had any trouble therefrom, nor were we ever in doubt as to the actual time of reaching bottom. It is advisable, however, that scales be used, at least until experience has taught at what rate it is safe to allow the wire to run out, and no assurance is given for casts deeper than have been taken by the "Blake." Soundings from that vessel have been taken in depths of 3,000 fathoms without using scales, the sinker having struck bottom when the wire was running out at the rate of one hundred turns in 1 minute 18 seconds. My informant states that the instant of reaching bottom was obvious, as in previous casts. It was my intention to devise a differential spring-scales to show the resistance by a single index, but I have failed thus far to carry out this intention. The method of measuring the resistance upon the reel by means of two scales, as shown in my drawing, is more exact, it is believed, than any other that has been employed, although there is the practical disadvantage of having to obtain simultaneous readings when the indices are not likely to be altogether steady. In practice, it will only be essential to read the instruments occasionally. By the habitual use of scales, and by keeping a systematic record of their readings with simultaneous readings of the dynamometer; the length and weight of the submerged wire; the length and weight of the whole amount of wire in actual use; size and weight of reel, rod, sinkers, &c., important data would be secured. In the Sigsbee experimental sounding-machine the friction of the several moving parts was too great to admit of weighing the strain on the wire closely enough to be of service in this respect, but in the later machine the dynamometer is sufficiently accurate, the accumulator being simply a large spring-scales with but little friction in its working parts.

The Odometer; giving the correct length of wire payed out, without reduction (N, Plate 37, and drawing, Plate 38).—This instrument is fitted to clutch the axle of the cross-head pulley with a spring snap. It records the revolutions of the pulley.

The kind used by us is known as Hunter's odometer. They may be purchased of James Green, instrument-maker, No. 20 West Fourth street, New York. In their usual commercial form they must be taken apart with a screw-driver for resetting the dials, but, at my request, Mr. Green made them as shown on Plate 38; that is, to admit of a convenient readjustment to the zero point by means of the milled-head screws. Their cost is from $14 to $17. In purchasing a register or odometer it must always be observed if the numbers on the dials increase in a direction to correspond with the direction of rotation of the reel or pulley on which they are to be used. A description of the odometer may be found in Knight's American Mechanical Dictionary, vol. ii, page 1544. Instead of the two cog-wheels having, respectively, one hundred and one teeth, as there described, they have ninety-nine and one hundred teeth, respectively.

The machine shown on Plates 8 to 15 was made for the Coast and Geodetic Survey by Mr. Daniel Ballauf, of Washington. It is an elaborate affair, made by the most skillful mechanics (model-makers), and is handsomely finished throughout. In fact, in point of workmanship, it is such a machine as would naturally be employed on board a vessel devoted almost exclusively to the performance of the work for which the machine is designed.

Mr. Ballauf submits the following prices for which he will manufacture a single machine, the standard of workmanship being that of the "Blake's" machine:

Machine complete, as shown on Plates 36, 37, and 38, including steel reel shown on Plate 16; register, Plate 38; clamp, Plate 36: the various castings and parts to be made of iron, steel, or brass, as may be best, $750.

If from the above the whole strain-pulley arrangement be omitted the cost will be $675.

If the strain-pulley arrangement be omitted, and a grooved spur fly-wheel be substituted, the cost will be $725. The cost alone of the new steel reel, Plate 16, Mr. Ballauf fixes at $125.*

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* Mr. Ballauf is now constructing two of the Sigsbee sounding-machines, one for the Navy and the other for the Coast and Geodetic Survey. The bed and nearly all other parts are made of steel. A number of modifications or improvements are introduced, and the machine folds in a box the dimensions of which are: length, 4 feet 4 inches; breadth, 1 foot 8 inches; depth, 2 feet 7 inches. In these machines the pipes will be of the same height above the bed as in the machine shown on Plate 8, but will not extend below the bed. The strain-pulley arrangement is done away with, and in its place is added a small vertical engine similar to that shown on Plate 18. The cost of each machine and all its accessories, at the present high price of material, is eleven hundred dollars, including:—machine complete, with springs and spring-scales; one spare spring and one spare spring-scales; steam-engine fastened to bed; tightening pulley for rope-belt; swivel pulley to fold back, and supplied with clamp shown on Plate 36; steel reel shown on Plates 16 and 17, with register shown on Plate 38; galvanized-iron tank for holding the reel and preserving fluid; box for stowing the machine, and several other small accessories or appliances. The steam-engine and the tank account for a part of the increased cost, the former costing $225.

APRIL, 1880.

Mr. Ballauf employs only the most skilled mechanics, men capable of making the most delicate instruments, and, therefore, getting high pay; hence it may be possible that the prices fixed by him are not so low as might be named elsewhere.

The "Blake's" machine stows, for transportion, in a box the dimensions of which are five feet nine inches, by two feet nine inches, by two feet one and one-half inches. If, however, the cross-head is to be left on its guides in transportation, as shown on Plate 12, the box will have to be made six feet long. The machine is complete as stowed, no accessories being required other than those stowed in the box, excepting the steam-engine and tank, which are not included in the prices quoted.

The original Thomson machine, as made in the United States, stows in a box the dimensions of which are four feet four inches, by two feet nine inches, by one foot seven inches, accessories not included, and is of less weight than the Sigsbee pattern, although more than one hundred pounds of lead or other material are needed for applying strain to the friction-rope of the former.

Sir William Thomson's later form of what has been styled the original machine—to which he has added the swivel or castor pulley and the strain-pulley—takes more room for stowage than either of the above. Rapid and safe work he seems justly to regard as of more importance than the saving of a small amount of cubic space. The small space required for a sounding-machine for wire is hardly to be compared with that formerly taken up by sounding-rope and its apparatus.

TO TAKE A SOUNDING WITH THE SIGSBEE SOUNDING-MACHINE.

(Plates 36, 37, 38.)

The reel containing the wire and stray-line being in its bearings, reeve the end of the stray-line up over the cross-head pulley, from inboard to outboard, and thence down through the fairleader which forms part of the attachment of the swivel-pulley. Secure the end of the stray-line to the sounding-rod.

Ship the pawl into the ratchet-wheel that is on the axle of the reel. Place the friction-line over the friction-score as shown in Figs. I, II, IV, and from the scales W reeve the line under the pulley Y on the same side of the bed as the friction-score; thence up and over the pulley Q, and down under the other pulley Y (Figs. I, II, III, and V). By means of the hauling part of the friction-line haul the cross-head well down on the guides against the resistance of the accumulator-springs G, G, to insure a large surplus of friction on the reel at the time of starting the sounding. Make fast the hauling part of the friction-line to the cleat Z (Figs. I, IV, V).

Connect the sinker with the sounding-rod—having previously cleaned the specimen-cup thoroughly—and get them over the side of the ship. letting the stray-line take the whole weight. Plates 8, 9, and 10 show the machine fully prepared for paying out.

See that the register and the odometer are properly set.

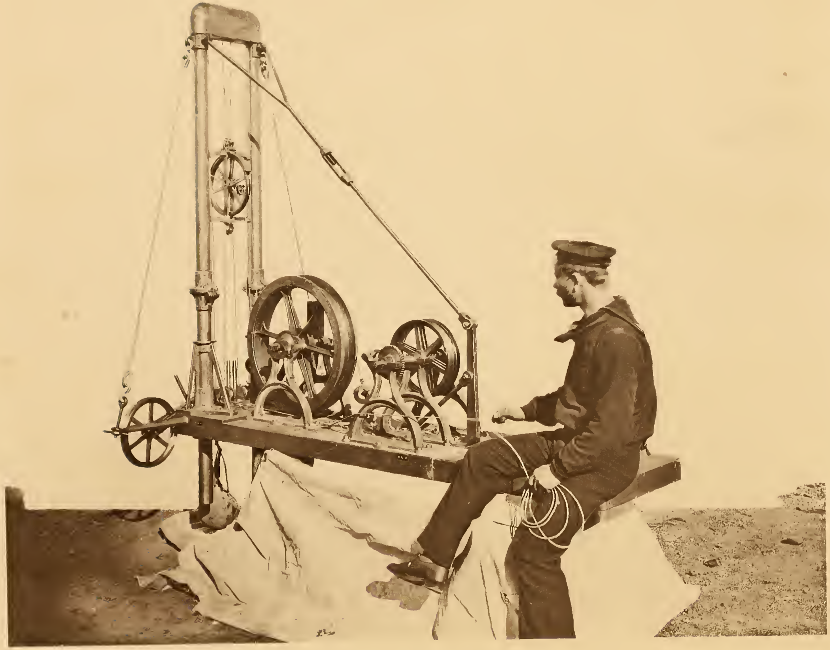
If desired, the shot may be lowered slowly to the water before paying out regularly, always remembering to set the register and the odometer properly. This was our usual custom when the vessel had considerable motion, the object being to prevent the shot pounding against the side of the vessel. Attend the friction-line, throw back the pawl, and let the reel revolve slowly until assured that everything is working well, when ease up the friction-line cautiously: keep the wire vertical, and follow out as nearly as practicable the rule governing the amount of resistance to be applied to the reel. (See Sir William Thomson's remarks, page 54.)

If a weight has been attached to the stray-line to prevent the kinking of the wire, be careful not to let the reel revolve rapidly until this weight is through the fairleader. Avoid any stoppage just as the end of the wire is leaving the reel.

It is impossible to say how fast the wire may be allowed to pay out, since the limit of safety varies with circumstances, depending on the weight of the reel and its contained wire, the weight of the sinker, the state of the sea, the extent and rapidity of the ship's rolling and pitching motions, &c.

To prevent the wire flying from the drum of the reel when paying out—an accident which sometimes happened to us on board the "Blake" when using the original machine—the Sigsbee machine is arranged to operate as a governor on the motions of the reel. The action of the governor may be explained as follows: If the ship roll downward on the side where

PLATE 10.



THE SIGSBEE SOUNDING MACHINE RIGGED FOR PAYING OUT.

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the machine is set up the strain upon the wire is thereupon lessened, and the consequent effort of the cross-head to rise—imparted by the reaction of the springs—is transferred to the friction-line. Thus a greater resistance is automatically placed upon the reel, checking its speed or stopping it altogether—rarely the latter—until the rising of the vessel or the slowing-down of the reel causes an increase of strain upon the wire. As the strain increases the cross-head is borne down, which eases the pull on the friction-line, allowing the reel to revolve more rapidly; and so on with reciprocal effect. When the vessel is quiet the accumulator has no inherent capability of varying the amount of resistance upon the reel. This alternating movement of the cross-head when paying out is, of course, scarcely perceptible to the eye. Although the effect of the governing action on the motion of the reel is distinctly seen, the motion is not fitful, but remarkably smooth. No instance is recalled of the wire jumping from the drum of the reel when using the governor. Commander Bartlett, during his six hundred and sixty-four casts with wire, met with no such accident.

From what has been said it follows that the operation of paying out is progressing safely *if several pounds of surplus resistance is upon the reel, according to the rule, and the wire is keeping constantly under tension.*

It appears by the records of work done in the Navy that the recommendation of Sir William Thomson to use a weight at the end of the wire has been held in practice, as much as four pounds sometimes being used.

If such a weight, or any other considerable weights—as water cups, &c.—be used on the stray-line or wire they should be taken into account in applying the resistance. The sinkers and sounding-rod being the only weights which are to be permitted to reach the bottom, all other submerged weights should be counterbalanced at the reel.

With the original sounding-machine for wire, when bottom is reached the weight of the sinker and sounding-rod ceases to act as a moving force for the reel; hence, if a resistance slightly in excess of the weight of the submerged wire and its attachments—above the rod and sinker—has been placed upon the reel the latter will stop. In the same case, with the Sigsbee form of the machine, the weight of the sinker and sounding-rod not only ceases to act as a moving force for the reel, but the force due to the weight of the sinker and rod is automatically transferred to the friction-line, because the cross-head, being freed from the bearing-down effort of the weight of the sinker and rod, rises and communicates that effort to the friction-line. This peculiarity may not appear to give any great advantage over the original machine, yet it is a safeguard, and provides a reaction against the momentum of the reel at a critical point. Since it results, without extra cost, from the action of such parts of the machinery as are devised for other, and perhaps more necessary, purposes, it may at least be considered an acceptable feature in the working of the apparatus.

In practice it is found, both with the original Thomson and the Sigsbee machines, that to maintain a rapid rate of paying out the pull upon the friction-line (not *friction,* but *pull* upon the line) has gradually to be reduced from the time of starting the sounding. This is chiefly due to the friction on the submerged wire. On board the "Blake" we would occasionally, in very deep water, find the cross-head nearly at the top of its guides, and the reel controlled by the resistance due to a very light strain on the friction-line. In this case we would lose to a considerable extent the governing action of the accumulator and the automatically increased resistance at the instant of striking bottom. The remedy was to use a friction-line of smaller stuff when sounding in very deep water, or to decrease the length of the arc of bearing-surface which the friction-line had in its score by making its standing part fast somewhere above the bed-board of the machine. The use of a heavier sinker will also serve the same purpose. In regard to the size of the friction-line only that part which is wrapped in the friction-score is of much moment.

In a heavy sea, if sounding from the bow, the violence of the vessel's motion may cause the reel to "race" occasionally, notwithstanding the governor. This will be understood when it is stated that the "Blake" has been known to plunge so quickly as to slack the wire when *reeling in* by steam. To provide against racing in seas exceptionally heavy for the work, we used a very simple and completely successful device. While the reel was unwinding the wire under the usual frictional control a small toggle turned into the friction-line outside of the pulley Y (Figs. I, III, V), on the same side of the bed as the friction-score of the reel, was made to bind with a force of several pounds against the pulley, by setting up taut on the standing part of the friction-line at the scales X (Fig. I). Thus, while the governor was free to automatically increase the friction upon the reel as occasion demanded, it was incapable of decreasing it to an amount less than that due to the resistance of the toggle against the pulley. Stretching of the friction-line will cause the toggle to recede from the pulley, and the friction-line may have to be set up afresh at the *standing* part several times during a deep cast in very heavy seas; this, however, does not necessitate a stoppage of the reel. A close inspection will show the toggle on Plate 9. While this device may be dispensed with, even in very heavy seas, by the exercise of a little care, its use under such circumstances permits a more rapid rate of descent.

When paying out wire, oil or fresh water should be applied freely to that part of the friction-line resting in the friction-score. This will give smooth work. Water, if used, must be applied frequently; oil not necessarily so often.

As soon as the sinker strikes bottom, which is made apparent by the stoppage of the reel, read the register or the odometer, and, at the same time, ship the cranks on the axles of the reel. Throw the bight of the friction-line out of its score, and, to insure the detaching of the sinker, pay out cautiously one or two turns of the wire, if necessary, until the strain upon it is eased. Then reel in a few turns slowly and carefully, when the distance which the cross-head is borne down along its guides will indicate if the sinker be clear. Usually, with a good form of detacher, it drops off at once on striking bottom, requiring no actual slacking of the stray-line or wire. The exceptions are most likely to occur when paying out slowly in strong currents. In paying out extra turns of wire to detach the sinker it should be remembered that the wire must not be allowed to coil on bottom; nor should the stray-line be allowed to foul the rod or sinker on the bottom. If a thermometer have been fastened to the stray-line for observing the bottom-water temperature, care should be exercised that the sounding-rod may not drag along the bottom while waiting for the thermometer to register. Although we always used steam for reeling in, it was our invariable custom first to reel in fifteen or twenty turns by hand before connecting with the engine, and with inexperienced supervision at the machine the last fifteen or twenty turns should also be got in by hand—that is, by men working at the cranks.

If the strain-pulley is to be employed for reeling in, Plate 36 (dotted line, Fig. I) and Plate 11 will show the manner of leading the wire, which is as follows: The last or uppermost turn of the wire upon the reel leads from the latter six or seven times around the wide score of the strain-pulley, "with the hands of a clock" or "with the sun," and thence underneath the reel, over the cross-head pulley and into the water. The power for reeling in is applied to the strain-pulley, from which the wire is passed to the reel with the tension reduced. To keep the parts of the wire from riding over each other on the strain-pulley a standard with a roller is interposed, as shown on Plates 11 and 36. It is seen that the wire, after coming in over the cross-head pulley, passes over a large part of the circumference of the coil contained on the drum of the reel. It is thought that this may possibly cause the wire to act as a belt to revolve the reel for taking the turns from the strain-pulley, but if the arrangement prove insufficient for the purpose stated, a loose belt of rope, just long enough to fit, should connect the friction-score of the reel with the score C (Fig. V, Plate 38) of the strain-pulley. The weight alone of a small rope would, doubtless, give enough friction for a connecting slip-belt.

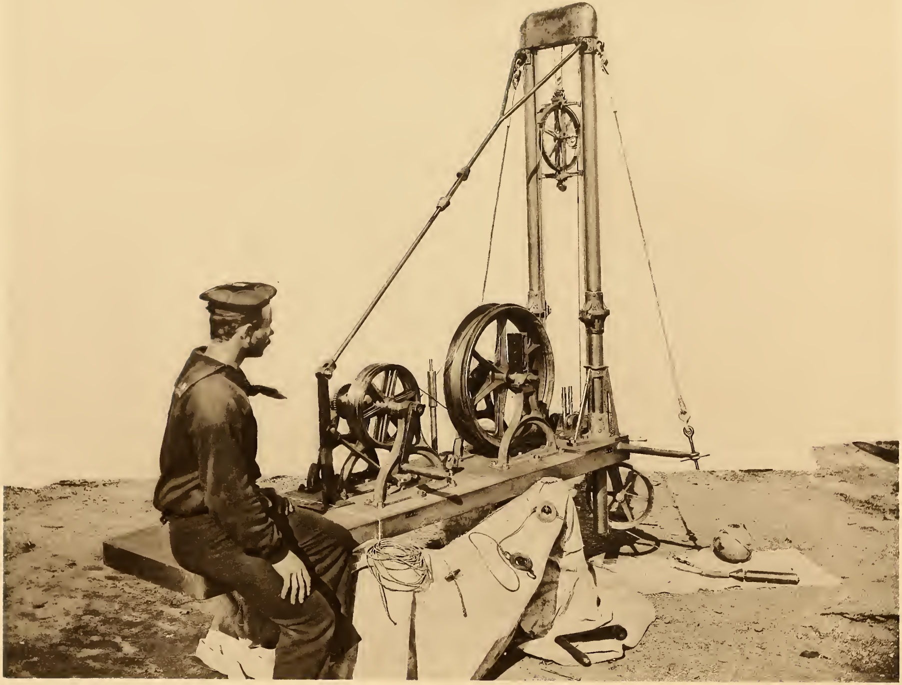
The use of the score D (Fig. V, Plate 38) is to connect the strain-pulley with a reeling-engine by a rope belt. Plate 13 shows the two connecting belts that have been described.

When the strain-pulley is not to be used a rope belt may be taken directly from the friction-score of the reel to the **V**-groove of the reeling-engine.

KEEPING A TIME-RECORD OF SOUNDINGS.

It was our custom to keep a record, as shown on Form 1, next page, at every sounding taken with wire. This practice is useful in various ways. The officer of the deck is thus kept constantly posted as to the speed of the machine, and is given experience with regard to its capabilities; should the register cease to record from any cause the fact is made known, and when plotting, if a non-agreement is observed between soundings on the same or intersecting lines, the means of verifying the figures relating to the soundings are at hand.

PLATE 11.



THE SIGSBEE SOUNDING MACHINE RIGGED FOR REELING IN, WITH THE STRAIN PULLEY BROUGHT INTO USE.

Heliotype Printing Co., 220 Devonshire St., Boston.

FORM 1.

U. S. COAST SURVEY STEAMER *"BLAKE."*

Locality, *20 miles N. W. of Sombrero Id.* Date, *April 23*, 187*9*. Sounding No. *25*. Line, *P. P.*

Turns of Reel as per Register.	Reeling out.					Reeling in.					Remarks. To be made by the Officer of the Deck.
	Times.			Intervals.		Times.			Intervals.		
	H.	M.	S.	M.	S.	H.	M.	S.	M.	S.	
0	11	21	32			12	30	20		55	Sinker used, *Shot.* Weight, *60* lbs.
100		22	34	1	02		29	25		47	Was sinker detached or recovered? *Detached.*
200		23	25		51		28	38		47	No. of fathoms of stray-line used, *9.*
300		24	15		50		27	51		49	No. of turns of wire in use on reel, *4,058.*
400		25	06		51		27	02		54	Kind of reel used, *Navy steel reel (reduced).*
500		25	58		52		26	08		54	Weight of reel used, *125* lbs.
600		26	52		54		25	14		59	Reeled in by *Steam* (hand or steam?).
700		27	46		54		24	15	1	01	Reeled in first *15* turns by hand.
800		28	43		57		23	14	1	04	Reeled in last *15* turns by hand.
900		29	43	1	00		22	10	1	03	Wind *N. E. to N. N. E.* Force 1 *to 3.*
1000		30	41		58		21	07	1	07	State of the sea. *Light swell from E. N. E.*
1100		31	43	1	02		20	00	1	10	Vessel rolling. *Easily.*
1200		32	46	1	03		18	50	1	10	Vessel pitching. *Easily.*
1300		33	48	1	02		17	40	1	13	*Modified Belknap rod with Sigsbee detacher used.*
1400		34	54	1	06		16	27	1	18	*Reeled in slowly because the wire had seen much previous*
1500		36	01	1	07		15	09	1	18	*service.*
1600		37	09	1	08		13	51	1	21	*Thermometer and water-cup on the stray-line.*
1700		38	15	1	06		12	30	1	23	LOSSES OR CASUALTIES.
1800		39	26	1	11		11	07	1	24	*None.*
1900		40	35	1	09		09	43	1	25	
2000		41	48	1	13		08	18	1	25	
2100		43	02	1	14		06	53	1	37	
2200		44	11	1	09		05	16	1	34	
2300		45	24	1	13		03	42	1	38	Reading of Register........ *2,765* turns.
2400		46	38	1	14		02	04	1	31	Correction for stray-line.... *6*
2500		47	53	1	15	12	00	33	1	56	Correction for turns of wire. *158*
2600		49	08	1	15		58	37	1	53	
2700		50	24	1	16		56	44		59	***Correct depth........ 2,929 fathoms.***
2765	11	51	17		53	11	55	45			
2900											
3000											
Totals.				29	45				34	35	

Signature of Officer of the Deck:...*H. M. Jacoby.*
Signature of the Recorder:...*L. P. Sigsbee.*

The above record was sent me by Commander Bartlett to show the working of the Sigsbee machine in the deepest cast for which it had been used up to that time. The figures represent fair work, excepting the reeling in, which is very slow for the "Blake." The average rate of paying out, per one hundred *fathoms*, is shown to have been 1^{m} 01^{s}, and for reeling in 1^{m} 11^{s}. The sinker touched bottom when the reel was revolving at the rate of one hundred *turns* (about one hundred and twelve fathoms) in 1^{m} 16^{s}. While reeling in from these two soundings it appears that the vessel was not steamed ahead. Probably the weakness of the wire had something to do with it, or, since these were the deepest casts ever made from the "Blake," it was decided to be cautious. The "Blake" being an economical vessel in the expenditure of coal, and working day and night with different officers in charge of the machine, to take much risk with the wire in order to make quick time is rarely attempted.

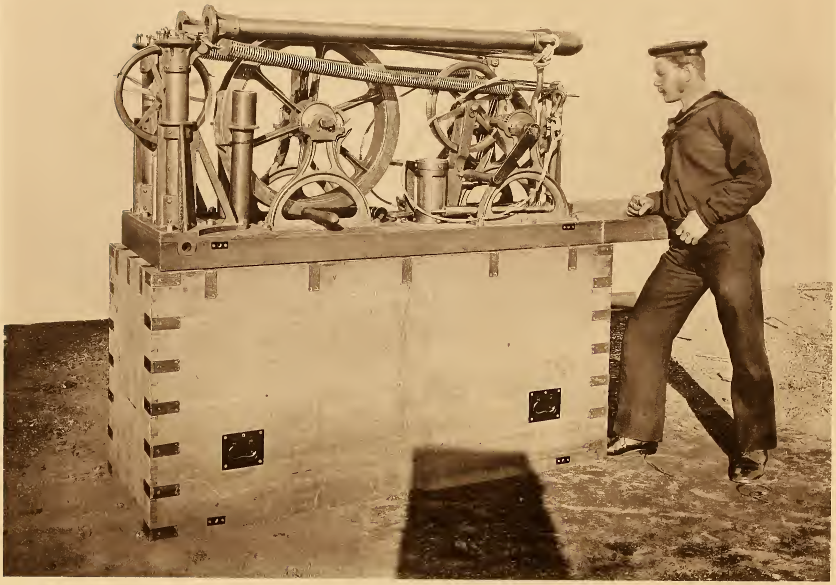
TIMES OF VARIOUS CASTS WITH SHOT-SINKERS (FOR DETACHING). TAKEN ON BOARD THE "BLAKE" WITH THE LATEST FORM OF THE SIGSBEE SOUNDING-MACHINE, SEASON OF 1878-'79.

[Commander J. R. Bartlett, U. S. N., Assistant Coast and Geodetic Survey, commanding.]

Depth in fathoms.	State of the sea.	Vessel rolling.	Vessel pitching.	Whole time paying out.		Average time per 100 fathoms paying out.		Whole time reeling in.		Average time per 100 fathoms reeling in.		Remarks.
				M.	S.	M.	S.	M.	S.	M.	S.	
1,161	Moderate	Slightly	Slightly	10	45	....	56	9	00	....	47	
1,226	....do	....do	....do	10	55	....	53	10	33	....	52	
1,404	....do	Moderately	Moderately	12	30	....	53	11	10	....	48	
2,028	....do	....do	....do	20	00	....	59	19	19	....	57	
2,040	....do	....do	....do	20	19	1	00	17	00	....	50	
1,549	....do	Easily	Easily	15	00	....	58	12	01	....	47	
1,403	....do	Moderately	Moderately	12	54	....	55	12	22	....	53	
1,604	....do	....do	....do	14	56	....	56	13	20	....	50	
1,586	....do	....do	....do	15	18	....	58	13	24	....	51	
1,419	....do	....do	....do	13	15	....	56	11	20	....	48	
3,045	Light swell	Easily	Easily	31	25	1	02	36	25	1	12	—Reeled back slowly; old wire weighted with thermometer and water-cup.
1,048	Moderate	....do	....do	9	30	....	54	6	46	....	39	
1,109	Long swell	Slightly	Slightly	9	45	....	53	8	45	....	47	
658	Moderate	Easily	Easily	4	48	....	44	4	28	....	41	
1,191	....do	....do	....do	9	29	....	48	9	44	....	49	
1,379	Rough	Deeply	Deeply	12	59	....	56	9	44	....	42	
1,542	Moderate	Moderately	Moderately	14	46	....	57	14	15	....	55	
1,547	....do	....do	....do	15	48	1	00	16	06	1	02	
1,561	Very rough	Deeply	Deeply	15	07	....	58	15	27	....	59	
1,225	Rough	Moderately	Considerably	10	25	....	51	11	15	....	55	
1,275	....do	Deeply	Deeply	11	55	....	56	9	35	....	45	
1,155	....do	....do	....do	11	25	....	59	9	00	....	47	

NOTE.—The above are taken from a single one of the "Blake's" sounding-record books sent me by Commander Bartlett. They comprise nearly all the soundings recorded in the book in depths exceeding 1,000 fathoms. The records of several casts taken in exceptionally slow time have not been included, so the times here given represent the ordinary *good* sounding-work of the party. Three officers, each in rotation, had charge of the machine in operation. Both day and night work are shown, no selection from either period having been made. In every case a modified Belknap Cylinder No. 2, with Sigsbee's detacher (Plates 2, 3, and 39), was used in connection with a sixty-pound shot-sinker, and a thermometer was attached to the stray-line. The reeling in was done by steam, excepting the first and last fifteen fathoms at each cast, which was done by hand. In some cases a large water-cup was also attached to the stray-line. One of the most satisfactory features shown by this table is the rapid work which was maintained, both in paying out and reeling in, when sounding in rough seas, with the vessel rolling and pitching deeply.

PLATE 12.



THE SIGSBEE SOUNDING MACHINE FOLDED FOR TRANSPORTATION.

Heliotype Printing Co., 220 Devonshire St., Boston.

HAULING BACK A LEAD SINKER.

After getting an accumulator the greater number of our casts no deeper than eight hundred or 1,000 fathoms were taken with the thirty-four-pound sinker, which we always hauled back by steam. The accumulator, acting as a dynamometer, will direct the judgment in regard to the safety of hauling back, but in respect to the advisability of the measure, economy of time and money will have much influence. We thought the small saving of shot-sinkers no object in depths greater than 1,000 or 1,200 fathoms, for the rate of paying out with a light lead then became so slow that the loss of time in favorable working weather was the more important consideration. In regard to the safety of hauling back the lead, the state of the sea made but little difference with us in a depth of 1,000 fathoms. Sometimes the accumulator cross-head would traverse its full range while we were hauling back in a heavy sea. The following shows work with the lead:

U. S. COAST SURVEY STEAMER "*BLAKE.*"

Locality, *Off Grenada.* Date, *March 2*, 1879. Sounding No. *37.* Line *K.*

TURNS OF REEL AS PER REGISTER.	REELING OUT.					REELING IN.					REMARKS. To be made by the Officer of the Deck.
	Times.			Intervals.		Times.			Intervals.		
	H.	M.	S.	M.	S.	H.	M.	S.	M.	S.	
0	4	20	45			4	43	30	1	00	Sinker used, *Lead.* Weight, *34* lbs.
100		21	42		57		42	30		46	Was sinker detached or recovered? *Recovered.*
200		22	35		53		41	44		43	No. of fathoms of stray-line used, *9.*
300		23	35	1	00		41	01		49	No. of turns of wire in use on reel, *4,387.*
400		24	30		55		40	12		50	Kind of reel used, *Navy steel* (*reduced*).
500		25	32	1	02		39	22	1	04	Weight of reel used, *125* lbs.
600		26	40	1	08		38	18	1	03	Reeled in by *Steam* (hand or steam?).
700		27	50	1	10		37	15	1	13	Reeled in first *8* turns by hand.
800		29	25	1	35		36	02	1	03	Reeled in last *15* turns by hand.
875	4	30	35	1	10	4	34	59			Wind, *East.* Force, *2.*
				9	50				8	31	State of the sea, *Moderate.*

Vessel rolling, } *Moderately.*
Vessel pitching, }

Reading of Register .... *875* turns.
Correction for stray-line *6*
Correction for turns of wire *74*
Correct depth* .... *955 fathoms.

LOSSES OR CASUALTIES.

None.

The times are fair, but would be slow for work with a shot-sinker. With the vessel quiet, and particularly when sounding with shot, considerable time is sometimes gained in deep soundings by allowing the reel to pay off the wire very rapidly, under less resistance than is called for by the rule, until the sinker has arrived within several hundred fathoms of the bottom, when the resistance is increased to the safety point. To attempt this, one must feel sure that he can foretell the depth approximately.

TIMES OF VARIOUS CASTS WITH LEAD SINKERS (FOR RECOVERY). TAKEN ON BOARD THE "BLAKE" WITH THE LATEST FORM OF THE SIGSBEE SOUNDING-MACHINE, SEASON OF 1878-'79.

[Commander J. R. Bartlett, U. S. N., Assistant Coast and Geodetic Survey, commanding.]

Depth in fathoms.	State of the sea.	Vessel rolling.	Vessel pitching.	Whole time paying out.		Average time per 100 fathoms paying out.		Whole time reeling in.		Average time per 100 fathoms reeling in.		Remarks
				M.	S.	M.	S.	M.	S.	M.	S.	
591	Rough	Heavily	Heavily	7	15	1	14	4	40	....	47	—Next sounding, 1h 30m afterwards, in 698 fathoms, taken with shot sinker; time per 100 fathoms paying out, 59s.
518	....do	Considerably	Considerably	5	40	1	06	5	05	1	00	
590	Moderately rough	Easily	Easily	5	46	....	59	4	40	....	47	
657	....do	....do	....do	6	45	1	02	5	25	....	50	
974	Rough	....do	....do	9	57	1	01	7	10	....	44	
955	Moderate	Moderately	Moderately	9	50	1	02	8	31	....	54	
576	Smooth	Steady	Steady	5	25	....	56	4	45	....	50	
750	Moderate	Easily	Easily	8	58	1	12	5	58	....	48	
792	....do	Moderately	Moderately	9	35	1	13	6	23	....	48	
813	Rough	Deeply	Deeply	10	13	1	15	6	22	....	47	
1, 104	Moderate	Moderately	Moderately	13	48	1	15	8	38	....	47	—Next sounding, 30m afterwards, in 758 fathoms, with shot; average time per 100 fathoms for paying out, 53s.
432	Smooth	Steady	Steady	3	56	....	55	3	30	....	50	
667	Rough	Deeply	Deeply	7	32	1	08	5	02	....	45	
808	Light swell	Steady	Steady	7	40	....	57	8	35	1	04	
642	Rough	Moderately	Moderately	5	30	....	51	8	15	1	17	
796	....do	Deeply	Considerably	8	20	1	03	7	55	1	00	

NOTE.—This table is made up from the same records as the table heretofore given. For each of the above casts a thirty-four-pound lead was used, and a thermometer was attached to the stray-line. In every case the lead was hauled back by steam. The figures, when compared with those exhibiting the times occupied in making casts with sixty-pound shot-sinkers, show slower and more irregular work. The advantage of working with an accumulator is shown by the rapid rate of reeling in which was maintained under all circumstances.

When a thirty-four-pound lead has reached a depth of 1,000 fathoms the weight of the submerged wire is twelve pounds, and if the resistance upon the reel is seventeen pounds—five pounds surplus—the effective weight of the sinker, on which we have to depend for rapid work, is but seventeen pounds; with a sixty-pound shot-sinker under like conditions the effective weight is forty-three pounds, a positive advantage of twenty-six pounds; with the seventy-two-pound sinker, sometimes employed, the effective weight is fifty-five pounds, and the gain on the lead thirty-eight pounds under the conditions cited. In a heavy sea it is advisable, in order to guard against the wire flying from the drum, to keep the submerged wire under stronger tension than is usual in a smooth sea. This is done by placing a greater resistance upon the reel than is called for by the rule, but for every pound of surplus resistance thus added the effective weight of the sinker is reduced by one pound, a loss which is obviously more of a disadvantage with the thirty-four-pound lead than with the sixty-pound shot.

THE CLAMP AND ITS USE.

Sometimes it becomes necessary to clamp the wire at the machine during the operation of sounding; for instance, a kink or a defective splice appears, or the wire flies from the reel, requiring a manipulation of the wire that is possible only when it is slack. Fig. XIII, Plate 36, shows a clamp made to fit into the fairleader on the forward part of the bed-board of the sounding-machine; it consists of the following: Two pieces, or chocks, of lignum-vitæ *a a*, the right and left hand screw *b*; and the guide bolts *c c*, set rigidly into one piece of the lignum-vitæ, and sliding freely in cylindrical holes in the other. For clamping, the wire being slipped into place as shown at *d*, the clamp is lowered to the fairleader and the wooden parts firmly set up against the wire by means of the screw; or the clamp may be clapped on the wire inboard of the cross-head pulley and lashed somewhere near the bottom of the guides, on the bed-board, in which case the submerged wire and weights will ride from the accumulator. A small box-like arrangement should be fitted to the bed-board of the sounding-machine for containing the clamp, where the latter may be in readiness for instant use. Marline or rope-yarn, though unhandy, may be used to stopper the wire.

STATIONS AT THE SOUNDING-MACHINE.

When sounding, the officer of the deck always stood forward of the machine so that he need never turn his back on any point requiring attention. In heavy seas it was the custom of the officer of the deck to keep the left hand on the friction-line just inboard of the reel (near the scales X, Plate 36), where any unusual slacking of the friction-line could be felt at once.

Three men were stationed at the sounding-machine: one out on the accommodation-grating to get over the rod and sinker, to fasten on the thermometer and water-cups, to guide the wire and report the direction in which it tended from time to time; one at the forward side of the machine to watch the register, to apply the alkaline mixture, to guide the wire to the reel, and to attend the hand-cranks; and another at the after side of the machine, to assist with the sinkers, thermometer, and water-cups, to attend the hauling part of the friction-line in paying out, to attend the throttle of the reeling-engine when reeling in, and to work at the hand-cranks when necessary.

ACCIDENTS.

The Friction-line Parts.—Stop the reel by seizing it with the hands about the flanges of the drum; but not by throwing the pawl into the ratchet-wheel, against which it is necessary to caution untrained men.

The Wire Fouls on the Vessel's Bottom in Paying Out.—It is not likely to foul in this way excepting by the catching of a splice. Ship the cranks and reel in one or two fathoms, or until the splice appears; if the wire still tend under the bottom, endeavor to clear it by backing or steaming ahead, by shifting the helm, or perhaps with the sails. When the wire is allowed to pay out under the vessel, across the keel, it is impossible to know its angle from a vertical direction, and the depth of the sounding will be in doubt.

The Wire Fouls on the Vessel's Bottom when Reeling In.—In this case, if the power for reeling in comes from an engine, there is little probability of the wire holding together; but should the wire foul and not part, pay out a

PLATE 13.

THE SIGSBEE SOUNDING MACHINE IN POSITION; RUN OUT FOR WORK.

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few fathoms, and then if it does not swing clear resort to manœuvring, as in the preceding case. If steaming ahead while reeling in, this accident will probably never happen, but most vessels do not follow that practice. Since it is not necessary to keep the wire strictly vertical while reeling in there is but little excuse for this mishap excepting on very dark nights, or when a shift of wind has occurred during the operation of sounding.

A Ridge Appears in the Coil of Wire when Paying Out.—This results when the wire has been carelessly wound in reeling back from a previous sounding. If the ridge begin to slip, as it probably will, so as to slack some of the turns, stop the reel, clamp the wire inboard of the cross-head pulley and cut it at the reel, letting the submerged wire and weights ride from the accumulator; or reel back, if possible. Wind wire from the working reel to a spare reel until the ridge is reduced; then wind back again to the working reel, cutting out all defective parts. When a ridge once begins to show slack turns, a persistence in paying out will cause the wire upon the reel to kink in many places. Although this case happened to us but once, I give the above from my own experience combined with that of others. The formation of a ridge is so much the result of carelessness that it is stretching a point to call it an accident.

POSITION OF THE SOUNDING-MACHINE: LAYING THE VESSEL FOR SOUNDING.

The proper place to set up the sounding-machine depends somewhat on the character and qualities of the vessel engaged in the work.

In general terms the jerky and oftentimes rapid motion of pitching, particularly in a short vessel, which would be felt to its fullest extent at the bow and stern, causes more trouble than the smoother and more regular rolling motion, the maximum effect of which is at the gangways; also, since the vessel is laid head or stern to wind for sounding, the pitching will generally be in excess of the rolling, considered in relation to the disturbing influence on the action of the sounding-machine.

Captain Belknap in his Pacific work sounded from the gangway of the "Tuscarora," and generally, I believe, laid the vessel with her stern to wind and sea. Most other naval officers who have had charge of sounding operations since then have retained the gangway position for the machine, but just how they have laid the vessel there is no available means for ascertaining. In sounding from that part of the vessel there is a difficulty in manœuvring to keep the wire vertical; in fact, decided failures sometimes result in this particular, as is shown by records to which I have had access. In a man-of-war, however, it is an important point to have the machine under the eye of the commanding officer, a convenience afforded by the gangway position.

From the "Blake," under my command, we always sounded from the port bow, as far forward as the machine could be set up (Plate 7; and G, Figs. 1 and 2, Plate 29), consequently we suffered the full effect of the pitching motion. For sounding, the vessel was laid head to wind, with mainsail set and the main boom amidships. Thus laid, the usual tendency of the vessel was to drift with the wind, drawing the wire ahead rather than drifting over it, which is a point of great importance for night-work. The rapidity with which the "Blake" would swing her stern to port in backing under ordinary circumstances—in the extent of which characteristic she was exceptional—suggested sounding from the *port* bow. If the wire tended under the bottom of the vessel we had, usually, only to give the main engine a few turns back to bring it clear. If it occurred while paying out, the speed of the reel was checked until the wire was again vertical, and thus no cast was taken from the "Blake" which was not to all appearances "up and down." All things considered, sounding from the bow is probably most favorable to accurate results, and also the most convenient when it is intended to reel in the wire vertically.

When the latest form of the Sigsbee machine was put on board, to be used in charge of Commander Bartlett, another position from which to sound became necessary to admit of reeling in while steaming ahead, an operation for the performance of which it has been shown the new machine is fitted. Accordingly, the position selected was just forward of the port fore-rigging (Plates 13, 14, 15; and G, Fig. 3, Plate 29). Here nearly all the advantage of the former position is retained, and there is a straight lead aft for hauling in the wire as it trails astern while the vessel has headway. Reports from the vessel assert the convenience of the new position.

In sounding from the stern there would be the danger of fouling the

PLATE 14.

THE SIGSBEE SOUNDING MACHINE IN POSITION; RUN IN WITH THE TUBES LOWERED AND THE ACCOMMODATION GRATING TRICED UP.

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wire by drifting over it, and the risk of fouling with the propeller in a screw vessel, unless the vessel were laid stern to wind; particularly would the latter be liable to happen at night, when it is difficult to see the wire after it has left the reel. The chief advantage to be derived from the position would be facility for reeling in and steaming ahead at the same time. On board a vessel having large running expenses, and of which nothing but depth and bottom-soil specimens were expected in the way of results, the stern would doubtless be the best place from which to sound. If strict accuracy in regard to depth were not required, so much the more reason for choosing the stern, for the wire then might be payed out slightly inclined from the vertical, tending astern, to keep it clear of the propeller, and any risk to the wire likely to ensue would be well taken in view of the saving effected by sending the vessel ahead on her course with the least possible delay.

With regard to the minor considerations which might be taken into account when selecting a position for the sounding-machine, such, for instance, as cleanliness, noise, deck space, appearances, proximity to the engine-room bells and the helm, the whipping about of running rigging, &c., no discussion is necessary.

REELING IN WHILE STEAMING AHEAD.

The economy of making headway on the projected course while the wire is being reeled in from deep casts is apparent. Discussion is not necessary to demonstrate that it can be done, for it has long been the practice on board at least one of the English cable steamships. The present position of the "Blake's" sounding-machine (Plates 13, 14, 15) is not the best that could be selected for this special purpose, but the machine itself is suited to any angle of direction which the wire would be allowed to take.*

The table here given shows the results of an experiment in towing wire from the "Blake" in 1877. The figures are chiefly valuable for show-

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* It is to be regretted that the value of the new position in this respect has not been put to a test, owing to the dredging, temperature, and water-specimen work which followed a great number of the casts made by the "Blake" on her recent cruise, requiring her continuance at the sounding station for some time after the cast. When Commander Bartlett had made all arrangements for securing important data in connection with this and other matters suitable for publication in this book, it became necessary to order the vessel north.

ing the small effect of the oscillations of the vessel in varying the strain upon the wire. The maximum strain nowhere exceeds the steady strain by more than five pounds, while a difference as great as eighty pounds has been known when reeling in with the wire vertical. It is to be regretted that the experiment was not repeated without the lead.

EXPERIMENT IN TOWING SOUNDING-WIRE FROM THE "BLAKE."

Fathoms of wire out.	Speed of the vessel, in knots and tenths.	Strain on the wire in pounds, showing the effect of the rolling and pitching of the vessel.			Speed of the wire through the water, per 100 fathoms.	Remarks.	Remarks.
		Minimum.	Steady.	Maximum.	*m.* *s.*		
(*)	8.3	41	45	49	0 42.8		During the operation the vessel was steaming in the trough of a moderately heavy sea, and was rolling and pitching considerably, sometimes even heavily. In the first column 8 fathoms of stray-line are included in the given length of wire out, and the strain in every case is that due to the pull of wire, lead, and 8 fathoms of stray-line. The lead used was 18 inches long, of the ordinary commercial pattern, fitted with a Stellwagen specimen-cup, the whole weighing 34 pounds.
(*)	5.3	30	34	37	1 07.0		
100	7.3	41	45	49	0 48.7		
100	6.3	39	41	43	0 56.4		
250	7.0	45	50	54	0 50.8		
250	4.0	35	42	47	1 28.8		
500	6.5	52	60	65	0 54.7		
500	3.6	37	43	44	1 38.7		
750	7.0	67	69	72	0 50.8		
750	3.6	43	45	46	1 38.7		
1,000	7.0	75	78	81	0 50.8	Pitching heavily.	
1,000	5.5	68	70	73	1 04.6		
1,250	7.0	91	93	96	0 50.8	Repeated.	Having paid out 2,000 fathoms, we commenced to reel in by steam, the vessel's speed being 6.6 knots. 100 fathoms came upon the reel in 3^{m} 10^{s}; but on attempting to reel in the second 100 fathoms at the rate of about 3^{m}, the vessel going at the same speed as before, the wire parted—a fair break, and not in a splice.
1,250	4.7	70	72	74	1 15.6		
1,500	6.7	100	102	103	0 53.0		
1,500	4.5	74	76	77	1 19.0		
1,750	6.5	105	108	110	0 54.7		
1,750	3.6	75	77	78	1 38.7		
2,000	7.3	125	126	128	0 48.7		
2,000	3.7	75	78	79	1 36.0		

* Lead and 8 fathoms of stray-line submerged.

It is seen that when the wire parted it was being hauled through the water, with the lead and stray-line attached, at a speed of 8.57 knots per hour or one hundred and forty-four and three-fourths fathoms per minute, which is at the rate of one hundred fathoms in 41.4 seconds. When there were 2,000 fathoms out, and the vessel was making a speed of 7.3 knots, the wire, line, and lead were being towed at the rate of one hundred fathoms in 48.7 seconds, yet the maximum strain upon the wire was only one hundred and twenty-eight pounds, of which about forty-five pounds were due to the stray-line and sinker.

THE SIGSBEE SOUNDING MACHINE IN POSITION; RUN OUT FOR WORK.

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Although the table shows that an accumulator, as such, is not required when reeling in while steaming ahead, yet as a dynamometer it would perform important service. The dynamometer, by showing the strain upon the wire at each instant, would permit a safe and rapid rate of reeling in without a resort to time-interval checks involving a considerable calculation, or to the use of prepared tables; and should sea-weed or other matter held in suspension below the surface of the water foul with the lead or sounding-rod the fact would be made known at once by the dynamometer.

In the performance of the operation under discussion the main object would be to get the vessel as far ahead on her course as possible; while the time consumed in reeling in would be of secondary importance, and need be limited only by the time required to reach the next sounding station.

If in the time that otherwise would be occupied by a vessel in reeling in with the wire vertical, she can succeed in steaming ahead on her course, however slowly, and at the expiration of that interval of time can start ahead at full speed with safety to the wire which is towing astern, she will obviously have gained by the method of steaming ahead while towing the wire. This suggests the following as being probably a good plan for general work in this particular.

Decide on the working strain to which it will be safe to submit the wire that is in use. After bottom has been reached send the vessel ahead at a speed which will admit of a slow rate of reeling in without exceeding the accepted working strain. Constantly keep this strain upon the wire—first, by gradually increasing the speed of the vessel while maintaining the initial rate of reeling in, and then, after the vessel has reached full speed, by gradually increasing the rate of reeling in.

I have known several cases in which sharks have parted the wire by seizing the bright instruments attached to the stray-line. Certainly below five hundred fathoms, and probably below one hundred, this remote danger will cease. When the wire is towing, the chances of being thus annoyed are greater than when reeled in vertically, and it is suggested that the outside of the instruments might be painted a dead black or a dark lead-color to make them less alluring to sharks.

DESCRIPTION OF A NEW STEEL REEL: REMARKS ON CRUSHING FORCE.

(Plate 16.)

A cast-steel drum, with the two outer flanges A, A, and the three inner flanges B, B, B, the thickness of metal being one-eighth of an inch throughout, excepting at the angles C, C, where it is somewhat thicker.

The one-eighth-inch sheet-steel side-plates D, D, set up to the drum by the half-inch steel socket-bolts E, E, E, &c., which pass through the inside flanges B, B, B, and are secured with the nuts F, F, &c. The drum should have as nearly as possible a perfect contact with the side plates.

The cast-steel friction-ring, with score G, secured to the steel bolts E, E, E, &c., by the iron screws H, H, H, &c.

The wrought-iron three-eighths-inch riveted socket-bolts I, I, I, &c.

The cast-iron center-block J, to which the steel side-plates are secured by the three-eighths-inch wrought-iron riveted bolts K, K, K, &c.

The steel axle L, to be fitted with cast-iron or steel ratchet-wheel and a steel worm, as shown on Plates 36, 37, 38.

The wrought-iron or steel key M.

The steel washers N, N, N, &c., to give additional strength to the outside flanges of the drum at the points C, C.

No brass is to be employed in the manufacture.

This reel weighs about eighty-one pounds without the axle ratchet-wheel and worm, and about ninety-five pounds when fully equipped.

The drum should exactly accommodate one fathom of the sounding-wire at a single turn. The diameter of a circle having a circumference of one fathom is 22.918 inches, and this being decreased by 0.028 inch, thickness of the wire, gives as the diameter of the drum 22.89 inches.

All the joints should have, as nearly as possible, a perfect fit, that the reel may be very strong as a whole.

A reel made after the drawings shown on Plate 16 was put on board the "Blake" when the vessel had come under the command of Commander Bartlett. The view of this reel from which Plate 17 was made was obtained during a rain and the plate is therefore not very successful.

Under the direction of Commander Bartlett, Lieutenant Wallis sub-

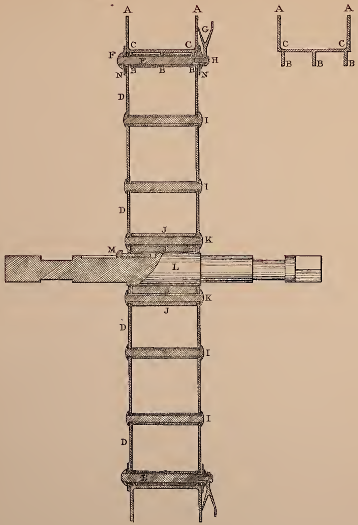

Fig. 1

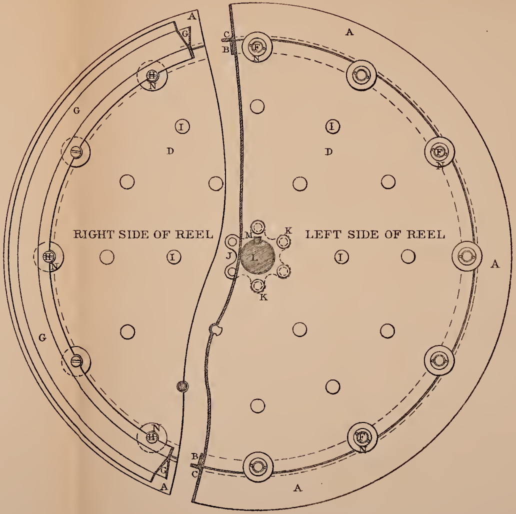

Fig. 2

NEW STEEL REEL FOR SOUNDING WITH WIRE, DEVISED BY LIEUT COMDR. C. D. SIGSBEE, U. S. N., ASSIST. COAST SURVEY.

jected the new steel reel to the following experimental test: 3,868 turns (4,025 fathoms) of sounding-wire was wrapped upon it under an invariable tension of fifty pounds. If every part of the reel and the enwrapped wire remained rigid throughout, then the reel must have sustained a crushing force of $172\frac{1520}{2240}$ tons; $\left(\frac{50 \times 2 \times 3868}{2240}\right)$. Gauges were carefully applied to various parts of the reel during the experiment and on its completion. After the whole 4,025 fathoms had been reeled up, the outer flanges A, A of the drum were found by the gauge to have retained the same distance from each other which they had at first, and no part of the reel had suffered any change that could be detected, excepting at the seam, on either side, where the side-plates are set up against the under side of the drum; here the outside face of the flange and the outside face of the side-plate—the vertical faces—were just visibly separated, whereas at first they had been in the same plane. The bearing contact of the joint, however, was perfect, and the side-plates simply gave the appearance of having been forced outward very slightly and evenly all around the seam. Care was taken to detect any excentricity, but the circularity, and the concentric relation, of the parts remained, apparently, perfect. The ultimate strength of the reel had not been reached. Should greater strength be required, the middle inner flange might be made deeper.

It is remarkable that the galvanized sheet-iron reel and the Navy brass reel should have resisted, even to the extent realized, the accumulated force which apparently has been brought upon them when reeling back from deep-sea casts. The explanation must, I think, be sought, first, in the elasticity of the reel and its coil of wire under severe compression; and, secondly, in the expansion upon the reel, in most cases, of a great deal of the wire that had been submerged—an action due to its change from a lower to a higher temperature soon after leaving the water. While it is evident that the turns of wire, under certain relative thermal conditions of the air and water, may contract upon the reel on leaving the water, it is nevertheless true that in nearly all of the casts yet taken by the Navy and by the Coast Survey the reverse must have been the case.

In a paper lately brought to my notice it is assumed that the wire, in a special case mentioned—depth 1,900 fathoms—must have contracted soon after leaving the water, causing a great accumulated force upon a reel which was crushed, the reason assigned for the assumption being that the air was of several degrees lower temperature than the water. Only the temperature of the surface-water was considered in connection with the air temperature—air, 60°, surface-water, 63°, Fahrenheit.

From records of serial temperature work previously done near the locality cited, I get the following relation of temperatures: Fahrenheit scale—air, 60°; water—surface, 59°; twenty fathoms, 57°; one hundred fathoms, 46°; one hundred and fifty fathoms, 44°; bottom, 1,900 fathoms, 35°. A few degrees of daily change in the temperature of the air or the surface-water will effect but little change in the water temperatures below ten or twenty fathoms.

From the figures given it is at once seen that in the case discussed by the paper in question the wire must have expanded on the reel. Every part of the submerged wire, excepting the upper one hundred fathoms, must have left the depth of one hundred fathoms, in the ascent, at a temperature certainly no higher than 46°, and in less than one minute and thirty seconds thereafter, as shown by the records, it was resting upon the reel.

REELING-ENGINE AND ACCESSORIES FOR SOUNDING PURPOSES.

During my first two years on board the "Blake" we reeled in the wire by means of a long rope belt taken over the friction-score of the reel and led through blocks to a large hoisting-engine fastened to the deck abaft the pilot-house, in the same place afterwards occupied by the engine shown on Plates 30, 31, 33, and others. Plate 29 (Figs. 1 and 2) will give a good idea of the length of belting required, G being the sounding-machine and A the hoisting-engine. Afterwards a Snyder horizontal engine was placed upon the bed-board of the experimental machine, as shown on Plate 7; it is also located on Plate 29 (Figs. 1 and 2), G and H indicating the sounding-machine and reeling-engine, respectively. With this we have reeled in as fast as one hundred turns—more than one hundred fathoms—in twenty-six seconds, and a speed of one hundred turns in forty-five seconds was a very common occurrence. The connection between the reel and the small

PLATE 17.

NEW STEEL REEL FOR SOUNDING WITH WIRE. THE CONSTRUCTION IS SHOWN IN PLATE 16.

Heliotype Printing Co., 220 Devonshire St., Boston

engine was made by a rope belt, for the reception of which the engine was provided with a **V**-groove fly-wheel. For tightening the belt I designed a pair of tightening-pulleys, which are shown imperfectly on Plates 7, 13, and 14. This arrangement may be described as follows: A standard, to the lower part of which a stud-bolt is fastened to form a pin or axle on which the lower pulley may revolve freely. The upper part of the standard is squared, and sliding freely upon it is a collar, to which a second stud-bolt is fastened to form a pin or axle on which the upper pulley may revolve freely. The upper part of the sliding collar is shaped so as to be capable of holding annular lead weights. The lower part of the endless belt is led over the top of the lower or stationary pulley, and the upper part under the upper or sliding pulley. Any desired degree of tightening may be given the belt by adding weights to the sliding collar.*

When the latest form of the Sigsbee sounding-machine was put on board the "Blake" it was not convenient to place the little reeling-engine upon the bed-board while the strain-pulley was retained. Accordingly, the engine was placed as shown at H, Fig. 3, Plate 29—G being the new sounding-machine. (See also Plates 13, 14.)

Plate 18 shows a small incline reeling-engine, designed at my request by Mr. Earle C. Bacon, of Messrs. Copeland & Bacon, New York, and intended to occupy the place upon the bed-board of the sounding-machine at present assigned to the strain-pulley. The cylinder is of Mr. Bacon's patent trunk pattern, of five and a half inches bore. The standards are joined at the bottom, being cast in one piece, and are cored out in order to make them as light as strength will permit. The **V**-groove pulley, as shown, might be dispensed with, and the fly-wheel given three scores, corresponding to those on the strain-pulley.† On board a vessel permanently engaged in deep-sea sounding such an engine would doubtless be connected with the boilers by piping; but for use on board vessels not likely to retain the sounding-machine as a fixture, rubber steam-hose might be used for the steam and exhaust pipes. In 1879 Mr. Bacon offered the following

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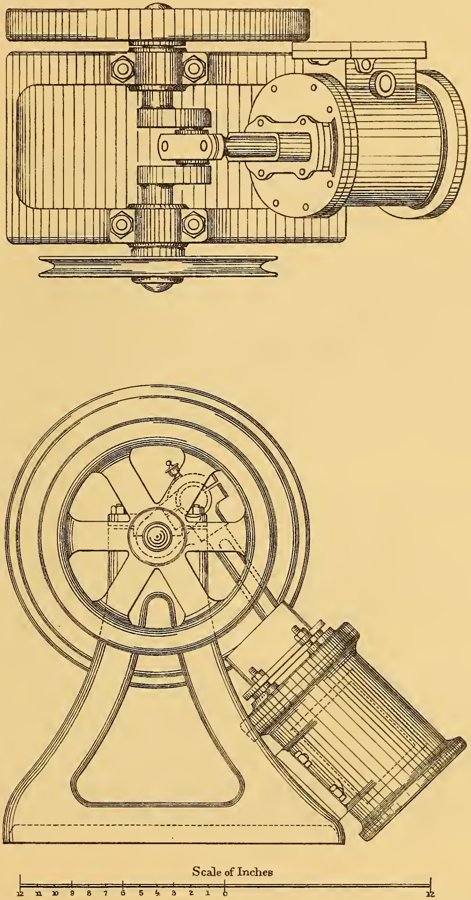
* The tightening-pulley designed for the new machines, now being made for the Navy and for the Coast and Geodetic Survey, is an improvement on the form described. April, 1880.

† At my request Mr. Bacon has changed the design somewhat, placing the cylinder between the standards, with its axis vertical. The size of the bed-plate is eighteen inches by ten and a half inches. April, 1880.

prices: For the engine complete, without connecting hose or piping, $225; for rubber steam-hose, three-quarter-inch inside diameter, five-ply, and served with marline, fifty cents per foot; for rubber exhaust-hose, one inch inside diameter, three-ply, and served with marline, fifty cents per foot; couplings, $5 per set. The "Blake's" reeling-engine was worked with a pressure of steam ranging from sixty to seventy-five pounds, for which the above-mentioned hose is adapted. The New York Rubber Belting Company advertise various grades of rubber steam-hose.

U. S. COAST SURVEY PLATE 18.

PLAN OF PATENT TRUNK REELING ENGINE FOR THE SIGSBEE SOUNDING MACHINE—TO OCCUPY THE PLACE ON THE BED BOARD AT PRESENT ASSIGNED TO THE STRAIN PULLEY, SHOULD THE LATTER NOT BE REQUIRED
DESIGNED BY MR. EARLE C. BACON OF MESSRS. COPELAND AND BACON, N.Y.



CHAPTER IV.

WATER SPECIMENS, DENSITIES, TEMPERATURES, AND CURRENTS; APPARATUS AND METHODS.

DISPOSITION OF WATER AND SOIL SPECIMENS.

The specimens of bottom soil or material obtained by the "Blake," during her sounding operations, were preserved in glass bottles which were simple cylindrical tubes closed at one end in the manufacture, about two and a half inches long and three-fourths of an inch in diameter, resembling a small plain beaker-glass, or the cylindrical part of a test-tube. Bottles of this kind are a commercial article, and may be obtained, I presume, in any large city. The wide, unobstructed mouth, which is a convenience both for inserting and extracting the specimen, should be closed with a flat selected cork.

The glass bottle for the preservation of water specimens was of a commercial pattern, having a very small neck and mouth, to close which we used a long smooth cork. Its capacity was eight ounces.

As an additional precaution, the corks of all bottles containing specimens were well waxed. In this state, and labeled with the forms shown on the next page, the specimens were sent to the office at Washington on the completion of each season's work.

No attempt to analyze water specimens was ever made on board the "Blake." Shortly before Professor Agassiz joined us for the dredging operations he had procured apparatus with a view of doing something in the way of gas analysis, but he afterwards decided that the proper facilities were not to be had on board the vessel. He suggested, as a plan for the future, that a properly furnished station be established on shore, convenient to some deep-sea basin, whence water specimens might be delivered to the station by the quick runs of a steamer detailed for the purpose. With a station at Tortugas, for instance, the "Blake" could deliver a specimen from 2,000 fathoms within twelve hours after its reception on board.

U. S. COAST AND GEODETIC SURVEY,
CARLILE P. PATTERSON, *Superintendent.*

Steamer "BLAKE,"
.........................., *U. S. N., Commanding.*

WATER SPECIMEN.

Locality: ....
Date: ...., *18* .
Lat. ....*N., Long.*............ *W.*
No. of specimen............, *Line*............
With what apparatus obtained:............
....
....
Depth of sounding............*Fms.*
Depth of specimen............ *Fms.*
Specific gravity............*at*
temperature of............*Fahr.*

All specimens taken at any sounding are given the serial number of that sounding.

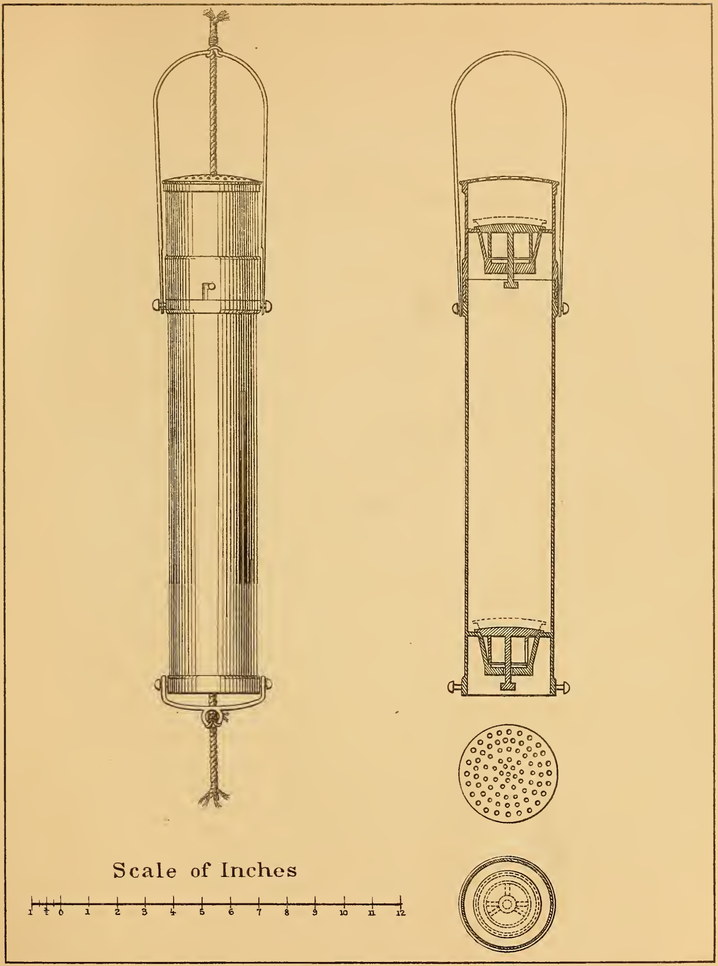
U. S. COAST AND GEODETIC SURVEY,
CARLILE P. PATTERSON, *Superintendent.*
Steamer "BLAKE."
....
U. S. N., Commanding.

SPECIMEN OF THE BOTTOM.
Locality:..........................
Date:.........................., *18* .
Lat.............*N., Long.*............*W.*
No. of specimen............, *Line*............
Depth:............ *Fms.*
Character of specimen:............
....
....
With what apparatus obtained:............
....

All specimens taken at any sounding are given the serial number of that sounding.

REMARKS ON WATER-CUPS, WITH SPECIAL REFERENCE TO THE SIGSBEE WATER-CUP.

Water-cup or water-bottle is the name generally applied to the instrument by means of which sub-surface water specimens are obtained. The work required of the cup or bottle, at any cast, is to bring a specimen from the greatest depth which the instrument reaches. Nearly all kinds of water-cups are provided with valves which are kept open by the resistance of the water during the descent, permitting a current of water through the cup, and which, on the ascent, are closed by their own weight or by the resistance of the water, thus preventing a reverse current from ejecting the inclosed specimen. With the exception of the Sigsbee water-cup, shortly to be described, there is no instrument known to me with the use



WATER SPECIMEN CUP FOR GETTING A SINGLE SPECIMEN AT EACH HAUL; INDEPENDENT POPPET VALVES: USED IN THE COAST SURVEY FOR A NUMBER OF YEARS.

of which, collectively, unimpaired specimens may be secured from more than one depth at a single cast.

Leaving the Sigsbee cup out of consideration, the water-cups in general use may be divided into two classes—viz, free-valve and lock-valve cups. In the former, the valves are free to act during all stages of the cast, but the valves of the latter fall and lock immediately at the first ascending movement through the water. In order to use water-cups collectively it is necessary to make stoppages for the purpose of clamping the successive cups to the rope during the operation of paying-out; and afterwards, when hauling back, a separate stoppage must be made to remove each cup as it comes to the surface. The rising and falling of the ship, which imparts a corresponding movement to the submerged water-cups, must be accepted as a condition attendant on the work; hence all free-valve cups are liable to empty their contents at any stoppage on the ascent, and lock-valve cups may have their valves closed and locked at the first stoppage during the operation of paying out.

A short time before he was detached, my predecessor in command of the "Blake" had been directed by the Superintendent of the Coast and Geodetic Survey to give special attention to the collection of water specimens from serial depths at various stations in the Gulf of Mexico, particularly off the mouth of the Mississippi River. The great delay on our lines of soundings which would result from the use of ordinary water-cups to the extent demanded by our instructions was at once apparent. The only form of cup that had previously been supplied to the "Blake" was of the kind shown on Plate 19. This had independent poppet-valves, and therefore belonged to the free-valve class. To meet this exigency in our work it appeared that some form of lock-valve cup should be designed, the use of which, collectively, would obviate the necessity of multiplying the casts for each station at which water specimens were to be obtained. It was an indispensable requisite that the proper action of the valves of such cups should be independent of the oscillations of the ship; that the valves should be free to open during the whole period of paying out, and that they should be kept closed or locked from the time of beginning the ascent. Soon after joining the "Blake" I devised a cup which in its working seemed to satisfy these conditions. This cup was improved from time to time, and is herein shown in its latest form. (Plates 20 and 40.)

DESCRIPTION OF THE SIGSBEE WATER-CUP.

(Plate 40.)

In Appendix No. 55, page 192, United States Coast Survey Report for 1854, is published a report by Assistant J. E. Hilgard concerning the action of sea-water on the metals used in the construction of certain instruments which, by the sinking of a Coast Survey schooner, had been submerged three weeks in five fathoms of water. Assistant Hilgard makes this remark: "*German silver, an alloy of copper and nickel, was not tarnished in the least degree, nor did it become so when afterwards exposed to the air without being cleaned with fresh water.*"

Probably the economy effected by using water-cups collectively would warrant the expense of making them wholly of German silver, although in the Sigsbee water-cup it is employed only for the more delicate working parts, the action of which might be seriously affected by corrosion, and the cleaning of which would be difficult. All parts not specified in the following description as being made of German silver are of brass.

The cylinder A (Figs. I, II, III, IV, V).

The thickness of metal to be no greater than is required for the turning of a strong screw-thread at either end.

The lower valve-seat B (Figs. I, II, III, IV, V), which screws to the cylinder by a *right-hand* screw-thread.

Though the lower valve-seat may be removed, this is not necessary for cleaning; there being no sharp angle at its inside junction with the cylinder, a cleaning rag thrust into the cylinder from above may be made to reach all parts.

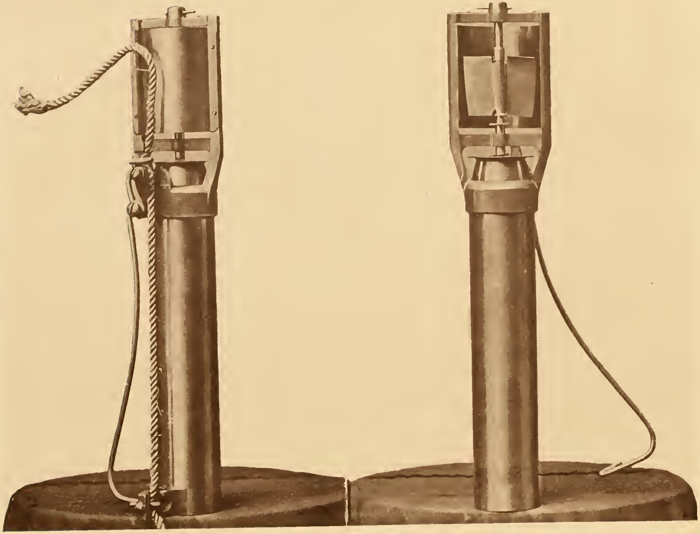
The detachable upper valve-seat C (Figs. I, II, III, IV, V).

This is made detachable that the valves may readily be removed for cleaning the parts.

The upper poppet-valve D (Figs. I, II, III, IV, V) and the lower poppet-valve E (Fig. I), connected by a stem, the valves being adjustable by means of a long, fine screw turned on the connecting stem at F (Fig. I).

The connecting stem should be made of the same material as the cylinder and the valves, so that all may expand or contract in the same proportion under change of temperature. It should not be secured to the lower valve by passing through it, thus making a joint through the valve, but should be fastened with a screw, as shown faintly in Fig. I, the threads then being soldered. The stem proper of the lower valve is squared at its lower end for the reception of a clock-key or crank, that the valves may be adjusted to their respective seats.

PLATE 20.



THE SIGSBEE WATER SPECIMEN CUP, FOR GETTING SPECIMENS FROM VARIOUS DEPTHS AT A SINGLE HAUL, BY USING A SEPARATE CUP FOR EACH DEPTH FROM WHICH A SPECIMEN IS REQUIRED. THE CONSTRUCTION IS SHOWN ON PLATE 40.

Heliotype Printing Co., 220 Devonshire St., Boston.

A small German-silver compression-spring at G (Fig. I).

To prevent a too easy disturbance of the adjustment of the valves, for which purpose the spring should be under a considerable pressure when the valves are adjusted.

The frame-work H (Figs. I, II, III, IV, V), fastened to the cylinder by a *left-hand* screw-thread, inclosing the upper valve-seat.

A *left-hand* thread is employed that the action of the spring-clamp (to be referred to hereafter) may not open the joint. The parts forming the joint should be ground into place to make a close contact.

The German-silver removable sleeve I (Figs. I, III).

To permit the removal of the propeller-shaft from its bearings.

The brass pin J (Figs. I, II, III, IV, V).

The German-silver shaft K (Figs. I, II, III), with *right-hand* screw-threads (forty-four to the inch) at L and M (Fig. I).

A German-silver propeller or fly; composed of two bent blades N, N (Figs. I, II), the hub O (Figs. I, II, IV), the inside screw-thread P (forty-four to the inch) (Fig. 1), the guide-cap Q (Figs. I, II, IV), removable, but fitting tight on the hub; and the beveled lugs R, R (Figs. I, II).

The lighter the propeller the better, as will be seen hereafter. The pitch of the propeller will also be referred to further on. The guide-cap and the lower end of the hub are made to fit close enough on the shaft to prevent grit or dirt from getting inside and among the screw-threads, but they should be capable of sliding *very freely* on the shaft. The threads of the hub and shaft should work together so freely as to permit the propeller to be revolved by a puff from the breath.

The German-silver bouching S (Fig. I), soldered to the frame-work.

A German-silver screw-cap, with milled head T, T (Figs. I, II, IV), beveled slots U, U (Figs. I, II), and inside screw-thread V (Fig. I).

The cap should fit the shaft in the manner described for the propeller-hub. Between the screw-cap and the bouching S there should be a considerable clearance, $\frac{1}{100}$ inch or more.

A clamp composed of the two lugs W, W, the pivot-screw X, and the German-silver or steel *spring-wire* Y (Figs. III, IV, V).

If these clamps are made with the upper arm of the lever a decided loop, as shown on the thermometer cases (Plates 2 and 3), they may be used on any size of sounding-rope. To change the power to suit different sizes of rope it is only necessary to bend the long arm of the lever slightly a short distance below the pivot-screw X. It takes but a few seconds to attach or remove a cup with these clamps. I have never known a case of slipping with them.

The cost of the water-cups is about $25 each.

WORKING OF THE SIGSBEE WATER-CUP.

To Adjust the Valves.—Hold the upper valve firmly, and unseat the lower valve by screwing it upwards. Then, maintaining the upper valve on its seat with the finger—or, better, by turning the screw-cap down upon it—

reseat the lower valve gently. In general, it will be necessary to readjust the valves only after the cup has been taken apart for cleaning or for other purposes.

The cup when in use comes to the surface filled with water, the screw-cap pressing upon the upper valve, thus securing both valves, and the propeller resting upon the screw-cap. To remove the specimen from the cup, first lift the propeller, and by giving it a few turns cause its threads to engage the screw-threads on the shaft; then turn up the screw-cap until it uncouples. With the cup in this condition the valves may be lifted and the water discharged. When the screw-cap is pressing upon the upper valve the threads inside the former are engaged with the threads of the shaft, but, on screwing up the cap when its lower thread clears the upper thread of the corresponding series on the shaft, the cap uncouples, which prevents any mistake being made at this point by the person who is handling the cup; afterwards the screw-cap may be turned in the same direction indefinitely without jamming or changing position along the shaft.

With the screw-cap up, and the propeller in any position, the cup is automatic, and may, if desired, be lowered into the water with no further preparation; yet it is a good practice to first screw up the propeller by hand to observe if the threads are in perfect working order.

Assuming the propeller to be low down on the shaft, or even resting upon the screw-cap, the action of the cup in the water is as follows:

As it descends the valves are lifted and held up by the resistance of the water; by the same agency the propeller is revolved and carried upwards until, like the screw-cap, it has become uncoupled, after which it revolves freely on the shaft impinging against the German-silver sleeve I. If the propeller hub were allowed to come in contact with the sleeve while the screw-threads were still engaged it might remain impacted during the subsequent ascent. To insure uncoupling at the proper time, the guide-cap, which fits over the top of the hub, must be set well home in its position when the propeller is fitted to its shaft. It will be noticed that the blades of the propeller are bent along their upper edges. With the blades thus bent, and all parts of the propeller made very light in weight, it has been found, experimentally, that the alternating movement of translation imparted to the submerged cup by the motions of the vessel in a sea-way will cause the propeller, when engaged with the threads on the shaft, to gradually screw up rather than down. This shows that stoppages in the descent, whether to attach additional cups to the rope or wire, or for any purpose whatever, may be made with safety if the vessel be kept idle in the water, that is, without headway or sternboard. Were the blades not bent it is evident that the propeller would gradually screw down by the same alternating movement, since its weight would assist its action in screwing down but resist it in screwing up. Even thus, experiments have shown that with the alternating movement continued for a longer time than would probably be occupied at any stoppage, the propeller would screw down on the shaft only a small proportion of the whole distance over which it must pass to reach the screw-cap. It is plain that, in the event of such action, the propeller would rise and uncouple each time that the descent was continued. However, the bending of the blades insures safety, and the valves are left free to open during the whole descent. At any stoppage in the descent each cup has within its cylinder a specimen of water from its locality at the time being, allowing a margin of one or two feet.

Immediately the ascent is begun the valves of each cup are pressed firmly on their seats by the resistance of the water, and each propeller begins to screw down along its shaft under the same influence. When the upper thread inside the hub of the propeller clears the lower corresponding thread on the shaft, the propeller uncouples and drops upon the screw-cap, which it clutches. The screw-cap is then carried down until it comes in contact with the upper valve, from which position it cannot be removed by the action of the water or of the propeller. Both valves having thus become locked, stoppages may be made thereafter during the ascent without risking the identity of the inclosed specimen of water.

The distance through which the cup must pass in order that the propeller may traverse the shaft and lock the valves may be varied by altering the pitch of the propeller blades. As shown in the drawings, the propeller would probably not perform its whole work short of fifty fathoms. I settled on about twenty-five fathoms as the most convenient distance. With this distance it would not be prudent to require the uppermost cup to bring a specimen from nearer the surface than fifty fathoms. If the propellers were arranged to lock the valves in an ascent of about twenty-five fathoms and the uppermost cup were lowered only to a depth of ten fathoms, for instance, obviously, when that cup had arrived at the height of the vessel's deck, the submerged cups having passed through a distance of only about twelve fathoms would not have become locked.

In Chapter II, page 40, the importance of keeping valves clear of muddy or gritty bottom has been stated. When a specimen of bottom water was desired the custom on board the "Blake" was to fasten a cup about two fathoms above the sinker. A method of fastening a Miller-Casella thermometer case to the water-cup is shown on Plate 40. This method was intended to save time when the temperature and a specimen were to be obtained from the same depth. Since that drawing was made all the thermometer cases on board the "Blake" have been fitted with spring-clamps, rendering their attachment to the rope, independently, an easy and rapid operation. (Plates 2 and 3.)

Each cup, as soon as discharged, should be thoroughly rinsed in fresh water. Water-cups were lowered by a rope, which for convenience we styled the temperature-rope, to be described shortly.

An explanation of some additional points connected with the cup is given for the benefit of those whose tastes may lead them to improve on what we have done; it being desirable that such persons should know the intention which induced the peculiar fashioning of the various parts. This, while suggesting to others, perhaps, a better mechanical shape, especially in details, may prevent a useless sacrifice of good features in the adoption of new ones.

A cup made from the drawings and scale of Plate 40 will be of light weight and convenient size, holding about twenty-two cubic inches of water. If a little more water be needed, the cylinder, connecting valve-stem, and the long arm of the spring-clamp may be lengthened, no other changes being made. In this way the Sigsbee cups furnished the Arctic exploring steamer "Jeannette" were given a greater capacity than those made strictly by the drawings and scale of Plate 40. For the "Blake's" dredging cruises especially large cups were made, larger perhaps than would now be thought necessary. These were about twelve inches between valves and of two and one-half inches diameter of cylinder, inside, holding about fifty-seven cubic inches of water, which is a little more than a quart. They weighed six and one-half pounds each, and were used with impunity at the end of the sounding-wire; but since the main object is to use the cups collectively, it is an obvious advantage to have them of lighter weight if possible.

A very pertinent question which has often been asked is this: "Will the threads of the propeller-hub and shaft always engage each other as desired, that the two parts may couple after they have been uncoupled?" No failures have occurred in this respect, and, in fact, there can be none when the threads are in good condition, for the hub being guided at each extremity its movement must be true.

The area of the upper valve proper is less than that of the lower valve, the set thus forming balance-valves. This arrangement resulted from a suggestion by Lieut. J. E. Pillsbury. It being thought doubtful by some persons that poppet-valves would always lift by the resistance of the water, Lieutenant Pillsbury suggested balance-valves for the purpose. It was at once evident that the use of valves so arranged would not only secure a favorable result in the descent, but that a desirable benefit might thereby be secured when the cup was ascending. When the cup enters the water, there being only atmospheric pressure in the chamber of the cylinder, if the valves do not lift there must soon prevail, as the descent continues, a greatly preponderating and constantly increasing pressure outside the cup, which must raise the connected valves. Once a current is established through the cup the resistance of the water acts upon the under surface of *both* valves. On the ascent both their own weight and the resistance of the water operate to close the valves. The valves once closed there is soon a preponderating pressure *inside* the cylinder—since the pressure outside is constantly lessening—and the effect of this is to seat the valves firmly. While it may be thought that these points are too fine to be of practical advantage, it is nevertheless true that there is nothing lost by having the mechanical arrangement of the valves theoretically correct; while by having the upper valve the smaller there is gained the undoubted practical advantage of exposing to the resistance of the water, in the descent, the largest possible area of the lower valve and the projecting flange of the upper valve. The downward extension of the lower valve-seat is intended to concentrate the effect of the resisting column of water on the under surface of the lower valve during the descent. Lieutenant Pillsbury proposed putting an air-tight bulb on the connecting stem of the valves in order to render the specific gravity of the valves and stem thus fitted only slightly greater than that of sea-water. The idea is ingenious, but its adoption is hardly necessary.

When a cup comes from the water the screw-cap is usually found to be more tightly set against the upper valve than can be attributed to the force which the small propeller could have exerted under the circumstances. Probably the following causes operate to effect this: First, a slight preponderating pressure within the cup; second, the expansion of the metal in the change from a colder to a warmer temperature, the screw-cap and upper valve having come in contact when slightly contracted by the low temperature of deep water.

The cup may be taken wholly apart without the aid of a screw-driver. *In detaching the screw-cap and the propeller from the shaft care must be taken not to injure the delicate screw-threads by stripping them.*

Lieutenant S. M. Ackley proposed making a hole through the cylinder just below the upper valve-seat, and covering this hole securely with a thin piece of sheet-rubber as a permanency, the object being to prevent the possible escape of gases past the valves by making provision for their expansion within the cup. It would be interesting to experiment with this device. Any distension observed in the rubber disk or diaphragm on coming out of the water would probably recommend its adoption, although by its use the valves would cease to be *balance-valves.*

A stop-cock device for transferring the water from the water-cup to another vessel without exposure to the atmosphere has received attention, but the design has not been completed.

WATER DENSITIES; HOW OBSERVED.

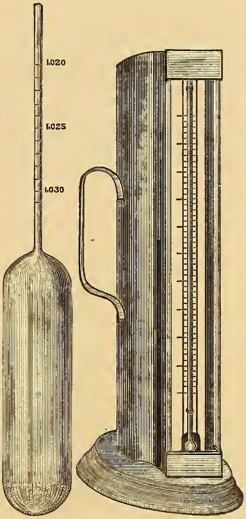
If a water specimen was to be saved for future examination its density was taken before bottling. Early in our work we were provided by the office with a special scale-areometer and its accompanying thermometer, which we always used thereafter. These instruments having been already described in Appendix No. 16, Coast Survey Report for 1874, the appendix is given below:

[From the United States Coast Survey Report for 1874.]

APPENDIX No. 16.

DESCRIPTION OF AN OCEAN SALINOMETER, BY J. E. HILGARD, ASSISTANT UNITED STATES COAST SURVEY.

The density of sea-water in different latitudes and at different depths is an element of so great importance in the study of ocean physics as to have caused a great deal of attention to be paid lately to its determination. The instruments employed for the purpose have been, almost without exception, areometers of various forms. The differences of density as arising from saltiness are so small that it is necessary to have a very sensitive instrument. As the density of ocean-water at the temperature of 60^{c} Fahr. only varies between the limits of 1.024 and 1.029, it is necessary, in order to determine differences to the hundredth part, that we should be able to observe accurately the half of a unit in the fourth-decimal place. This gives a great extension to the scale and involves the use of a series of floats if the scale starts from fresh water, or else the instrument assumes dimensions which make it unfit for use on board ship.



D.—HILGARD'S OCEAN SALINOMETER.

With a view to the convenient adaptation to practical use, the apparatus figured below has been devised for the Coast Survey by Assistant Hilgard.

The instrument consists of a single float about 9 inches in length. The scale extends from 1.020 to 1.031, in order to give sufficient range for the effect of temperature. Each unit in the third place, or thousandths of the density of fresh water, is represented by a length of 0.3 of an inch, which is subdivided into five parts, admitting of an accurate reading of a unit in the fourth place of decimals by estimation. The float is accompanied by a copper can, with a thermometer inserted within the cavity, which is glazed in front. In use the can is nearly filled with water, so as to overflow when the float is inserted, the reading being then taken with ease at the top of the liquid. For convenience and security two such floats and the can are packed together in a suitable case, and a supply of floats and thermometers, securely packed in saw-dust, is kept on hand to replace the broken ones.

The following table has been derived from the observations of the expansibility of sea-water, made by Prof. J. S. Hubbard, U. S. N. Column II contains a table of reductions for temperature of salinometer readings to the standard of 60° Fahr. To facilitate the use of this table the following directions are given:

Record the actual observation of hydrometer and thermometer. From Column II (which is applicable to any degree of saltiness within the given limits) take the number corresponding to the observed temperature and multiply this number by the number of degrees and fractions of a degree that the observed temperature differs from 60°. Apply this product as a correction, with proper sign, to the reading of the salinometer, and the result will be the reading of the salinometer at the standard temperature of 60° Fahr.

Example.—Actual reading of thermometer = 80°.5; actual reading of salinometer = 1.02425.

Opposite 80°.5 in Column II is +0.0001585, which multiplied by 20.5 gives as a product +0.003249. Add this to the observed reading of salinometer, and 1.02750 will result as the reading of the salinometer at the standard temperature.

Temp.	Coeff. for reduction to 60°.	Temp.	Coeff. for reduction to 60°.	Temp.	Coeff. for reduction to 60°.	Temp.	Coeff. for reduction to 60°.
°		°		°		°	
50	—0.000108	60	+0.000000	70	+0.000145	80	+0.000158
51	—0.000110	61	+0.000130	71	+0.000146	81	+0.000159
52	—0.000112	62	+0.000135	72	+0.000147	82	+0.000160
53	—0.000113	63	+0.000137	73	+0.000148	83	+0.000162
54	—0.000115	64	+0.000137	74	+0.000149	84	+0.000163
55	—0.000118	65	+0.000138	75	+0.000151	85	+0.000164
56	—0.000120	66	+0.000140	76	+0.000152	86	+0.000166
57	—0.000120	67	+0.000141	77	+0.000154	87	+0.000167
58	—0.000120	68	+0.000142	78	+0.000156	88	+0.000168
59	—0.000120	69	+0.000143	79	+0.000157	89	+0.000170

A method quite different in practice for determining the density of sea-water has been suggested by Prof. Wolcott Gibbs, of Harvard University. It depends upon the determination of the index of refraction by means of an angular instrument similar to the sextant. As all navigators are familiar with the use of the sextant, and as the observation can be made without hinderance from the motion of the ship, this form of the instrument may be found to possess certain advantages.

NOTE IN 1876.—When the table of reductions for temperature above given was constructed, the investigations relative to the same subject made by Thorpe and Rücker (Royal Society's Proceedings, January, 1876) were not known. The following comparison of the results of the experiments on the thermal dilation of sea-water, as taken from Professor Hubbard's tables and as derived from the results of Thorpe and Rücker, show the differences within the range of temperature covered by our table of corrections:

Temperature.	Volume.	
	Hubbard.	Thorpe and Rücker.
°		
50	0.99895	0.99902
55	0.99943	0.99946
60	1.00000	1.00000
65	1.00067	1.00059
70	1.00142	1.00127
75	1.00221	1.00205
80	1.00309	1.00280
85	1.00402	1.00364

An optical densimeter, invented by Professor Hilgard, was not made wholly available for use on board the "Blake" during the period of my command, but Professor Hilgard has been kind enough to prepare for this volume the following abstract of Appendix No. 11, Report of 1877, United States Coast and Geodetic Survey, in which the instrument is described.

HILGARD'S OPTICAL DENSIMETER FOR OCEAN WATER.

[From Coast Survey Report for 1877, Appendix No 11.]

The determination of the density of the ocean in different parts of the world, and at various depths, is admitted to be an element of the physical condition of our globe which it is important to determine with great precision. As the object of this notice is only to describe a new instrument for finding such densities, there is no occasion to discuss the importance of their ascertainment further than to consider the degree of precision requisite for useful results, and which can be reached by the instrumental means available on shipboard. Account is taken only of the density of ocean water uninfluenced by the immediate proximity of fresh-water streams. As the sensible effect of such is variable in different seasons and at different stages of the tide, no great precision in any single observation of the density of the water is useful, because the densities will differ sensibly in adjacent threads of the current, and the value can only be obtained by the average of a great number of observations of approximate accuracy. Ordinary hydrometer-floats ranging from the density of fresh water to that of ocean water, with a stem of three inches graduated from 1.000 to 1.030, will sufficiently serve such experimental purposes. When, however, we get away from such local conditions, and inquire into the general regimen of the ocean, affected in part by the fresh-water outflow from the continents, but mainly by the general thermal circulation, it becomes important to measure the differences of density with the greatest precision that can practically be obtained.

These considerations are equally important with regard to the density of ocean water in different parts of the surface and at various depths. If the specimens secured could be preserved without sensible change until they could be opportunely submitted to a laboratory investigation, the task of the naval officer would be reduced to collecting specimens and hermetically sealing them up, but it is reasonably to be supposed that he would have a desire to ascertain the results for himself.

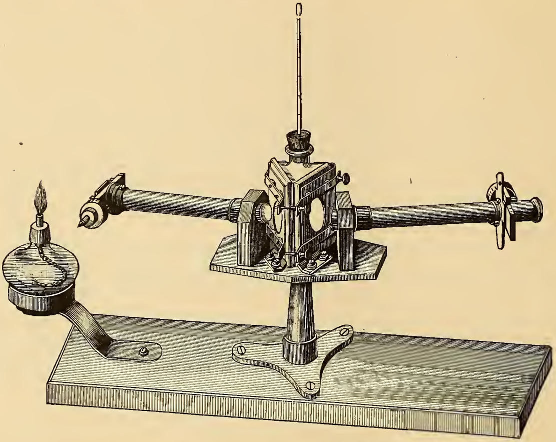
The want of suitable instruments has been met to a certain degree by hydrometers (which might properly be called "*stem floats*") specially adapted to sea-water. This method of ascertaining the density does not, however, admit of great precision on shipboard, because the float partakes of the movements of the vessel, and oscillates between wide limits—wider in proportion to its sensitiveness. and generally uncomformable to the oscillations of the ship. Hence it becomes very difficult to read the average position of the float with a sufficient degree of precision, unless the sea be exceptionally calm.

The average density of the ocean properly speaking, unaffected by local causes, will not vary, when reduced to a common temperature, more than one-thousandth part from the average value. It is therefore necessary, in order to obtain any useful results, that the density should be ascertained to at least one-ten-thousandth part of the whole, or practically a unit in the fourth decimal place. Now, a hydrometer or *stem-float* of that degree of sensibility, while perfectly available on shore, is so susceptible of the movements of the vessel as generally to render observations quite impracticable on shipboard. For this reason it has been deemed advisable to abandon that most direct mode of ascertaining the density, and to resort to other means offered us by physical science.

With this view, the optical densimeter, described below, has been devised, which obviates all the difficulties arising from the movement of the vessel. The basis of this instrument is the change in the refractive power of a saline solution of greater or less density. The instrument consists, substantially, of a hollow prism filled with the water under observation, transmitting from a collimating telescope a line of monochromatic light to an observing telescope in which the refracted position of that line is read by means of a micrometer. The monochromatic light employed is a sodium flame, obtained by adding a small proportion of a solution of common salt to the alcohol of the lâmp. The accompanying illustration exhibits the instrument in the proportions that have been found advantageous. The temperature of the liquid under observation is found by means of a thermometer inserted through the neck of the hollow prism, but which is withdrawn when the optical observation is made.

The glass prism rests on three little knobs, so as to have a firm support. Attached to the stand carrying the telescopes are two guides, by means of which the prism is made always to occupy exactly the same position, so that all observations are made under the same angle. A small thumb-screw on the side of the prism, not seen in the plate, forces the prism closely into the guides.

It is obvious that the sensibility of this apparatus is not affected by the movements of the vessel, and that its power of measurement might be increased by either enlarging or increasing the power of the telescopes, or by introducing an additional prism. But it will be seen at once that the practical accuracy is limited to the ascertainment of the temperature at which the observation is made.



E.—HILGARD'S OPTICAL DENSIMETER.

Now, at the average temperature at which such observations would be made—say 68° F. or 20° C.—a change of one degree Fahrenheit causes a change of specific gravity of about 0.0002, and since we cannot expect to ascertain the temperature more correctly than within two or three tenths of a degree Fahrenheit, it is obvious that any attempt to ascertain the density more nearly than 0.00006 would prove futile on that account.

The observations made with the optical densimeter show that a single determination by this instrument possesses that degree of accuracy, and any greater degree of refinement would be lost in the uncertainty of the physical conditions of the specimen.

The reading of distilled water being a fixed point on the scale of reference, it is not necessary to observe distilled water for every determination. A frequent check should, however, be made of the constancy of this reading.

The following will serve as an example of record and reduction of observations:

No. of sample.	Latitude and longitude.	Depth in fathoms.	Date of taking.	Date of observation.	Micrometer readings.	Temp., Fahr.	Reduced micrometer reading.	Difference of micrometer.	Specific gravity at 60° F.
Distilled water.				June 28	274.8 75.4 75.1 76.1 275.2	70°			
					275.3		302.5		1.00000
28	37¼ N. 72½ W.	100	June 22	June 28	655.0 54.6 54.3 54.8 653.9	71°			
					654.5		690.5	388.0	1.02769
29	37¼ N. 72½ W.	50	June 22	June 28	658.0 59.1 58.2 57.3 658.1	70°			
					658.3		690.6	388.1	1.02770

SERIAL WATER TEMPERATURES; HOW TAKEN.

As has been shown in Chapter I, obtaining serial water temperatures was a very important feature of our work. The instrument used by us was the Miller-Casella deep-sea maximum and minimum thermometer. The readings were first recorded in a book containing forms like that shown below, and were afterwards transferred to the General Record, Form 3, given in Chapter VI.

FORM 2.

U. S. COAST SURVEY STEAMER *"BLAKE"*

Locality, ——. Date, ——, 18—. Sounding No. —. Line, —.

Depth, in fathoms.	Temperatures.								Remarks.
	Reading.		Correction.		Corrected.		No. of the Thermometer.	Kind of Thermometer used.	
	Min.	Max.	Min.	Max.	Min.	Max.			
Surface.									Temperature of Air__________ Temperature of Thermometer-locker__________________

Signature of the Officer of the Deck:____

Signature of the Recorder:____

All bottom temperatures were taken by attaching a thermometer to the stray-line of the sounding-wire, or to the sounding-rope just above the sinker. Those at intermediate depths were obtained, for the first three years, with the aid of a hemp rope of one and one-half inches or one and three-fourths inches circumference, called the temperature-rope. This rope, when we were at work, was kept laid down upon the quarter-deck in long coils or fakes, with the greatest diameter athwartships, each fake only partially covering the preceding one; in which way the fakes were gradually worked along the deck for a considerable distance, forming a worm. This method we adopted from Commander Howell's practice, and it was found to work admirably, one man being able to manage the coil handily at a very rapid rate of reeling in. The chief advantage derived was the free circulation of air about the various parts. Our upper-deck being painted, we had no trouble in keeping the rope in good condition for a long time. The size of the rope was larger than necessary for the purpose of taking temperatures, but we also used it for sounding in depths less than one hundred fathoms; made it serve as an anchoring-line for a boat when taking current observations, and have even anchored the vessel by it, with a kedge, for short times. One-inch hemp rope would suffice for taking temperature observations and for obtaining water specimens. The temperature-rope, weighted with a fifty-pound lead sinker, was payed out through a snatch-block hooked to a swivel-eye in the end of an iron crane, the crane being shipped into a socket on the vessel's rail, over the bowsprit. (Plate 24.) Thermometers and water-cups were attached to the rope at intervals as desired. The descent of the rope at any stage could easily be checked and stopped by two or three men. The system of marking this rope was very simple. It is given from memory.

To one hundred fathoms the marks were the same as are in general use for lead-lines; after that, as follows:

At 100 fathoms, 1 white rag.
At 200 fathoms, 2 white rags.
At 300 fathoms, 3 white rags.
At 400 fathoms, 1 red rag.
At 500 fathoms, 2 red rags.
At 600 fathoms, 3 red rags.
At 700 fathoms, 1 blue rag.
At 800 fathoms, 2 blue rags.
At 900 fathoms, 3 blue rags.

At 1,000 fathoms, 4 white rags.

Intermediate fathoms were marked by using pieces of soft leather punched through with a large hole one-half inch in diameter, or small holes one-quarter inch in diameter, or both; thus—

At 10 fathoms, 1 small hole.
At 20 fathoms, 2 small holes.
At 30 fathoms, 3 small holes.
At 40 fathoms, 4 small holes.
At 50 fathoms, 0 small hole, 1 large hole.
At 60 fathoms, 1 small hole, 1 large hole.
At 70 fathoms, 2 small holes, 1 large hole.
At 80 fathoms, 3 small holes, 1 large hole.
At 90 fathoms, 4 small holes, 1 large hole.

The marks throughout the length of each succeeding 1,000 fathoms were a repetition of those of the first 1,000 fathoms, excepting that the service or navigational marks, as on the outer one hundred fathoms, were not repeated, the leather tallies being used instead.

If marks were needed only at every twenty-five fathoms, the fifty, one hundred, and 1,000-fathom marks might be retained as given, and a knotted piece of cod-line, or other small stuff, used for the twenty-five and seventy-five-fathom marks.

The leather tallies are very distinct at night, holes being more readily distinguishable than color by the light of a lantern, but the trouble with them—and with all other pendent marks in long-continued use—is their liability to be frayed or torn off in passing through blocks or over winch-heads; it would, therefore, be a convenience to dispense with marks and pay out over a measuring pulley.

For taking serial temperatures in the season of 1877–'78, we fitted out with 1,000 fathoms of one-eighth inch diameter steel-wire rope, having a hemp heart. This was wound upon an iron drum or reel controlled by a friction-brake. (F, Figs. 1 and 2, Plate 29.) On the axle of the reel was a **V**-groove pulley for connecting by a rope belt with the main hoisting-engine, for reeling in. It will be shown hereafter how, during this season, we reeled in our heavy wire dredge-rope by taking it around a winch-head of the engine "*on the bight*," whence it was passed to the reel. This was inadmissible with the smaller rope, owing to its greater tendency to kink when released from tension; consequently it had to be taken directly upon the reel after passing in over the leading-block at the end of the crane. With the wire rope we could work with great rapidity, but its vibration in the water was so decided that it sometimes had the effect of displacing the indices in the tubes of the Miller-Casella thermometers; hence we were not sorry when the rope parted while we were taking serial temperatures in a heavy sea. It was supposed to have a breaking strain of 1,900 pounds, but it parted when only five hundred fathoms had been payed off the reel, although a short time before we had taken a cast and bottom temperature in over 1,500 fathoms, without the least trouble, by means of the piano-forte wire.

Doubtless the marks worked through between the strands may have weakened the steel temperature-rope somewhat in places, but it is probable that steel rope of such small size—needing to be made of very small wires to secure flexibility—cannot be depended on to withstand the violence of deep-sea work for any great length of time, as the strength of the wires will soon become impaired by corrosion. I think steel rope of one-fourth inch diameter, with a hemp heart, would serve for a temperature-rope, particularly if used in connection with an accumulator having enough elastic movement to afford a slight cushioning.

After parting our steel temperature-rope, serial temperatures were taken with the aid of piano-forte wire during the remainder of the season, a spare sounding-reel being used for the purpose and no accidents happening.

During our first season, when working in very deep water, we usually took the sounding and the temperatures at the same time, sounding from the bow and lowering the thermometers from the gangway. This we did without trouble; but in the next season, south, we twice fouled the wire with the rope in strong currents, after which we did not attempt serial temperatures until the sounding had been completed.

Commander Bartlett has used the steel dredge-rope for taking serial temperatures.

The instrument next to the Miller-Casella most generally used for finding sub-surface temperatures is a recent form of Negretti and Zambra's deep-sea thermometer.

DESCRIPTION OF THE MILLER-CASELLA DEEP-SEA THERMOMETER.

(Plates 21, 22.)

A glass tube bent in the form of **U** is fastened to a vulcanite frame, and to the latter are screwed white glass slabs containing the graduated scales. Each limb of the tube terminates in a bulb. A column of mercury occupies the bend and a part of the capillary tube of each limb. The large bulb and its corresponding limb, above the mercury, are wholly filled with a mixture of creosote and water; the opposite limb above the mercury is partially filled with the same mixture, the remaining space therein being occupied by compressed air. In the mixture on each side is a steel index having a horse-hair tied around it near the upper extremity. The ends of the elastic horse-hair being held in a pendent position by the inner walls of the tube exert enough pressure to oppose a frictional resistance to a movement of the index in elevation or depression. As thus described, the instrument is a self-registering maximum and minimum thermometer for ordinary use. The indications are given by the expansion and contraction of the creosote and water mixture in the large, full bulb. The instrument is set by bringing the lower ends of the indices in contact with the mercury by means of a magnet provided for the purpose. Then, when the instrument is submitted to a higher temperature, the expansion of the mixture in the large bulb depresses the column of mercury on that side and correspondingly elevates it on the other side. A decrease of temperature contracts the mixture in the large bulb, and by the elastic force of the compressed air in the smaller bulb a transference of the column of mercury takes place in precisely the reverse manner to that which occurs on a rising temperature. Thus the mercury rises in the left limb for a lower and in the right limb for a higher temperature. The greater the change of temperature the higher the point reached in the respective limbs; hence the scale on the left is graduated from the top downwards, and that on the right from the bottom upwards. The rising of the mercury in either limb carries with it the index of that limb, and on

PLATE 21.

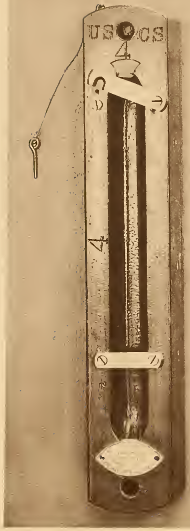


FIG. 1. FIG. 2. FIG. 3.

FIG. 1. CASE FOR THE NEGRETTI-ZAMBRA DEEP-SEA THERMOMETER.
FIG 2. THE NEGRETTI-ZAMBRA DEEP-SEA THERMOMETER, BULB DOWN.
FIG. 3. THE MILLER-CASELLA DEEP-SEA THERMOMETER APART FROM ITS CASE.

Heliotype Printing Co., 220 Devonshire St., Boston.

the retreat of the mercury the index remains at the highest point reached. The bottom of the index, being the part which has been in contact with the mercury, gives the point at which to take the reading.

It was found that instruments made as described were liable to considerable error, in excess, amounting sometimes to as much as ten degrees in deep casts, due to the pressure of the water; the pressure, by compressing the large, full bulb, forced part of the contents into the capillary tube, producing the same result as an increase of temperature.*

In April, 1869, Dr. D. A. Miller, vice-president of the Royal Society, proposed surrounding the larger bulb by another bulb, the latter to provide a shield for the former. All thermometers styled Miller-Casella are constructed with this outer bulb, which is fused to the stem or capillary tube just below the inner bulb. The space intervening between the two bulbs is nearly filled with alcohol, a small portion or bell containing only rarified air and the vapor of alcohol. The space filled by the air and vapor receives any of the spirits that may be displaced by the compression of the outer bulb. Thus the inner bulb is almost wholly relieved from pressure, and the alcohol serves as a medium for the transmission of temperature. Dr. C. Wyville Thomson, now Sir C. Wyville Thomson, estimated from the results of experiments with a number of the protected instruments that their mean error due to pressure was as follows:

For 250 fathoms, 0°.079 C. (=0°.142 F.).
For 2,500 fathoms, 0°.79 C. (=1°.42 F.).

These, if applied as corrections, are subtractive.

Of thirty-six Miller-Casella thermometers recently purchased by the Coast and Geodetic Survey, the mean error of all due to a pressure of three and one-half tons was 1°.1 Fahrenheit, as ascertained by the makers. The greatest single error was 1°.7 and the least 0°.6.

The instrument attached to its frame is kept, both for stowage and use, in a perforated copper case. As provided by the manufacturers the case must be attached to the rope by stops, but all of the "Blake's" cases are fitted with the spring-clamp shown on Plates 2 and 3.

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* For an interesting and instructive description of the Miller-Casella thermometer, see "Depths of the Sea," by Dr. C. Wyville Thomson, pp. 288–299.

The Miller-Casella thermometer is made by L. Casella, scientific instrument maker, 147 Holborn Bars, London, E. C. The catalogue price of the instrument is £2 5*s*., with case and magnet.

REMARKS CONCERNING THE MILLER-CASELLA THERMOMETER.

There can be but little doubt that the Miller-Casella thermometer, when properly managed, gives in most cases a close approximation to the temperature of the depth to which it has been lowered, but the immobility of the indices, after the retreat of the mercury, being dependent on friction alone, is not absolutely assured, and herein, perhaps, lies the chief objection to the instrument. There is nothing in its appearance to point out an error in this respect when it has occurred. The only safeguard, when but a single instrument is used for each depth of a series, is to compare carefully the indications at the same or different series of observations, the surest means of doing this effectually being to construct curves like those shown on Form 14 (Chapter VI).

When all the indications of a set of serial observations are correct the gradients of the curve sometimes change rapidly, but a decided angular deviation from the general contour of the curve is perhaps nearly always due to an erroneous record by the instrument.

Sometimes a particle of mercury gets above an index, or one of the latter becomes immersed in the mercury; an index becomes jammed in the tube, or the column of mercury breaks. These are mere accidental defects, which, being apparent to the eye, point directly to an error, and they may in most cases be remedied on board the vessel.

When a particle of mercury gets above an index the latter may be drawn by the magnet into an enlargement or swelling of the tube, which all of these thermometers have just below each bulb; the mercury will then fall clear. When a column of mercury breaks, its integrity may be restored by placing the instrument in warm water or by gently tapping the bottom of the frame against some resisting substance, both of which methods require caution. On one occasion, in my experience, when the water was too warm there was a general disturbance inside the tube, which ruined the instrument; it was, perhaps, caused by part of the compressed

PLATE 22.

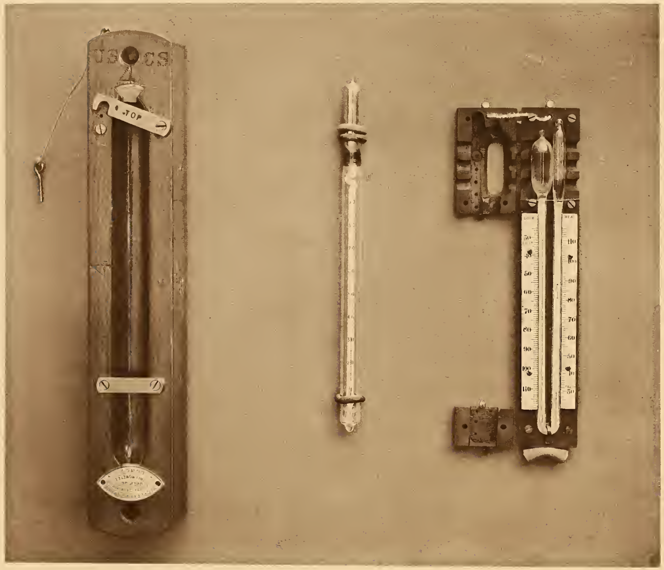


FIG. 1. FIG. 2. FIG. 3.

FIG. 1. CASE FOR THE NEGRETTI-ZAMBRA DEEP-SEA THERMOMETER.
FIG 2. THE NEGRETTI-ZAMBRA DEEP-SEA THERMOMETER, BULB UP.
FIG 3. THE MILLER-CASELLA DEEP-SEA THERMOMETER, WITH THE BULBS EXPOSED

Heliotype Printing Co., 220 Devonshire St., Boston

air being carried by expansion into the opposite limb. The tube is almost certain to become loosened on the frame by the tapping process, which reminds me of a detail in the construction of the instrument that brings about much annoyance. The fastening which is intended to hold the tube in place on the frame is a soft copper band passing half around the tube at the bottom of the bend and fastened only *by one end* to the frame. The object of this is probably to allow for the expansion of the glass, and to give a slight cushioning—enough to prevent the tube from breaking in the event of a violent shock such as would be caused by the case striking on hard bottom, but in prolonged work—or in tapping the frame—it permits the shifting of the scale, sometimes as much as 1½°.

For several years after construction thermometers undergo a change which results in a displacement or "*elevation*" of the zero point, sometimes amounting to as much as 2°, making the indications too low. There is a scratch on the tube of the Miller-Casella thermometer at or near the freezing point, and others at intervals of 20°. These are probably made in the process of calibrating the tube. Should the scale shift, the scratch nearest the freezing point, or any other, may be made use of to effect a readjustment, if the point on the scale to which it corresponds has been previously ascertained.

On board the "Blake" all attempts to extricate an index which had become immersed in mercury were unsuccessful. An index jammed in the tube may sometimes be cleared by alternately tapping the frame and using the magnet. If it can be drawn up into the enlargement of the tube already mentioned it may be found in working order when again drawn down. Tapping the frame or swinging it about the head for the same purpose should not be allowed except as a last resort, and then only in the presence of the person charged with the care of the instruments, who should verify the correctness of the scales afterwards.

A great advantage afforded by the Miller-Casella thermometer is its adaptability to collective use; that is, it may be used to obtain temperatures at various depths at a single haul, by employing it in any number desired, one or more at the several depths of a series. Although the instrument sometimes records erroneously through the disturbance of the index, several of them lowered to the same depth would, by checking each other, make the probability of error in this respect very remote.

Under certain relative thermal conditions of air and water a maximum and minimum thermometer may not give trustworthy indications when set as usual—that is, at air temperature. We will consider an actual case from the "Blake's" work:

	°
Air	51
Water:	
Surface	71
50 fathoms	63
100 fathoms	60½
200 fathoms	50
700 fathoms	39½

The indices of all the instruments are set at 51°, the temperature of the air. The instruments at fifty and one hundred fathoms will not indicate the temperature of their respective depths by the minimum scale, because the mercury in the minimum limb will retreat from the index in water which is of a higher temperature than that at which the instruments were set. The maximum scale may give true indications at those depths if in the passage of the instruments through the warmer upper strata the indices are not carried above 63° and 60½° respectively. This is merely a case at hand, but it shows that other cases might arise in which much would be left to conjecture.

The way in which we managed to make the Miller-Casellas serve our purpose in this and similar instances was to immerse them in warm water, raising their temperature considerably above that of the air; then, after setting them while in the warm water, to attach each in turn quickly to the rope and lower it at once into the sea. The minimum scales then gave acceptable readings. The case already presented is a representative one of a class, and a general rule may be stated as follows: The temperature of a stratum which is at once colder than the strata above and warmer than the air will not be indicated at all by the minimum scale, and often only with uncertainty by the maximum scale.

From what has been said it is seen that a maximum and minimum thermometer is not well adapted to ascertaining the temperature of intermediate warm or cold strata.

An important matter to know when using any thermometer in deep-sea operations is the time that it requires to take up any change of temperature. The Miller-Casella thermometer, being protected by the outer bulb, is sluggish in its action, particularly as its indication nears the temperature of the surrounding medium. Commander Lester A. Beardslee, U. S. N., made a series of experiments with the Miller-Casellas while on duty with the Commission of Fish and Fisheries. Through the courtesy of Prof. Spencer F. Baird, Commissioner, I am enabled to give one of Commander Beardslee's tables.

In each case the Miller-Casella and a standard were simultaneously placed in a bath, the temperature of which was lower than the temperature indicated by the instrument at the instant of immersion. Commander Beardslee thus describes the standard thermometer used for comparison:

> "A mercurial standard, made by L. Casella, of London, No. 7432, reading from zero up to 120°, on a scale marked on the glass, and twelve inches long, giving 10° to the inch; bulb cylindrical, .75 of an inch in length. No mounting."

Concerning the ice-bath tests, the last two of the series, he says:

> "In test No. 1, in ice, the instrument (Miller-Casella) was placed on its back in a trench cut in the ice, and the bulbs covered with pounded ice. The mercury corresponded in its action very closely to the action of a bath of 50° until it reached that point.
>
> "In test No. 2 the upper portion of the ebonite guard was removed, thus letting the crushed ice come into immediate contact with the upper portion of the bulbs. This induced quicker action, but still slower than a bath of 35°, and at last, as in former cases, the mercury apparently ceased to fall at 35°."

These and other experiments with the Miller-Casellas, by Commander Beardslee, are given in Appendix C, Report of the Commissioner of Fish and Fisheries for 1877, Prof. Spencer F. Baird, Commissioner.

Experiments with Miller-Casella No. 1844.

Time interval.	Bath, 60°.		Bath, 55°.		Bath, 50°.		Bath, 45°.		Bath, 40°.		Bath, 35°.		Ice-bath, 32½°.		Ice-bath, 32½°.	
	Standard.	Miller-Casella.	Standard.	Miller-Casella.	Standard.	Miller-Casella.	Standard.	Miller-Casella.	Standard.	Miller-Casella.	Standard.	Miller-Casella.	Standard.	Miller-Casella.	Standard.	Miller-Casella.
m. *s.*	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0 00	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
0 20	60.0	68.2	55.0	67.5	50.0	68.0	45.0	67.5	40.0	66.5	35.0	64.5	38.0	67.5	32.5	66.0
0 40	60.0	67.5	55.0	64.5	50.0	65.0	45.0	64.5	40.1	63.1	34.6	58.5	32.5	65.0	32.5	61.2
1 00	60.0	66.5	55.0	62.5	50.2	63.0	45.0	62.0	40.2	59.8	34.6	54.5	32.5	63.5	32.5	57.5
1 20	60.0	66.0	55.0	60.5	50.2	61.0	45.0	59.5	40.2	56.9	34.6	50.0	32.5	61.8	32.5	54.0
1 40	60.0	65.0	55.0	59.2	50.5	59.5	45.0	57.8	40.2	54.5	34.6	48.0	32.5	60.2	32.5	52.0
2 00	60.0	64.5	55.0	58.2	50.2	58.2	45.0	56.0	40.2	52.4	34.6	46.0	32.5	59.0	32.5	50.0
2 20	60.0	64.0	55.0	57.5	50.5	57.0	45.0	55.0	40.0	50.1	35.0	44.5	32.5	58.0	32.5	48.0
2 40	60.0	63.5	55.0	57.0	50.5	56.6	45.5	54.0	40.0	49.4	35.0	43.5	32.5	57.0	32.5	46.8
3 00	60.0	63.0	55.0	56.6	50.5	55.0	45.0	53.0	40.1	48.1	35.0	42.0	32.5	56.2	32.5	46.6
4 00	60.5	62.0	55.2	56.0	50.0	53.2	45.0	50.2	40.2	46.3	35.0	40.5	32.5	54.0	32.5	44.8
5 00	60.5	61.8	55.2	55.6	50.2	52.6	45.0	48.8	40.2	44.0	34.6	37.0	32.5	52.0	32.5	40.0
6 00	60.5	61.5	55.0	55.2	50.4	52.2	45.0	47.5	40.2	42.2	34.6	35.5	32.5	50.5	32.5	38.8
7 00	60.5	61.2	55.0	55.0	50.0	51.8	45.0	47.0	40.0	41.8	34.8	35.0	32.5	49.0	32.5	37.5
8 .00	60.5	61.0	55.0	55.0	50.0	51.2	45.0	46.0	39.8	41.2	34.5	35.0	32.5	47.5	32.5	37.2
9 00	60.5	61.0	55.0	55.0	50.2	51.2	44.8	46.0	39.0	40.6	34.5	34.5	32.5	46.2	32.5	36.8
10 00	60.5	61.0	55.0	55.0	50.4	51.0	45.0	45.8	39.5	40.2	34.5	34.5	32.5	45.0	32.5	36.5
11 00	------	------	------	------	50.4	51.0	45.0	45.8	40.0	40.0	34.5	34.5	32.5	43.0	32.5	36.2
12 00	------	------	------	------	------	------	45.0	45.8	40.0	40.0	------	------	32.5	42.2	32.5	36.0
13 00	------	------	------	------	------	------	45.0	45.8	40.0	40.0	------	------	32.5	40.5	32.5	35.4
14 00	------	------	------	------	------	------	------	------	------	------	------	------	32.5	39.5	32.5	35.0
15 00	------	------	------	------	------	------	------	------	------	------	------	------	32.5	38.5	32.5	35.0
20 00	------	------	------	------	------	------	------	------	------	------	------	------	32.5	38.0	32.5	35.0
22. 00	------	------	------	------	------	------	------	------	------	------	------	------	32.5	35.6	32.5	35.0
25 00	------	------	------	------	------	------	------	------	------	------	------	------	32.5	35.1	32.5	35.0
														35.2	------	------

It should be remembered that a thermometer in actual use at sea is recording during the descent, which may be taken into account in time allowance. It will also register changes more quickly when passing through water than when resting in a still bath.

DESCRIPTION OF NEGRETTI & ZAMBRA'S DEEP-SEA THERMOMETER.

(Plates 21, 22, and 23.)

The following description of this thermometer is copied from the catalogue of the makers, Messrs. Negretti & Zambra, Holborn Viaduct, London, E. C. This is done for convenience, not necessarily as an expression of my opinion. The few words interpolated by me are inclosed in brackets.

The letters of reference employed in the catalogue, being only three in number, are retained, although the plates given in this book are not lettered.

Negretti & Zambra's thermometer in a very different shape was sent us for trial, on board the "Blake," during the early part of my command, but it was so cumbersome, expensive, and left so much open to doubt in its indications, that it was reported on adversely to the Superintendent of the Coast and Geodetic Survey. Since then the makers have issued it in a shape that seems to promise much in the way of correct results. It is still open to some improvement, even for taking a single temperature at a haul, and it cannot be used collectively like the Miller-Casella, although it is probably more trustworthy when used singly. This late form of the instrument has been used in the Caribbean Sea and Passages by the "Blake" under the command of Commander Bartlett, and also in the Arctic Sea by the Norwegians.

"The construction of this thermometer will be readily understood by reference to [Plates 21 and 22]. The bulb is cylindrical, and mercury is the thermometrical fluid. The neck of the bulb is contracted in a peculiar manner at A [immediately below the bulb], and upon the shape and fineness of this contraction the success of the instrument mainly depends. Beyond A the tube is bent, and a small catch reservoir is formed at B [in the bend], for a purpose to be presently explained. At the end of the tube a small receptacle, C, is provided. When the bulb is downward the glass contains sufficient mercury to fill the bulb, tube, and a part of the receptacle C, if the temperature is high, leaving sufficient space in C. When the thermometer is held bulb upward the mercury breaks at A, but by its own weight flows down the tube, filling C and a portion of the tube above C in relation to the existing temperature. The scale accordingly is made to read upwards from C. To set the instrument for observation it is only necessary to place it bulb downward, then the mercury takes the temperature just as an ordinary thermometer. When at any time or at any place the temperature is required, all that has to be done is to turn the thermometer bulb upward and keep it in this position until read off. The reading may be taken at any time after, for the quantity of mercury in the lower part of the stem which gives the reading is too small to be sensibly influenced by a change of temperature, unless it is very great, while that in the bulb will continue to contract with greater cold and to expand with greater heat, and in the latter case some mercury will pass the contraction A and may fall down and lodge at B [in the catch reservoir], but it cannot go further so long as the bulb is upward, and thus the temperature to be read off will not be vitiated. Now, whenever the thermometer can be handled it can readily be turned bulb upward for reading off the existing temperature. It must be clearly understood that the thermometer is only intended to give the temperature at the time and place when and where it is turned over; it is simply a recording thermometer; it cannot be used as a self-registering maximum or minimum, though it could be constructed to act as a maximum if required. But at a depth in the sea some contrivances must be provided for turning the thermometer bulb upward. For this purpose the thermometer is fitted into a wooden frame, loaded with shot, free to move from end to end of it, and heavy enough to render the whole instrument just buoyant in sea-water.

"In using the thermometer a cord is rove through the hole in the frame nearest the bulb, and the instrument is fastened by this cord to the sounding-line. In descending the thermometer will be pulled down with the bulb downwards [Fig. 1, Plate 23], but upon being pulled up the instrument, owing to the resistance through the water, and consequent displacement of its center of gravity, will turn over and come up bulb uppermost [Fig. 2, Plate 23]; the temperature of the spot where it turned over will then be indicated.

"As regards the thermometer itself, it was necessary, in order to make it perfectly satisfactory, to protect it against pressure, even if intended for shallow seas as well as for the deepest. For whether used in deep or shallow water, unless withdrawn from pressure, its indications would always be more or less in error. Like an ordinary thermometer, it is devoid of air, and so quite different from Sixe's, which, containing compressed air, has a certain internal resistance. Hence it would be more affected by pressure than Sixe's, however thick the glass of the bulb. By the simple expedient of placing the thermometer entirely in a shield of glass hermetically sealed the effect of external pressure is entirely eliminated. The shield must, of course, be strong. It need not be exhausted of air. It must, however, render the enclosed thermometer more difficult to be affected by changes of temperature; in other words, it will make it sluggish.

"To counteract this sluggishness in that portion of the shield surrounding the bulb some mercury is introduced and confined there by a partition cemented in the shield around the neck of the thermometer bulb. This mercury acts as a carrier of heat from the exterior of the shield to the interior of the thermometer; and the efficacy of this arrangement has been experimentally determined, the instrument thus protected being, in fact, far superior in sensibility to Sixe's thermometer.

"So long as the shield withstands the pressure—that is, does not break—the thermometer will be unaffected by pressure, and there is abundant experience to show that such a shield will stand the pressure of the deepest ocean. The greatest pressure can never affect a thermometer so protected. Doubtless the shield will be compressed a little under great pressure, but this can never exert an internal pressure sufficient to have an appreciable effect upon the thermometer. This method of shielding is quite efficacious, and deep-sea thermometers so protected do not require to be tested for pressure in the hydraulic press. The thermometer will simply require to be tested for sensitiveness and for errors of graduation very accurately, because it is a standard instrument adapted to determine very small differences of temperature as well as large ones, even one or two tenths of a degree in shallow waters. The test for sensitiveness should determine how many seconds the instrument requires to take up a change of five degrees rise or fall, and the time has been found from five to ten seconds.

"A considerable number of these instruments have already been tested at the Kew Observatory with perfectly satisfactory results, which place beyond doubt their value as standard deep-sea thermometers.

"Thus, provided the turning-over gear is found to answer, this instrument evidently possesses great advantages. It has no attached scale, the figuring and graduations being distinctly marked on the stem itself, and the shield effectually preserves them from obliteration by sea-water. The part of the stem which forms the background to the graduations is enameled white to give distinctness to the mercury.

"The hole at the top of the frame is for the purpose of lowering and keeping the thermometer upright until it has reached the water. This is effected by putting a cord through the hole and both ends of it kept in the hand until the thermometer has reached the water, then one end is let go and the cord pulled on board. This operation is not imperative, but it saves the thermometer from being knocked about previous to reaching the water.

"Price for Negretti & Zambra's new patent standard deep-sea thermometers, £2 10*s*."

REMARKS CONCERNING NEGRETTI & ZAMBRA'S THERMOMETER.

Previous to their use on board the "Blake" Prof. Spencer F. Baird had used them in the work of the Commission of Fish and Fisheries as deep as two hundred fathoms, and thought highly of them.

Commander Bartlett, while thinking well of them, found that their wooden cases when recovered from eight hundred fathoms were compressed and shriveled. The pressure at eight hundred fathoms is about one ton on a square inch. Prof. J. E. Hilgard suggests that the wooden case might be replaced by a case of thin metal, filled with paraffine.

The Superintendent of the Coast and Geodetic Survey wishing to make a preliminary trial of them in actual use in advance of reports from Commander Bartlett, a few experiments were carried out by Lieut. S. M. Ackley, commanding the Coast Survey schooner "Eagre." The following describes some of these experiments:

Experiment No. 1.—Lower the mercury to freezing point (32°), then reverse, bringing the bulb uppermost. While retained in that position submit the instrument to a temperature of about 85°. Note if the catch reservoir wholly or partially fill, and if it overflow at what temperature as indicated by the instrument.

Report.—"The catch reservoir partially filled but did not overflow."

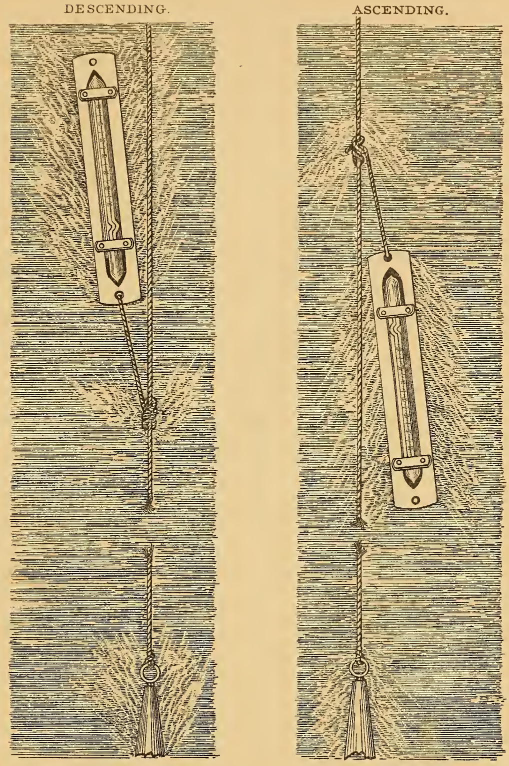


Fig. 1 Fig. 2

THE NEGRETTI-ZAMBRA DEEP-SEA THERMOMETER IN USE.

An instrument in the ascent from deep water will pass through water of a higher temperature than that in which it reversed; hence the catch reservoir will contain some mercury on arriving at the surface. In experiment No. 1 a temperature higher than 85° might have been chosen, but other experiments have shown that the catch reservoir will not be made to overflow by any higher temperature to which the thermometer would be exposed in work at sea.

Experiment No. 2.—With the catch reservoir partially filled, as in experiment No. 1, tilt the thermometer case and slap it roughly. Note if any of the contents of the reservoir pass down into the tube; also if the bulb discharge any more mercury into the reservoir under this treatment.

Report.—"None of the contents of the reservoir passed down into the tube. Bulb did not discharge more mercury into the tube."

Experiment No. 3.—Lower three Negretti & Zambra thermometers, attached as nearly as may be to the same place on the rope, to a depth of 500 fathoms, and haul back without stopping at that depth or at any point on the ascent. Note the indications given by each instrument.

Report.—"Instrument No. 4, 47°.5; instrument No. 5, 47°.5; instrument No. 6, 47°.5."

Experiment No. 4.—The same as experiment No. 3, excepting to delay seven minutes at the depth of 500 fathoms before hauling back.

Report.—"Instrument No. 4, 46°.2; instrument No. 5, 46°.2; instrument No. 6, 46°.2."

Experiment No. 5.—The same as experiment No. 3, excepting to delay seven minutes at 500 fathoms, and again seven minutes at 300 fathoms on the ascent.

Report.—"Instrument No. 4, 47°; instrument No. 5, 60°; instrument No. 6, 47°—*vessel drifted quite fast, so that the line was at an angle.*"

Experiment No. 6.—At that same station and in as limited a time as practicable take temperatures at 150, 300, and 500 fathoms, by a separate haul for each depth, without stopping on the ascent. Then with the same instruments take temperatures simultaneously at the same depths by using a separate thermometer, attached to the same rope, for each depth; this will require stoppages both in paying out and in hauling back for the purpose of attaching and removing instruments.

Report.—"Taken separately at 150 fathoms: Instrument No. 4, 68°; instrument No. 5, 67°.5; instrument No. 6, 68°.

"Same at 300 fathoms: Instrument No. 4, 54°.5; instrument No. 5, 54°; instrument No. 6, 54°.5.

"Same at 500 fathoms: Instrument No. 4, 46°.5; instrument No. 5, 46°.5; instrument No. 6, 46°.5

"Taken simultaneously: At 150 fathoms, instrument No. 4, 75°.5; at 300 fathoms, instrument No. 5, 59°.5; at 500 fathoms, instrument No. 6, 64°."

During the course of the experiments the vessel was pitching moderately.

The difference between the indications obtained at the separate casts in experiments Nos. 3 and 4 may have been partially due to the inclination of the line caused by the drifting of the vessel, the "Eagre" having no steam.

Experiments Nos. 5 and 6 show that a stoppage during the ascent is inadmissible, and that the thermometers must not be used collectively, in the sense in which I have employed that term.

In experiment No. 6, at the separate casts, instrument No. 5 gave a temperature 0°.5 lower than instruments Nos. 4 and 6, both at one hundred and fifty fathoms and at three hundred fathoms. Since all had agreed in the first and second experiments, it is highly probable that instrument No. 5 was somewhat defective in its construction, and that the column of mercury did not break at precisely the same point in the tube each time on reversal. Surgeon Jerome H. Kidder, U. S. N., assigned to duty with the Commission of Fish and Fisheries, found this defect in one or more of Negretti & Zambra's thermometers, but he was afterwards informed by Prof. H. Y. Hind that the makers had given assurances of greater correctness in the latter instruments.

It is uncertain how, in experiment No. 6, "*taken simultaneously*," the indications 75°.5, 59°.5, and 64° occurred, as each instrument would have been expected to give an approximate temperature of the depth at which the last stoppage was made on the ascent—one hundred and fifty fathoms =68°. Perhaps a short stoppage may have been made, inadvertently, as instrument No. 4 was near the surface, which would account for its indicating 75°.5. Instruments Nos. 5 and 6 evidently reversed at some intermediate point below one hundred and fifty fathoms, but not at that depth.

Dr. Kidder found that while most of the Negretti & Zambra deep-sea thermometers had been carefully calibrated, one or two notable exceptions occurred in his comparisons, in a single instance producing at one point of the scale an error as great as 2°.

The instrument is perfectly protected against pressure so long as the outer casing remains intact.

COMPARATIVE TEST OF THE MILLER-CASELLA AND NEGRETTI & ZAMBRA'S DEEP-SEA THERMOMETERS.

At my request, Prof. J. E. Hilgard had the following comparative tests for sensitiveness made at the Coast and Geodetic Survey Office by Mr. W. Suess.

Time.		Standard.	Time.		Miller-Casella.	Time.		Negretti & Zambra.
H.	M.		H.	M.		H.	M.	
		°			°			°
9	**24**	**40.0**	**9**	**28**	**40.0**	**9**	**25**	**40.0**
	30	**40.0**		**30**	**40.0**		**30**	**40.0**
	32	50.0					33	50.0
	34	**50.0**		**34**	**49.0**		**34**	**50.0**
	37	60.0					37	60.0
	38	**60.0**		**38**	**58.5**		**38**	**60.0**
	40	70.0		40	67.0		40	69.9
	42	**70.0**		**42**	**69.0**		**42**	**70.0**
	45	80.0		45	79.0		45	79.0
	46	**80.0**		**46**	**79.5**		**46**	**80.0**
	49	90.0		49	88.0		49	88.5
	50	**90.0**		**50**	**89.0**		**50**	**89.0**
	55	**90.0**		**55**	**90.0**		**53**	**90.0**
10	**00**	**90.0**	**10**	**00**	**90.0**	**10**	**00**	**90.0**
	02	80.0		02	83.0		02	80.0
	04	**80.0**		**04**	**81.3**		**04**	**80.0**
	06	70.0		06	74.0		06	70.0
	08	**70.0**		**08**	**72.0**		**08**	**70.0**
	10	60.0		10	63.0		10	60.0
	12	**60.0**		**12**	**61.8**		**12**	**60.0**
	14	50.0		14	53.6		14	49.9
	16	**50.0**		**16**	**51.1**		**16**	**49.9**
	18	40.0		18	46.5		18	40.0
	20	**40.0**		**20**	**42.5**		**20**	**40.0**
	24	**40.0**		**24**	**40.0**		**24**	**40.0**

The instruments used were a Casella mercurial standard (unprotected), No. 13416; a Miller-Casella deep-sea thermometer, No. 31488; and a Negretti & Zambra's deep-sea thermometer, No. 42665.

These instruments were placed in a bath of 40°, and at 9^h 30^m, when all had acquired the temperature of the bath, the experiment was carried forward. Readings were taken every four minutes, as shown by the large figures in the "time" columns. Immediately after each of these readings warm water was added in sufficient quantity to raise the temperature of the bath 10°. The small figures in the "time" columns show the readings of the several instruments at the instant the standard had acquired the changed temperature of the bath. After the standard had reached 90°, time was allowed for the deep-sea thermometers to acquire this temperature; then, at $10^h\ 00^m$ the character of the experiment was changed and the temperature of the bath was gradually lowered to 40°. The previous system of times and changes was adhered to, but the process was exactly reversed.

These tests show Negretti & Zambra's deep-sea thermometer to be more sensitive than the Miller-Casella deep-sea thermometer. If the former is as well protected against pressure as the latter, it is the better instrument in regard to the quality of sensitiveness.

A STANDARD THERMOMETER FOR COMPARISON; HOW TO SELECT ONE.

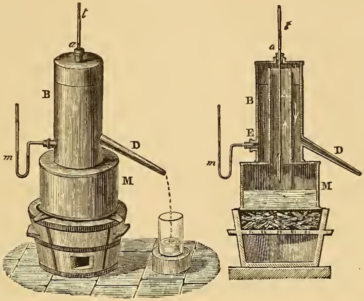
All thermometers should be compared with a standard when received for use on board ship, and the operation should be repeated from time to time.

It is well to provide a standard which has been thoroughly tested by an expert, but, if necessary, any mercurial thermometer of first quality, having wide divisions, a full-range scale marked on the tube, and which is known to be several years old, may be made to serve for the purpose by carefully verifying its graduation. An old thermometer should be chosen in order to avoid the "elevation of the zero point" that thermometers undergo for several years after manufacture.

The freezing and boiling points are the fixed points on which the whole graduation depends, and they may be tested with but little trouble.

Melting ice or snow always gives the point of freezing, 32° of the Fahrenheit scale. Provide any vessel which will hold a good quantity of crushed ice, and which will admit of an unobstructed escape of the water from the bottom. A copper cylinder with an inverted-cone bottom, having a hole in the apex, may be used; or an ordinary water-cooler open at the top and having a spigot at the bottom will suffice. Surround the thermometer with crushed ice nearly up to the mark of 32°, and let it stand there for fifteen minutes in a place having a temperature above 32°, for the ice must be in a melting condition. At the end of this time note the height at which the mercury stands. The point reached is that of 32°, or the freezing point.

Next the boiling point, 212° of the Fahrenheit scale, must be determined, and this is done by placing the thermometer in the vapor arising from boiling water. An apparatus and the method of proceeding are described in Ganot's Physics. The cuts and the text used herein for describing this part of the operation are copied from that work.



F.—APPARATUS FOR FIXING THE BOILING POINT OF THERMOMETERS.

"In both, the same letters designate the same parts. The whole of the apparatus is of copper. A central tube, A, open at both ends, is fixed on a cylindrical vessel containing water; a second tube, B, concentric with the first, and surrounding it, is fixed on the same vessel, M. In this second cylinder, which is closed at both ends, there are three tubulures, *a*, E, D. A cork, in which is the thermometer *t*, fits in *a*. To E a glass tube containing mercury is attached, which serves as a manometer for measuring the pressure of the vapor in the apparatus. D is an escape tube for the vapor and condensed water.*

"The apparatus is placed on a furnace and heated till the water boils; the vapor produced in M rises in tube A, and passing through the two tubes in the direction of the arrows, escapes by the tubulure D. The thermometer, *t*, being thus surrounded with vapor, the mercury expands, and when it has become stationary the point at which it stops is marked. This is the point sought for. The object of the second case, B, is to avoid the cooling of the central tubulure by its contact with the air."

In the following paragraph I quote from Ganot, but have changed his figures to suit the units of measure adopted in this book:

"The determination of the point 212° Fahrenheit would seem to require that the height of the barometer during the experiment should be thirty inches, for when the barometric height is greater or less than this quantity water boils either above or below 212°. But the point 212° may always be exactly obtained by making a correction introduced by M. Biot. He found that for every 0.6 inch difference in height of the barometer there was a difference in the boiling point of 1°. If, for example, the height of the barometer is 30.4 inches, that is, 0.4 inch, or two-thirds of 0.6 above 30 inches, water would boil at $212\frac{2}{3}$°. Consequently $212\frac{2}{3}$° would have to be marked at the point at which the mercury stops."

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*The glass tube may be dispensed with when a barometer is at hand, if there is a free escape for the vapor.

In the manufacture of thermometers the tubes are first tested to ascertain if the bore or chamber of the capillary tube is of the same caliber throughout its whole length. When a tube is found to be perfect in this respect, it only requires to be divided into one hundred and eighty equal divisions (212°–32°) between the boiling and the freezing points, that each division may correspond to one degree of temperature; but when the tube is not perfect it needs to be calibrated. In this process a short column of mercury being introduced into the tube, the latter is manipulated so that the mercury may be moved about from place to place. The length of the column at different localities is marked on the tube, which is thus divided into sections of equal capacity, although it may be of different length. Each section is then subdivided, independently, into degrees.

In selecting a standard the instrument should be tested for calibration thus: Hold the tube in a horizontal position over the flame of a spirit-lamp so that the heat may be concentrated on the tube at a point about an inch or more from the end of the column of mercury, or, better, direct the flame to that point with a blow-pipe, observing caution. In a short time remove the tube from the flame, and, still holding it horizontal, give it a slight motion as if throwing a dart, with the small end of the tube foremost. This will break the column of mercury at the heated point. Move the detached column about as in the process of calibration, noting at each change in its position the number of divisions that it spans. The number should be the same throughout if the tube has been properly calibrated in the manufacture. If any discrepancies are discovered, pursue the process until they are localized, and note the points and the quantity of error in a table. When the experiment has been carried as far as the main column of mercury, join the two portions and again break the column, this time detaching a greater length than before, which will permit the examination to be carried to a lower point on the tube. Continue the process by detaching in this way a greater length of mercury each time, until the whole range of the scale has been tested and the table of errors or corrections completed. It is plain that the operation may be facilitated by selecting a cool place in which to perform it, for when the mercury stands low in the tube the first length detached may be moved through a great part of the tube.

COMPARISON OF THERMOMETERS WITH A STANDARD.

The graduation of deep-sea thermometers not being carried above 130° Fahrenheit, the points on the scale that may be most accurately compared are the freezing point and that of water at about the temperature of the surrounding air. Any change of temperature of water under such circumstances would be very slow, thereby affording opportunity for a careful comparison. Several places having different temperatures might be occupied in turn, and a number of points tested in water with great nicety. A quiet place, free from draughts, should be selected.

The freezing point may be fixed independently by the melting-ice test; but by also placing the standard in ice the subsequent process of comparison may be somewhat shortened. Next make a bath of ice-water; remove the ice and immerse therein the standard and the instruments to be compared, keeping the bulbs on the same level. Let the water become gradually warmer, reading off from time to time; or the operation may be more quickly completed by occasionally adding a little warm water to the bath, which must be stirred almost constantly to preserve an even temperature throughout. Thermometers suitable for standards are much more rapid in acquiring the temperature of the surrounding medium than the Miller-Casellas, which, by being protected against pressure in the manner already described, are very sluggish, making their comparison a slow process.

Before reading off the Miller-Casellas the bath should be kept for a considerable time at the same temperature by adding ice-water or warm water in small quantities, as occasion may require, and stirring vigorously.

In reading off the indications the question of parallax must be considered, and the eye placed on a level with the top of the column of mercury.

DETERMINATION OF SURFACE AND SUB-SURFACE CURRENTS.

The demands of the more prominent features of the "Blake's" work permitted only a few observations for the determination of sub-surface currents, but for those at the surface we observed frequently whenever working in depths not exceeding two hundred fathoms. Preceding the current observations, the cast for depth was made with rope, the lead weighing one hundred and fifty pounds. The depth of water having been ascertained, slack-line was payed out from the vessel, and the dinghy, in charge of the assistant-navigator, was lowered and made fast to the bight of the sounding-rope, after which slack-line was again payed out from the vessel that the movements of the latter might not influence the boat during the process of taking the observations. The apparatus used is shown on Plate 5.

The peculiar shape of the cans shown on Plate 5 originated, I believe, with Prof. Henry Mitchell, Physical-hydrographer of the Coast and Geodetic Survey. The cans are made of galvanized sheet-iron, and in shape are, respectively, a cylinder of eight inches diameter and eleven inches height, and a cylinder of equal dimensions surmounted by a cone three inches in height. At the top of each is a small aperture. In use the aperture of the lower can is kept open to the entrance of water to facilitate the sinking of the can and to prevent it from crushing under pressure, while that of the upper can is kept closed by a cork, no water being admitted. For any observation both cans are used. They are connected by a length of sounding-wire (diameter .028 inch), and are so loaded with old scraps of lead or iron, or with pebbles, that when set adrift the lower can will sink to the full extent of the connecting wire, while the upper can will be submerged only to the base of its conical top, thus making the submerged surface of the two cans equal, which simplifies the problems relating to the determination of the sub-surface currents from the data obtained by observation. For observing surface currents the lower can is sunk to a depth of one or two fathoms, simply to counteract the effect of winds and surface-wash on the floating can; for sub-surface currents it is lowered to the depth at which it is desired to know the current, the distance being regulated by the connecting wire. To the upper can is attached a graduated line, marked for knots and tenths, the length of each knot being fifty and seven-tenths feet, to correspond to a time-interval of thirty seconds. Sometimes a few fathoms of stray-line are interposed between the floating can and the initial mark, the last being a white rag. Observations are made from the boat as a station point; those for velocity, excepting in the modification which will be mentioned, being made after the manner of observing the speed of a vessel with the log-chip. The direction of the movement of a can is obtained by compass bearings from the station point.

In the "Blake's" work, if only the surface current was to be observed, the apparatus taken into the boat embraced one set of two cans, the graduated line wound upon a hand-reel, and the time-glass or chronoscope. The force employed consisted of two men in charge of an officer. One man fastened the boat to the sounding-line and then held the glass or chronoscope; the other got over the cans and held the reel, while the officer read the divisions on the line and took the bearings. The rapidity with which Mr. Peck, Master, and afterwards Lieutenant Sharrer, could accomplish this kind of work with the little dinghy, even in moderately rough seas, was remarkable. We generally made use of their observations in shaping the course. The direction and velocity of the current would be shouted to those on board the vessel before the dinghy got alongside, and the course to be steered, allowing for the current found, was generally known by the time the boat was at the davits.*

When it was desired to observe for sub-surface currents, a cutter, manned by four men in charge of an officer, was used instead of the dinghy. A spare sounding-machine, like that shown on Plate 6, was lashed in the stern of the boat, and contained the sounding or connecting wire in five or ten fathom lengths, each length having at one end a small brass thimble and at the other a small snap-hook. To join the successive lengths it was only necessary to snap the hook of each into the thimble of its neighboring length. The reel projected slightly over the gunwale of the boat; in its friction-score was laid a simple friction-line, the standing part of which was secured to the bed-board of the machine in advance of the reel, the inboard or hauling part being managed by hand. To get overboard a set of cans for sub-surface observation, the lower can, after being attached to the snap-hook at the outer end of the wire, was allowed to sink rapidly, the wire paying out from the reel, which meanwhile was kept under frictional control. When the snap-hook had cleared the reel, denoting that the can had reached the

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* When not on our sounding-lines we occasionally took current observations for navigating purposes, if "on soundings." By resorting to this expedient we were sometimes enabled to perform, with safety, feats of piloting which otherwise would have been extremely hazardous.

required depth, the reel was stopped, and the upper can, which had previously been fitted with the graduated line, was then quickly attached to the submerged wire and set adrift.

The methods of observing currents from a boat are inexact at the best, and are particularly so when a graduated line must be used; hence the mean of a number of observations should be obtained when possible. In a "straight current," as in a river or a canal, a measured base on shore, parallel to the axis of the stream, with ranges and theodolites at each end, has been made use of instead of the graduated line. Electric current meters have also been used successfully for determining the velocity of the lower strata in rivers and canals, but I think no meter has yet been adopted which will record the *direction* of sub-surface currents in ocean depths.*

There will be described under Cases I and II the methods employed by the "Blake" for determining sub-surface currents, one case being a modification of the other; also, under Case III, a better method, a description of which, with special reference to spherical floats, is given in Appendix No. 26, Coast Survey Report for 1859, page 311, by Prof. Henry Mitchell. It will be observed that Cases I and II do not involve the departure of the vessel from her station near the position of the sounding, even though long delayed there, while in Case III she might be required to temporarily abandon the line of soundings in order to pick up the boat. This will explain why we did not adopt the most accurate method.

Case I.—During the whole period of observation the boat remains

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* Mr. Clemens Herschel, civil and hydraulic engineer, has devised some electric current meters which are favorably known. They are manufactured and sold by Buff & Berger, 9 Province Court, Boston, Mass. These meters do not record the direction. Mr. Herschel is very sanguine of the future success of meters in deep-sea current work. His own statements in reference to the subject are here given:

"Electric current meters are now made in serviceable form for deep-sea observations in this country. They have been used in ten to fifteen fathoms on the rivers connecting the great Lakes, as detailed in the several reports of the Chief of Engineers United States Army, Survey of the Great Lakes, in the years 1868 to 1872; also, in depths up to twenty fathoms on the Uruguay, Paraña, La Plata, and other large rivers in South America, as described in Rèvy's Hydraulics of Great Rivers, E. & F. N. Spon, London and New York. A skillful observer should find no insuperable difficulty in using them at much greater depths. Several of these instruments could also be strung on one and the same vertical guide-wire, and *simultaneous* observations of the currents at different depths be taken in this manner.

"An instrument for observing the *direction* of sub-surface currents at any depth is described in the Minutes of the Proceedings of the Institution of Civil Engineers of London, session 1875–'76, Pt. III."

anchored by the sounding-rope. Preceding and following the observations for sub-surface current, and, if necessary, at intermediate stages, observations are made for ascertaining the surface current. Stated in general terms, the sub-surface current at any depth is found by first establishing, by observation, its relationship to the surface current, when, the latter having been ascertained directly by observation, the former may be deduced. The observations for sub-surface currents are executed in the same way as those for surface current, excepting that the lower can is sunk to the depth of the stratum the flow of which it is desired to know, and that the time during which the connected cans are allowed to drift is generally increased to some multiple of thirty seconds, requiring a corresponding division of the reading of the graduated line. This increase of the time interval is also sometimes necessary in the observation of surface currents when there is a low velocity.

While the lower can of a sub-surface set is sinking it may be successively, under the influence of several currents, setting in different directions, in which case the upper can, when set afloat and released from restraint, will sometimes not attain a steady movement until some yards removed from the station point. In most instances, however, particularly when the lower can is not sunk to any great depth, it will be found in practice that the movement of the cans is so slow that the station point may be accepted as the point of departure of the upper can in taking up the true or resultant movement, and consequently the point from which to reckon the compass bearing and the reading of the graduated line.

Case I is when the station point may be taken as the point of departure. It is assumed that the connecting wire of the sub-surface set of cans is rigid and vertical, and that it has no effect on the movement of the cans. The direction of the movement of the upper can is obtained by a compass bearing from the boat, and this, with the reading of the graduated line, is accepted as giving the resultant of the movements of the upper and lower strata, the latter at the depth to which the lower can is sunk.

Let $v =$ velocity of the surface current $=$ the velocity which the upper can would have if moving alone;

$v^1 =$ velocity of the sub-surface current $=$ the velocity which the lower can would have if moving alone in a horizontal plane;

$V =$ resultant velocity of the upper and lower currents $=$ the velocity of the connected cans;

$a =$ angle included between the directions of v and V;

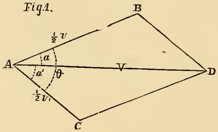
$a^1 =$ angle included between the directions of v^1 and V;

$\theta =$ angle included between the directions of v and v^1.

v and V are given by the readings of the graduated line; a is given by the difference between the compass bearings taken at the surface and sub-surface observations respectively. Since $\theta = a + a^1$, if a^1 is found we readily get θ.

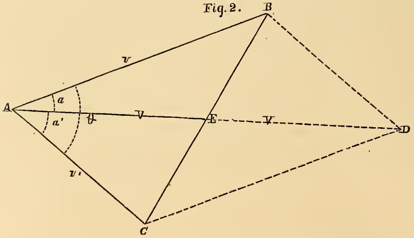
If v and v^1 are in the same vertical plane, $V = \frac{1}{2}(v + v^1)$. If v and v^1 are not in the same vertical plane, $V =$ the half-sum of the projections of v and v^1 on the vertical plane containing V, or $=$ the sum of the projections of $\frac{1}{2} v$ and $\frac{1}{2} v^1$ on that plane, and the solution may be effected by constructing the parallelogram of velocities. The method of solution by projection admits of greater accuracy than the means employed in observing, and this method practiced on board the "Blake."

Fig. 1.



In Fig. 1 make $A B = \frac{1}{2} v$, $A D = V$ and $B A D = a$. Completing the parallelogram A, B, C, D, we get the side $A C = \frac{1}{2} v^1$, and the angle $B A C = \theta$; or, in Fig. 2, since the diagonals of a parallelogram mutually bisect, make $A B = v$, $A E = V$, and $B A E = a$. Draw B E and produce it to C, making $E C = B E$. Then $A C = v^1$ and $B A C = \theta$.

Fig. 2.

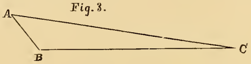


If it be intended to effect a solution by computation, A B $= \frac{1}{2} v$ and A D $=$ V (Fig. 1) may be referred to rectangular axes and the usual formulæ employed, or the solution may be obtained from the two equal triangles of the parallelogram; since B D $=$ A C $= \frac{1}{2} v^1$, and B D A $=$ C A D $= a^1$, we have given, in the triangle A B D, the two sides A B and A D, and the included angle B A D, to find the side B D and the angle B D A.

Case II.—When, at the observation for sub-surface current, the station point may not be accepted as the point of departure of the upper can in taking up its true movement, a modification of the method described under Case I becomes necessary. The stray-line is dispensed with, and the can is secured to the graduated line at the initial point, the white rag. When the upper can, after having been set adrift, has attained a steady movement, time is noted, and a simultaneous compass bearing of the can and reading of the graduated line are taken at the station point. When the movement has continued for thirty seconds—or some multiple of thirty seconds—a bearing and a reading are again taken. These give the data for finding V and a.

In the triangle A B C, Fig. 3, let A be the station point, B the position of the upper can at the first reading of the graduated line, and C its position at the second reading; then, from the readings and the bearings, we have the two sides A B and A C, and the included angle B A C, from which we may find the side B C $=$ V, and also the angle A B C, or the angle A C B, either of which, by its relation to one of the two compass bearings already taken, will give the compass direction of V.

Fig. 3.



Having V and its compass direction, the compass direction and extent of v being known from observation, we readily get a, whence v^1 and the angle θ (Fig. 1) may be found as in Case I.

Case III.—The observations for surface current are made from a boat at anchor, as in Cases I and II, but those for sub-surface current are made as follows: Having ascertained the surface current and lowered the sub-surface set of cans, the latter are released without any graduated line attached. At the same time the boat is cast off from the sounding-rope and her course laid in the line of movement of the floating can, near which object her head is constantly kept, care being taken that the manœuvring of the boat may not influence the motion of the can. Everything being ready, the set of cans used for the surface observation—with the graduated line attached, but without stray-line—is placed overboard as close as possible to the floating can of the sub-surface set and is quickly released, time being noted. The graduated line is payed out as necessary, and the boat constantly kept in her position near the floating can of the sub-surface set, as before. If there is any difference in the direction or velocity of the flow of the upper and lower strata the two sets of cans separate. At the end of the selected time interval the distance separating the two floating cans is measured by means of the graduated line, and a compass bearing of one can from the other can is taken at the station point, in the bow of the boat.

This measurement gives in the triangle A B E, Fig. 2, the side B E; the compass bearing, together with the compass bearing taken at the observation for surface current, gives the angle A B E. The side $A B = v$ being known, we have, in the two sides and the included angle cited, the data for finding the side $A E = V$, and the angle $B A E = a$. With V and a known, v^1 and θ may be found as in Case I.

When there is a swift surface current it would perhaps be easier to keep the boat near the floating can of the surface set, in which case the graduated line would have to be attached to the other floating can, but in the method as stated the boat's head at the time of getting over the second set of cans has already been laid in the direction of the movement attained by the sub-surface cans; hence, to follow the other set would often require an abrupt change of course and no inconsiderable manœuvring.

The difficulties in the way of accurate observation from a boat are evident to the nautical person. The boat is generally restless, and, when anchored to a long riding-scope at short stay, is liable to provide only a shifting station point. A bucket towed astern may lessen the swinging of the boat, but her instability cannot be overcome. The sinking and deflection of the graduated line, and the oscillations of the compass-card, are obstacles in the way of trustworthy observations.

REMARKS ON THE CONDITIONS ATTENDING DEEP-SEA WORK.

The conditions attending deep-sea work should be borne in mind in devising apparatus intended for the prosecution of such work. This as a fact seems to be self-evident, but in the observance it is not always fulfilled, as many of the deep-sea appliances which have been devised from time to time bear evidence. Some of these conditions are stated as a reminder to those who have had no actual experience in the work.

Rolling and Pitching of the Vessel.—This is an important matter to be considered, as has been made to appear many times in this book.

Drifting of the Vessel.—Under the influence of wind or current, or both, a vessel will drift away from the position which she occupied at the beginning of an operation. That there are sometimes sub-surface currents to be encountered, and that they are frequently found to move in a different vertical plane from that in which the surface current moves, must also be considered.

Corrosive Action of Sea-water on Metals.—By corrosive action, if the metal employed in the construction of apparatus used for submarine work be not properly chosen, the friction of working parts may be much increased, contact of valves with their seats may be destroyed, and parts not accessible for cleaning may become much fouled.

Specific Gravity of Sea-water.—It must be remembered that in sea-water bodies are more buoyant than in fresh water.

Thermal Differences.—Instruments in leaving the vessel and descending to deep water may be exposed to a wide range of temperature, often from over 100° in the sunshine to nearly 32° in the deep water. In this connection it should be remembered that different metals or materials expand or contract unequally under the influence of heat or cold. In delicately-adjusted parts unforeseen contact or breaking of contact may result from much change of temperature.

Since the lubricating oils do not retain their fluidity at a low temperature, they should not be used to lubricate parts of instruments which are to be submerged in cold water. The water acts as a lubricant.

Hydrostatic Pressure.—The pressure on any plane surface immersed in a fluid is equal to the weight of a column of the fluid whose height is equal to the perpendicular depth of the center of gravity of the surface, and whose base is equal to the surface pressed.

Taking the specific gravity of sea-water as 1.026, the weight of a cubic inch would be .594 ounce avoirdupois. The weight of a column having a height of one fathom (seventy-two inches) and a base of one square inch would be 42.768 ounces, whence we would get the following approximate pressures on the square inch:

	Pounds.
At a depth of 1 fathom	2.674
At a depth of 10 fathoms	26.740
At a depth of 100 fathoms	267.400
At a depth of 1,000 fathoms	2,674.000

Few valves will resist or retain the pressure in very deep water, and hermetically-closed chambers must be strong not to be collapsed. Material which was buoyant at the surface may become water-logged, or materials may be compressed until they lose their former shape.

While many other points should be considered, according to the character of the work or the machinery, the foregoing are some of those which are most prominent in importance because of their bearing on ordinary operations.

STRENGTH OF SPRINGS.

One of my chief troubles at the outset of our deep-sea work was in getting any information concerning springs for mechanical uses; even the workmen who made springs apparently knew little more concerning them than was to be obtained by experiment in each individual case.

The use of springs for delicate mechanical operations at sea should be avoided as much as possible, particularly if the instrument with which they are employed is intended to be submerged, for the springs will then undergo considerable change of temperature and sometimes much rough usage. The action of springs in air certainly does not furnish a true measure of that which they have in mud.

If a flat or sheet spring be used, its broad surface, or the surface which is at right angles to the plane of flexure, should not be presented to the resistance of the water in its movement through it, unless the effect of such resistance on the flexure of the spring be taken into account.

The following is copied from Principles of Mechanics, by W. J. Miller, C. E., London, 1874; E. & F. N. Spon:

"A spring being a bar of metal in a coiled form, when weights are applied either to compress or extend the coil, we have a corresponding compression or extension of the metal, and, therefore, this change of figure will be directly as the weight or force W applied, and directly as the number of coils. Let $N =$ number of coils, $D =$ mean diameter of coil, and $d =$ side of wire if square and diameter if round (round steel is usually preferred by engineers, as the square form is apt to crack at the edges during coiling); then elongation or compression $= W \times N$. If we now vary the diameter, and consider similar parts of such different sized coils as *beams* undergoing bending, we may apply the formula for the deflection of beams already given. We shall thus have the elongation or compression *directly* as $W \times N \times D^3$.

"Again, if the section of metal be varied, and if we still consider part of the spring as a beam, we have the deflection or change of curve as $b \times d^3$ ($b =$ breadth), or, in this case, since $b = d$, as d^4, and, therefore, the elongation or compression of the coil will be inversely as d^4, and the formula will, therefore, be—

$$\text{Elongation or compression} = \frac{W \times N \times D^3}{d^4} \times C;$$

$C =$ a constant determined by experiment.

"If the diameter and thickness of wire be expressed in inches and the weight in pounds, then it appears from experiment that for steel springs of square section—

$$C = \frac{1}{2,200,000};$$

and for round section—

$$C = \frac{}{1,470,000}$$

the elongation or compression being obtained in inches."

CHAPTER V AND APPENDIX.

DREDGING AND TRAWLING; APPARATUS AND METHODS.

FITTING THE "BLAKE" FOR DREDGING.

On the arrival of the "Blake" at New York, in July, 1877, following the close of a winter season in the Gulf of Mexico, it was announced by the Superintendent of the Coast and Geodetic Survey that a part of the winter season of 1877–'78, in the Gulf, would be given up to dredging, for which purpose Prof. Alexander Agassiz would be associated with the Coast Survey party. Professor Agassiz had recommended the use of steel-wire rope for dredging, and his recommendation had been approved by the Superintendent.

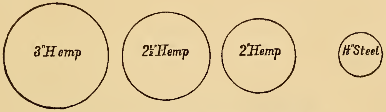
The "Blake's" party organization for the purposes of deep-sea work had existed for five years continuously: two years under the command of Commander J. A. Howell, U. S. N., and three years under my command. Since under the liberal control of the Superintendent, the arrangements of the vessel for the work in which she was engaged had been made very complete, and the party on board had become experienced in the conduct of most deep-sea operations, opportunity was offered for undertaking dredging at much less trouble and expense than would have been possible with a new organization. There was needed for the dredging operations the direction of a capable naturalist, which was secured to the full in the services of Professor Agassiz; but, for the vessel, only such additional apparatus was necessary as belonged strictly to a dredging outfit.

The adoption of steel-wire rope, although presenting to our minds at the outset a few difficulties, which we confidently expected to overcome after a short experience, simplified matters as compared with what had previously been thought proper in a dredging outfit. Before that time

THE "BLAKE" AT THE WASHINGTON NAVY YARD. THE DREDGING GEAR READY FOR WORK.

Heliotype Printing Co., 220 Devonshire St., Boston

dredge-ropes had been of hemp or manila, and usually, for deep work, a tapering rope of three inches, two and a half inches, and two inches in circumference had been employed. The size of the steel rope selected for our work was one and one-eighth inches in circumference throughout its whole length.



G.—COMPARATIVE SIZE OF DREDGE-ROPES.

Professor Agassiz and his indefatigable associate, Mr. S. W. Garman, did everything pertaining to their own special work as naturalists, and in addition accepted a share in fitting the vessel. In the division of work agreed upon, Professor Agassiz provided the dredges, trawls, tow-nets, &c., while the Coast Survey party planned and placed on board the means for working the wire rope. In its several stages of progress the preparation of the vessel was reported to the Superintendent for sanction or improvement, and as a rule our plans were also submitted by me to the valuable criticism and suggestions of Professor Agassiz.

The dredging cruise of the ensuing season (1877–'78) having proved successful, and having demonstrated the efficacy of the steel rope so opportunely recommended by Professor Agassiz, the vessel was refitted to continue the dredging work on a second cruise during part of another winter season (1878–'79).

Improvements were made in dredges and trawls during the first cruise, and a practical experience gained which suggested improvement or modification in the method of operating the wire rope. On the completion of the second fitting of the vessel for a dredging cruise and the regular party work to follow, Commander John R. Bartlett, U. S. N., succeeded to the command. For this second preparation, the duties were divided between the naturalists and the Coast Survey party precisely as before, Professor Agassiz adding to his own special duties as naturalist the supervision of the manufacture of trawls and dredges, this time after the improved forms, and the party on board, under the control of the Superintendent, devising, purchasing, and putting in place the system of machinery necessary for conducting the work.

In the operations at sea, the management of the vessel and of the machinery was in charge of the Naval Assistants, but no dredging was undertaken excepting in localities indicated by Professor Agassiz, he being the recognized director of the dredging operations. Although a division of duties was necessary, no stiff lines were drawn, but all exercised a common interest in the conduct of the work and in the improvement of details. When the work of each dredging cruise had been completed, and the naturalists had left the vessel, the regular work of the party, consisting of observations for depths, serial temperatures, currents, densities, &c., was resumed in charge of the naval officers, this work in each case occupying several months after the close of the dredging operations.

In the course of the present chapter the methods of each dredging cruise will first be explained, and this will be followed by detailed descriptions of apparatus as finally approved and adopted. There will also be given in the appendix to this chapter descriptions of a few of the appliances used by the United States Commission of Fish and Fisheries. The appendix was written by Prof. A. E. Verrill, and I am enabled to publish it through the good offices of Prof. Spencer F. Baird, United States Commissioner of Fish and Fisheries. In selecting from the material placed at my disposal by Professors Baird and Verrill, only those things have been chosen which, as it seemed to me, might in one way or another have proved a desirable supplement to the outfit of the "Blake." It is not thought consistent to depart so widely from the title of this book as to include all the valuable appliances of the Commission.

In letters to the Superintendent of the Coast and Geodetic Survey, which have been published as Bulletins of the Museum of Comparative Zoölogy at Harvard College, Cambridge, Mass., Professor Agassiz has set forth the valuable results obtained in his department of science by the dredging cruises of the "Blake."

The heliotype views show the vessel prepared for the *second* dredging cruise, excepting that in some of them the experimental Sigsbee sounding-

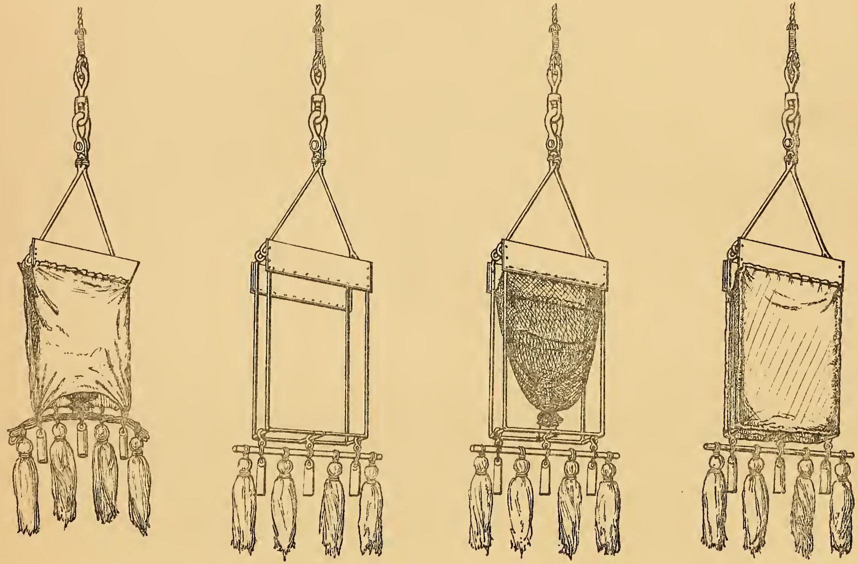


Fig. 1 *Fig. 2* *Fig. 3* *Fig. 4*

FIG. 1 STYLE OF DREDGE SUPPLIED FOR THE FIRST DREDGING EXPEDITION OF THE "BLAKE". FIG'S. 2, 3 & 4. DREDGE DEVISED BY LIEUT. COMDR. C. D SIGSBEE, U. S. N. AND MASTER H. M. JACOBY, U. S. N. AND ADOPTED FOR USE.

machine—which soon after these views were taken was replaced by the later form of the same machine (Plate 8)—is still in position.

THE FIRST DREDGING CRUISE.

(Figs. 1 and 2, Plate 29.)

Apparatus and Methods.—In preparing the vessel for this cruise it was agreed, owing to the somewhat experimental nature of the work and the short time allotted for its execution, that the expenses should be restricted to the lowest figure; consequently the main hoisting-engine, although of doubtful power for very deep work, was fitted with a winch-head and continued in use. The trouble to be feared with the steel rope was kinking, but from motives of economy a considerable risk was knowingly taken in this respect in adopting the plan by which we first worked the dredge-rope.

There were provided but two lengths of the steel dredge-rope, each being 3,000 fathoms. One length was kept on a large iron reel, B, which was mounted on standards and controlled by a friction-brake. The reel was the same that is shown on several of the plates, but on this cruise it was operated by hand-cranks, and the friction-lever was on the after side. A swinging-boom, D, provided with topping-lift and guys, was mounted on the foremast by means of a band and goose-neck. At the outer end of the boom was a large iron snatch-block, C, hooked to a pendant that connected with an accumulator or dynamometer. The pendant rove through a small iron leading-block of extra strength permanently secured at the boom end; thence over a sheave in the heel of the boom, whence it was made fast to the accumulator, the latter at the outset being laid on the upper side of the boom, and afterwards, as being more favorable to its proper action, suspended from the mast-head. The positions of the several independent parts of the dredging apparatus are very well indicated by the plans on Plate 29 and by the heliotype views.

In paying out (Fig. 1), the dredge-rope passed directly from the reel through the pendant-block, under frictional control at the reel. For hauling back (Fig. 2), it was first stoppered abreast the pilot-house *k*, then slacked at the reel and led through a second large iron snatch-block, C, forward of the reel and abreast the winch-head of the hoisting-engine. With the bight of rope formed between the deck-block and the reel eight or nine turns were taken around the winch-head of the engine. This operation completed, the cranks of the reel were manned, the strain on the rope taken up by the engine, stoppers "come up," and the rope brought in at a rate varying from one minute to six or seven minutes per one hundred fathoms, according to circumstances. As the rope, while coming in, passed off the winch-head it was wound "hand taut" upon the reel. For the purposes of winding and guiding, a guy-rope was used, one end of which was made fast to the vessel's rail, the other end being turned over an iron thimble through which the dredge-rope was always kept rove. For stoppers, several long lengths of sennit were used. The stations of men are shown by crosses on the plate. The objectionable feature of this method of winding the wire rope was in taking turns around the winch-head "*on the bight*," which, by twisting the rope, promoted kinking. Watchfulness and care were necessary, but exercising these we were able to avoid kinks, excepting at the outer one or two hundred fathoms, where a kink was perhaps an advantage rather than a drawback. Kinks were easily straightened out, but they left the rope less strong than before.

At our first attempt with the dredge we were brought to grief by an indescribable tangle of the outer two hundred fathoms of the dredge-rope, which happened in this wise: The rope had been payed out rapidly, the vessel backing slowly meanwhile and drawing the rope ahead; the large, insufficiently-weighted dredge having met with more resistance than the compact and heavy steel rope, the bight of the latter had landed first, and the outer two hundred fathoms of the rope, still descending, had gone down upon its own parts in confused coils.

This we afterwards came to consider a most fortunate and timely accident, for, it having taught us how to lower the dredge, we did not again meet with a like trouble during the whole progress of the work. Thereafter the dredge, more heavily weighted, was lowered with the submerged rope kept vertical and under strong tension until the bottom had been approached to about fifty fathoms, when the rate of paying out was diminished and the vessel slowly backed until the dredge took ground, after

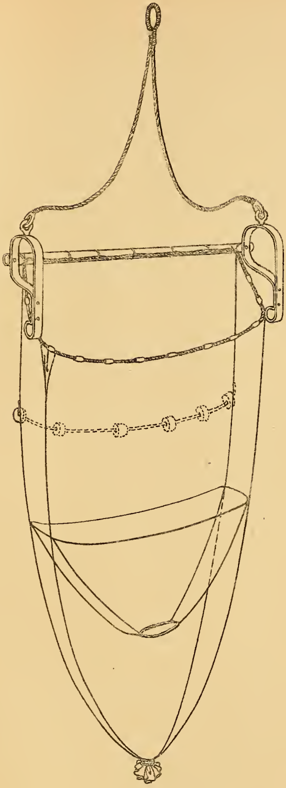


Fig. 1

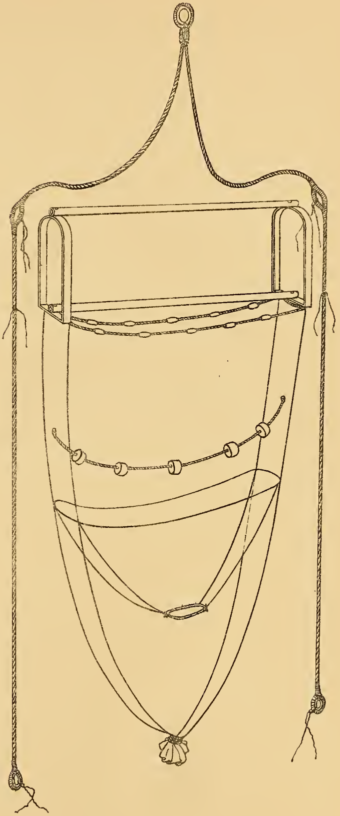


Fig 2

FIG. 1 PLAN OF TRAWL AS FIRST USED ON BOARD THE "BLAKE."
FIG. 2. PLAN OF TRAWL AS IMPROVED BY PROFESSOR AGASSIZ, LIEUT. COMDR. SIGSBEE AND LIEUT. ACKLEY

which the rate of paying out was increased and the vessel backed according to circumstances, *the rope always being kept well taut.*

The extent to which the boom was topped up for work is shown on Plates 24 and 30. A sounding, and an observation for bottom temperature, preceded the dredging operations at each station occupied.

For lowering the trawl, with its heavy iron frame and long, pendent bag, a different method was adopted, as suggested by consideration of the unequal resistances encountered by the parts mentioned in passing through the water, it being necessary to guard against the bag getting up over the frame-work. With the end of the bag well weighted, the trawl was payed out cautiously, the vessel backing slowly to keep the rope tending slightly ahead. As the trawl neared bottom the reel was stopped for several minutes, while the backing of the vessel was continued. Then the work of paying out was resumed until the trawl had landed. Our method in this respect increased the probability of planting the trawl fairly on its runners and of keeping the rope taut at a critical moment.

The steel dredge-rope when held in the hand always gave the most decided indications of the dragging of a dredge or trawl along the bottom, and as soon as the implement was felt to be "biting" the additional scope of dredge-rope thought necessary was payed out as desired by backing the vessel and regulating the friction at the reel.

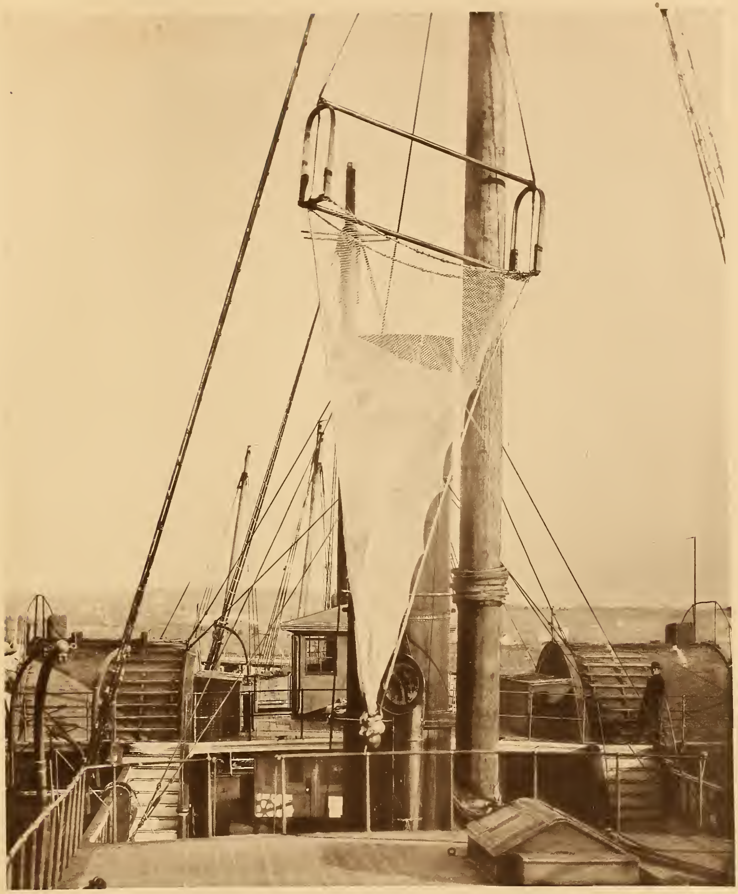
No weights were used on the steel rope in advance of the dredge or trawl, as is necessary when the rope employed is of hemp or manila. The weight of the steel rope alone was found to keep the implement flat.

The length of rope payed out, whether for dredging or trawling, generally followed this rule: In depths no greater than three hundred and fifty fathoms, equal to twice the depth of water; in depths exceeding that, one-third greater than the depth of water.

A tackle from the forward part of the swinging-boom was used for hoisting the dredge and its contents over the rail to the deck, but the trawl, being unwieldy, was first swung abreast of the fore rigging by means of a mast-head tackle, from which position it was hoisted until the frame had cleared the vessel's rail, when the netting was gathered aboard by hand.

Professor Agassiz suggests the use of a light gaff on the forward part of the foremast for this purpose.

It has been stated that the dredge and the trawl were improved during the first dredging cruise; in what respect will now be shown. Those with which we fitted out are illustrated in Fig. 1, Plate 25, and Fig. 1, Plate 26, respectively. Early in our work it was noticed that the dredge gave but few specimens of animal forms from soft bottoms, even when it came up filled with the bottom material. This material being ordinarily of a moderately tenacious character, requiring a long-continued manipulation to force a quantity of it through a sieve in water, it was supposed that the dredge on reaching bottom soon became surcharged with the mud or ooze, and that very little washing out through the netting taking place thereafter, other matter was excluded after the first few feet had been traversed. Additional evidence on this point was afforded by the profusion of specimens brought up on the tangles from the same localities, and also by the disproportionately greater number obtained in the trawl as compared with the dredge. The opinion was broached early in the work that the dredge should skim the ground rather than plow into it, and in its form should partake of the characteristics of both the dredge and the trawl. Although this view was opposed to previous practice, Professor Agassiz thought it worth submitting to experiment. Accordingly, Master H. M. Jacoby and the writer improvised a dredge which would not plow, and it proved so successful at the first venture that afterwards, at Key West, a drawing was prepared from which an improved dredge, as shown in Figs. 2, 3, and 4, Plate 25, was constructed. The new dredge was used thereafter with much better results than we had met with in the use of the old dredge. With the former more than thirty hauls were made, some of them on very soft bottom, but in only two or three instances did it bring up more than several handfuls of mud or ooze, although by lining the bottom of the bag with closely-woven stuff, bottom material in considerable quantity might nearly always have been obtained. It is evident that the improved dredge, without the special lining, collects the material of soft bottoms in such small quantities that the much-desired washing through the netting of this material in the process of dragging actually takes place.



THE IMPROVED TRAWL READY FOR USE. SEE FIGURE 2, PLATE 26.

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With the style of trawl that had previously been used for deep-sea work it was essential to success that it should land fairly on its runners; that is, with the beam uppermost. Although it would land as desired in most cases, yet experience had shown repeated failures, and a failure in deep water involved the loss of much time and the risk of valuable gear without compensation.

Professor Agassiz, Lieutenant Ackley, and the writer, in the course of a conversation, each offered suggestions until we had succeeded in drawing up a rough design for the trawl shown in Fig. 2, Plate 26, and also on Plates 27 and 28, and we afterwards had much reason to be gratified with the working of the improved implement.

THE SECOND DREDGING CRUISE.

(Fig. 3, Plate 29.)

Apparatus and Methods.—The first dredging cruise having established beyond doubt the superiority of steel rope over hemp or manila for dredging purposes, the Superintendent authorized a more complete outfit for the second cruise.

Fig. 3 shows the method of working the dredge-rope during this cruise. The reel B, containing the rope, was the same that had previously been used, but it was reversed to bring the brake-lever on the forward side, and was provided with a small double-cylinder reversible steam-engine, E, for winding the wire. The lead of the rope was as follows: From the reel it followed the course of the dotted line, passing through the several iron snatch-blocks C, C, &c., eight or ten turns being taken around the winch-head of the hoisting-engine A. This was the lead of the rope, both for paying out and for hauling back; there was no need to take turns around the winch-head "on the bight" as before, and thus the rope could be kept constantly under tension, which is almost a necessity in working wire rope. The fleet aft, from the reel B to the first block C, was a long one, rendering it easy to guide the wire evenly on the reel when hauling back. The swinging-boom and its fittings were the same as before, excepting that a new accumulator, or dynamometer, Fig. 3, Plate 34, was provided. The new hoisting-engine A was very different from that formerly used. On the latter the winch-head was permanently connected with the crank-shaft by gearing, and could not be worked independently of the engine.

The new engine (Plate 33) will be more fully described hereafter, but it is necessary to give some idea of it at this point in order to explain clearly the operation of dredging during the second cruise.

The winch-head, which over its smallest circumference exactly accommodated one fathom of the rope in a single turn, was fitted with a friction-band, the lever for which could be instantly locked in position, either when the friction-band was out of contact or when binding with full force. By means of a clutch and lever, the latter fitted to lock in position, the winch-head could be connected or disconnected from the engine at will. A worm on the hub of the winch-head was made to engage the gears of a counter or register such as was used on the sounding-machine. By this means, due to a timely suggestion by Lieut. W. O. Sharrer, it was no longer necessary to mark the dredge-rope; the counter gave the length of rope out with a percentage of error too small to be of consequence in dredging, for the exact depth was always first ascertained with the sounding-machine. All appliances for controlling the engine were placed on the starboard side, and one man standing on that side, as shown by the cross on Fig. 3, performed five duties—viz, to attend the throttle, the friction-lever, the clutch-lever, the reversing-lever, and to read the counter.

At the dredge-reel the arrangement was similar; the man standing at that point attended the throttle, the friction-lever, the clutch-lever, and the reversing-lever. In addition, he could guide the rope on the reel in case of emergency.

The drawings for the hoisting-engine were made by Mr. Earle C. Bacon, of Messrs. Copeland & Bacon, 85 Liberty street, New York. I stated to him the size of cylinders, relation of gears, the action required of the several parts, the positions of levers and throttle—in general terms the requirements; and he then worked the whole out in his own way—no easy matter, as may easily be seen—using his patent trunk-cylinders; and so successful was he in the design that not a single fault has been found with his engine by those who have used it. He worked out the form of the winding-engine at the reel, and with the same success.

THE IMPROVED TRAWL SHOWN AS HAVING "TRIPPED" AFTER FOULING WITH ROUGH BOTTOM.

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On this cruise the methods adopted for planting the dredge and trawl were practically the same as on the previous cruise, but as regards the working of the machinery and gear Professor Agassiz and Commander Bartlett state that the drawbacks which had been experienced before were not met with at all. The work proceeded smoothly, and without accident which could in any way be laid to the agency of the machinery. The rope could be wound upon the reel with nice regularity.

The operation of paying out rope was managed as follows: the dredge or trawl being shackled to the rope and over the side, the counter set, the friction-brake at the reel in hand, and the engine at the reel out of gear, the brake at the hoisting-engine was thrown out of action and locked; the winch-head was clutched to the gears and the link adjusted for reversing the engine. In this state *everything* was ready. The weight of the dredge or trawl alone not being sufficient to overcome the various resistances opposing the movement of the rope, it was necessary to pay out with the hoisting-engine until the weight of several hundred fathoms of rope had been added thereto. All that was required to start the operation, after the preparatory measures already described, was to open the throttle. When the submerged weights were sufficiently heavy to overhaul the rope, the throttle was closed and the winch-head unclutched from the gears. The friction-brake at the reel needed careful attention, particularly when the hoisting-engine was turning over, for the latter was powerful enough to part the rope, while the former could give a resistance much beyond the breaking strain of the rope.

In dragging, the strain was taken at the winch-head, controlled by the brake, backed, if necessary, by the brake at the reel.

For hauling back, the winch-head and the reel were thrown into gear with their respective engines, and the links of each engine adjusted for winding up the rope. The brake at the reel was secured out of action, and the throttle of the winding-engine was then opened slightly. As nearly as possible at the same time steam was turned on at the hoisting-engine and the brake on the winch-head locked out of action. Afterwards the speed of the winding-engine was regulated to suit that of the hoisting-engine, the object being to keep the rope taut between the two engines in order to avoid kinking, and at the same time not to wind it upon the reel under so severe a tension as to accumulate a great crushing force upon the drum or barrel of the reel.

After our first dredging cruise it was the general opinion on board that, in dredging, an accumulator was not a necessity, excepting as a dynamometer and to give a slight elastic cushioning. A critical moment in dredging is when a dredge or trawl which has fouled with the bottom is in the usual position for breaking ground—that is, when the rope is vertical and under great strain. At such a time it is desirable to know the condition of affairs below, and this a dynamometer will show, although after a short experience a person can form a correct judgment by holding the rope in his hand. When the dredge is foul, it must generally be broken adrift by strain, not by cushioning. Sometimes, however, a little manœuvring of the vessel over the rope may serve to clear a foul, and then cushioning is desirable. When dragging, the change in form of the catenary of the rope gives the effect of an accumulator. The "Blake's" accumulator was capable of extending about six feet, and this was found to give ample cushioning. The deepest haul made by the vessel was in 2,400 fathoms.

During this dredging cruise the trawl was still further improved in a manner which will be explained in its proper place.

On the first dredging cruise tow-nets had been used only at or near the surface, because Professor Agassiz had but little confidence in the value of the tow-net as it had generally been worked in deep waters—*i. e.*, with the mouth wide open during the several processes of lowering, dragging, and hauling back. The exact habitat of specimens brought to the surface in this way was thought to be very much in doubt. The desirability of having a tow-net which could be kept closed in lowering and hauling back, and yet be kept open when dragging, was several times the subject of conversation on board. I suggested something of this kind: the net to be fastened to the dredge-rope and lowered with the mouth closed; when dragging, a weight to be sent down on the rope, which would open the tow-net and at the same time detach itself and fall clear; when ready to haul back, a second weight to be sent down to close the mouth of the net. This

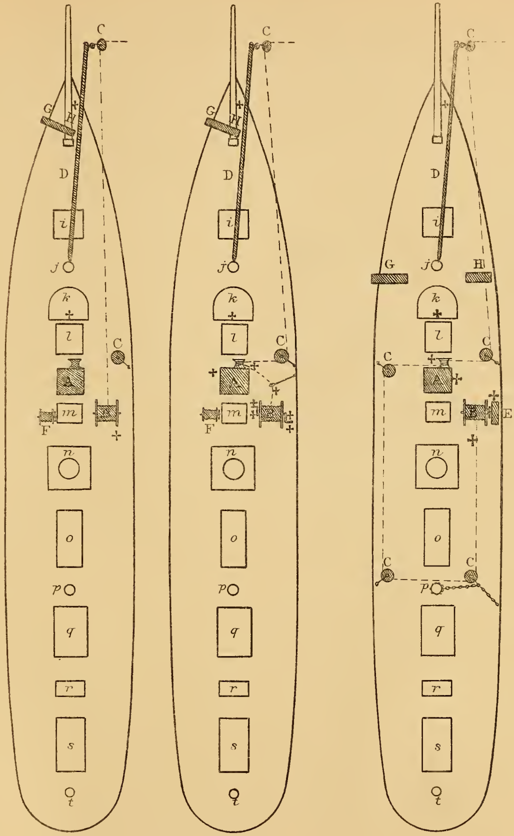

Fig. 1 *Fig 2* *Fig. 3*

PLANS OF THE DECK AND APPARATUS OF THE "BLAKE."
FIG'S. 1 & 2. DURING THE FIRST DREDGING EXPEDITION.
FIG. 3. DURING THE SECOND DREDGING EXPEDITION.

is a vague suggestion, but it might perhaps be put in mechanical shape.* On the second dredging cruise an open-mouth tow-net was tried in deep water, but not with much success in getting specimens.

Another device, called the tangle-bar drag, for dragging along the bottom, was used on the second cruise. It was towed by a bridle, and had swabs secured along its whole length. This apparatus brought up specimens in great profusion.

GENERAL REMARKS.

The advantages gained by the use of wire rope for dredging purposes are chiefly in the following particulars: compactness, strength, durability, neatness, facility of handling with a small force, celerity of operations, and economy.

The duration of the dragging-interval was made much shorter in the "Blake's" work than had previously been the practice. In the greater depths, where more time was consumed in lowering and hauling back, a longer interval was usually allowed than in depths less than five hundred fathoms. This restriction of the dragging-interval was perhaps a natural consequence of the increased facilities gained in dredging with wire rope, but it seems a reasonable way of working from other points of view. A first haul will generally indicate, to some extent, the fertility in specimens of the bottom that is being worked, whence barren ground may be abandoned or rich ground worked exhaustively. The longer the dredge or trawl is

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* An apparatus for this purpose, which has recently been devised by the writer, at the request and with the assistance of Professor Agassiz, has now been made by authority from the Superintendent of the Coast and Geodetic Survey. It will be tested during the coming summer, and doubtless will be published afterwards, with such improvements as experience may suggest to Professor Agassiz, under whose direction it will be used Our plan is to trap the specimens by giving to a cylinder, covered with gauze at the upper end and having a flap valve at the lower end, a rapid vertical descent between any two depths, as may be desired; the valve during such descent to keep open, but to remain closed during the processes of lowering and hauling back with the rope. An idea of what it is intended to effect may be stated briefly thus: Specimens are to be obtained between the intermediate depths *a* and *b*, the former being the uppermost. With the apparatus in position, there is at *a* the cylinder suspended from a friction *clamp* in such a way that the weight of the cylinder and its frame keeps the valve closed; at *b* there is a friction *buffer*. Everything being ready, a small weight or messenger is sent down, which on striking the clamp disengages the latter and also the cylinder, when messenger, clamp, and cylinder descend by their own weight to *b* with the valve open during the passage. When the cylinder-frame strikes the buffer at *b* the valve is thereupon closed, and it is kept closed thereafter by the weight of the messenger, clamp, and cylinder. The friction buffer, which is four inches long, may be regulated on board to give as many feet of cushioning as desired. All parts are simple and strong. The size of the cylinder for trial is: height, two feet; diameter, ten inches.

APRIL, 1880.

dragged the greater the probability of fouling and losing the implement and its contents, although the probability of fouling in very deep water is generally not so great as in the lesser depths. Professor Agassiz found that some of the more delicate specimens were much injured when a long dragging-period had been allowed. On the first dredging cruise, with the imperfect machinery then on board, we would haul as many as eight times in one day in depths varying from one hundred fathoms to 1,500 fathoms. On one occasion we made a fine haul at eight hundred fathoms in one hour and twenty minutes, including twenty-three minutes for dragging. The time was taken on letting go and again when the dredge or trawl appeared above water. After the departure of Professor Agassiz from the vessel, shortly before the expiration of the first dredging cruise, we made in one day, between 7 a. m. and 5 p. m., ten hauls with the dredge off Havana in depths from fifty to four hundred fathoms. The bottom was rough and the dredge fouled at every haul, but no losses occurred, and the hauls were rich. Throughout the second cruise the work seems to have been done intentionally somewhat slower than before, but at the same time with greater steadiness.

The following may be set down for safe work: Time per one hundred fathoms paying out and hauling back, three to five minutes, according to circumstances; time for dragging, ten to thirty minutes, according to depth and the character of the bottom. The rate of dragging may be from one and a half to three miles per hour, according to the character of the bottom and the state of the sea. Paying out, and also hauling back after the dredge or trawl is off bottom, is so easily done that there is a great temptation to work rapidly, but it should be remembered that in paying out it is of the first importance to plant the implement properly on the bottom, and that in hauling back the delicate specimens may be injured by too great speed.

DREDGES: THE OLD PATTERN AND THE IMPROVED PATTERN.

(Plate 25.)

The objection to the old dredge for general use has already been stated, but as it has hitherto been regarded almost as a standard form, and in special cases would be more serviceable than that which is herein styled the improved dredge, a description of it is given.

The Old-pattern Dredge (Fig. 1).—There is a frame consisting of two flaring mouth-pieces of flat wrought-iron, beveled on their front edges, perforated with a row of holes along their rear edges, and joined to each other at their ends by bent wrought-iron braces. The braces serve also to hold the two wrought-iron arms forming the span or bridle by which the dredge is attached to the dredge-rope. A band of netting is stitched along one of its edges to the frame by means of pliable wire passed through the holes already mentioned; the free edge of the band is then gathered and seized so as to complete an open-mouth bag. Two lengths of stiff cotton canvas stitched to the frame over the netting form a shield for the latter when the dredge is dragging. The rear edges of the lengths of canvas and the bottom-seizing of the netting bag are stopped to a wisp of ratans, which serves also for fastening on sinking weights and swabs or tangles. One arm of the dredge is longer than its fellow, and to the eye of the long arm the dredge-rope is shackled. The eye of the short arm is seized with five or six turns of rope-yarn to the eye of the long arm. In the event of a foul on rough bottom endangering the dredge-rope, the rope-yarn seizing will part and allow the dredge to slew, an action which rarely fails to disengage it from an obstruction. These dredges are of different sizes, the frame of that for general use being about three feet wide, eight inches deep in the throat, and its length to the end of the bag being about four feet.

The Improved Dredge (Figs. 2, 3, and 4).—By reason of having flaring mouth-pieces, and a flexible body composed of the bag and shield, the old-pattern dredge is almost sure to plow deeply into yielding bottoms. Since the object sought in the fashioning of the new dredge was to effect a skimming of the bottom rather than a deep penetration therein, a very decided departure from the form of the old dredge was necessary.

The frame of the new dredge is a rectangular skeleton box made of wrought-iron. The mouth-pieces are flat, beveled on the forward inner edges, perforated along the rear edges as on the old dredge, and are riveted to the skeleton or bar-iron portions of the frame-work, in which position they are held parallel. The rear of the upper and lower sides of the skeleton are connected by three riveted braces, the whole frame-work being rigid. A tangle-bar of wood, bar-iron, or iron pipe, to carry the weights and tangles, has seized to it three sister-hooks, which are hooked severally around the braces and moused. The arms are like those of the old dredge, one arm being longer than the other. A netting bag and canvas shield, as in the case of the old dredge, are stitched with pliable wire to the dredge-frame. A trap like that of the trawl is fitted inside the main bag. The bottom of the main bag is stopped to the middle brace at the rear of the frame. Each flap of the canvas shield is turned over and around its own side and end of the skeleton frame, and stitched to its own part with stout twine, presenting a tolerably smooth sliding-surface.

DIMENSIONS OF IMPROVED DREDGE.

	Ft.	In.
Length from mouth to rear of frame	4	0
Depth between mouth-plates or flanges	0	9
Width of frame	3	0
Mouth-plates: Width	0	4¼
Thickness of metal	0	⅜
Distance of row of holes from rear edge	0	¼
Distance apart of holes	0	1½
Skeleton frame, diameter of round-iron	0	½
Long arm: Length	3	1
Diameter of round-iron	0	¾
Short arm; Length	2	11
Diameter of round-iron	0	¾
Shield (cotton canvas)	No. 3.	
Netting for main bag and trap: Mesh (square)	¼ inch.	
Stuff (tarred cotton)	$\frac{24}{9}$ thread.*	

If it be intended to bring up a specimen of the bottom material with this dredge, the bottom of the main bag may be lined for a short distance with muslin.

THE IMPROVED TRAWL.

(Fig. 2, Plate 26.)

The plate shows the general plan, not the details.

Two wrought-iron runners are connected by two wrought-iron pipes or beams as shown, excepting that the ends of the beams fit into collars which are riveted to the runners. The several parts of the frame are rigidly

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* See netting for dredges and trawls, page 154.

joined together, so that, when dragging, the runners move in parallel planes at right angles to the axes of the beams. An open-mouth netting bag, roped all round the mouth, and with the roping leaded at intervals, is laced along the rear ends of the runners and strongly secured to the corresponding corners. This leaves two free bights or loops of roping, one of which trails on the ground when the trawl is being dragged. The mouth of the bag should be made large enough to allow either loop that may be uppermost to hang as low as the beam when the trawl is lying flat. This and all other netting bags described herein are made from netting purchased in long lengths or bolts. The main bag is formed from a rectangular piece of netting cut from the bolt, the raw edges being joined in a seam to run lengthwise on the bag. The lower edge of the band, opposite the mouth, is then gathered and the folds are seized together. A second but shorter bag, called a trap, is fitted neatly within the main bag at one-half or one-third the length of the main bag from the frame, forming a pocket of considerable size for the reception and retention of specimens, the only entrance or exit being through a small hole in the bottom of the trap so long as the bottom of the main bag is kept closed. The netting around this trap-hole is either roped or bound with heavy wire, the latter being preferable, as a rope grommet often twists into a "figure-of-eight" in water. From the grommet or wire hoop, as may be, several long stops are passed to the seizing at the bottom of the main bag to protect the trap against reversion. The trap may be made from a triangular piece of netting.

In order to prevent the uppermost side of the main bag from falling and closing the entrance to the trap when dragging, a piece of rope somewhat longer than the width of the main bag, and having corks strung upon it at intervals, is fastened by each end to the sides of the main bag, inside the latter.

As thus described, and fitted with the bridle shown in Fig. 1, we have the trawl as improved on the first dredging cruise. Afterwards other improvements were adopted. . I modified the bridle, making it as shown in Fig. 2. The new bridle is secured to the runners at the front beam by lashings passed through cut-splices in the rope; to the runners at the rear beam by lashings taken around the rope, and to the seizing at the end of the main bag by lashings taken through thimbles which are turned into eye-splices. The function of the new bridle is to bring up the trawl rear end foremost in the event of severe fouling on bottom, the tripping being brought about by the parting of the lashings. (Plates 27, 28.) Fouling with the trawl we found to be a very serious matter, as it was sometimes impossible to clear it when using the old style of bridle.

As used on the second dredging cruise the mouth of the main bag was made larger; the roping was carried forward and made fast to the runners at each end of the front beam, giving a longer bight of the roping to trail on the ground than before; and to prevent the uppermost bight from falling and closing the entrance to the bag a rectangular piece of netting was stretched between the two beams and laced to them along their whole length. The latter contrivance is also intended to guide certain specimens into the bag. These improvements are, I believe, by Professor Agassiz and Ensign G. H. Peters.

Professor Agassiz added a netting jacket inside of the main bag from the mouth of the trap downwards. The bottom of the jacket was lined with four feet of a smaller size of netting, and was closed by gathering the folds as in the case of the main bag.

An idea which occurred independently to Professor Agassiz and myself, but which was not put in practice, was to make the mouth of the main bag larger, and to reeve the roping through bull's-eyes or thimbles at each of the rear corners of the runners. The strain on the dragging bight would then gather the slack of the uppermost bight through these fairleaders, keeping it clear of the mouth of the bag and lengthening the dragging bight. It would involve some little trouble to adapt the roping to this movement in order that the netting might not be dragged through the fairleaders, and that the strain on the corners of the runners caused by the pull of the dragging bight might not be multiplied. The following suggestion is offered for this purpose: A rope, of the same length and size as that used for the roping, to be rove through the fairleaders and made into a band; the roping of the bag to be seized to this band at short intervals, excepting for a certain distance near each fairleader, where it is to be left free to permit the traveling of the band through the fairleaders as required.

By a careful arrangement of the end seizings of the series, the traveling of the band might be stopped at such a point and in such a manner as to avoid multiplying the strain at the corners of the frame. Toggles turned into the roping might also be used for the purpose.

A comparison of Figs. 1 and 2, Plate 26, will show, without further explanation, the points of difference between the improved trawl and the trawl that we first used.

DIMENSIONS OF STANDARD TRAWL FOR DEEP-SEA WORK, No. 1.

Runners:	Length	48	inches.
	Depth	30	inches.
	Width	3	inches.
	Thickness of metal	½	inch.
Front pipe or beam:	Length	10	feet.
	Outside diameter	2$\frac{5}{16}$	inches.
	Thickness of metal	$\frac{3}{16}$	inch.
Rear pipe or beam:	Length	10	feet.
	Outside diameter	2	inches.
	Thickness of metal	$\frac{3}{16}$	inch.
Collars on ends of beams:	Length	2¼	inches.
	Thickness of metal	¼	inch.
	Diameter of bolt	¾	inch.
Rope:	For bridle (hemp or manila)	3	inches.
	For roping (hemp or manila)	2½	inches.
Main bag:	Length	15	feet.
	Size of mesh (square)	1	inch.
	Stuff (cotton)	21	thread.
Trap:	Mesh (square)	½	inch.
	Stuff (cotton)	15	thread.
Jacket:	Mesh (square)	½	inch.
	Stuff (cotton)	15	thread.
Bottom lining:	Mesh (square)	¼	inch.
	Stuff (cotton)	$\frac{24}{9}$	thread

DIMENSIONS OF SMALL BUT HEAVY TRAWL FOR INSHORE WORK, No. 2.

Runners:	Length	30	inches.
	Depth	14	inches.
	Width	3	inches.
	Thickness of metal	¾	inch.
Front pipe or beam:	Length	8	feet.
	Outside diameter	2	inches.
	Thickness of metal		Thick.
Rear pipe or beam:	Length	8	feet.
	Outside diameter	1¼	inches.
	Thickness of metal		Thick.
Ropes and netting			Same as for large trawl.

DIMENSIONS OF LIGHT TRAWL FOR DRAGGING RAPIDLY, No. 3.

Runners:	Length	48	inches.
	Depth, at rear end 24 inches, tapering forward to	18	inches.
	Width	2	inches.
	Thickness of metal	½	inch.

Front pipe or beam:	**Length**	10	feet.
	Outside diameter	$2\frac{5}{16}$	inches.
	Thickness of metal	$\frac{3}{16}$	inch.
Rear pipe or beam:	**Length**	10	feet.
	Outside diameter	$2\frac{1}{4}$	inches.
	Thickness of metal	$\frac{3}{16}$	inch.
Ropes and netting		Same as for standard trawl.	

No. 3 trawl is recommended by Professor Agassiz for rapid dragging. He states that they get, usually, more fishes and crustacea. In his notes, from which the tables of dimensions have been mainly compiled, I do not find the size of the beams of No. 3, so I have made them the same as those of the large trawl.

The cost of the "Blake's" trawl-frames was from $17 to $20 each.

WEIGHTING DREDGES AND TRAWLS; TANGLES.

When fitting out for each dredging cruise we purchased a number of cast-iron twelve-pound weights, which we used as sinking-weights for dredges and trawls. Although we were plentifully supplied with sounding-shot these lighter sinkers were found to be more generally useful—permitting a better distribution of weights.

Our custom was to load the trawl with two twelve-pound weights on each runner and a sixty-pound sounding-shot at the end of the main bag, as shown on Plate 27. It is, perhaps, better and cheaper to load the runners in this way than to make them heavier in the manufacture. In the lesser depths probably no extra weight would be needed. Another way of loading the bag of the trawl is to string two or three sounding-shot on a cheap form of sounding-rod trailing from the bottom seizing of the bag; the shot are detached on striking bottom. This insures a good descent, but is expensive.

The dredge was generally weighted with three twelve-pound sinkers suspended from the tangle-bar, which was of wood. Sometimes we would also lash a twelve-pound sinker transversely on each side of the mouth. We used a wooden tangle-bar that it might break if badly jammed between rocks.

Four tangles were lashed to the tangle-bar of the dredge. These were simply large swabs of hemp rope-yarns. The length of the tangles should

PLATE 30.

VIEW OF THE "BLAKE'S" DECK LOOKING FORWARD FROM THE BOW OF THE STARBOARD QUARTER-BOAT. READY FOR PAYING OUT THE DREDGE.

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be less than that of the dredge, otherwise they may float over the mouth of the dredge and foul while paying out. After being picked over, the tangles often remain matted with sponges, broken spines, &c. The best way to clear them is by towing them overboard.

THE TANGLE-BAR DRAG.

The use of this implement from the "Blake" was begun on the second dredging cruise, at the instance of Professor Agassiz. A wrought-iron plate six feet long, three inches wide, and half an inch thick, with the forward edge beveled, had fastened to it at intervals along the rear edge a number of tangles to be dragged along the bottom. At each end and midway between on the front edge were eye-bolts for attaching the three legs of a bridle, and midway on the rear edge was another eye-bolt from which a sixty-pound sinker was dragged by a short length of rope. This drag was used with great success. I think twelve was the number of tangles attached to a single bar.

TOW-NETS OR DRAG-NETS.

Those used by us on the first dredging cruise were brought on board by Professor Agassiz. They were composed of a bag of embroidery canvas, Swiss muslin, or some similar stuff laced to a ring of brass wire one-fourth of an inch thick. To the ring was secured the three or four legs of a bridle to which the tow-line was bent. The nets may be of any dimensions desired. Ours, which were only used near the surface, were about fifteen inches across the mouth.

Professor Agassiz has sent me a diagram of a large drag-net used in deep water on the second dredging cruise. In this the mouth-ring was of three-fourths-inch wrought-iron and elliptical in shape, the diameters being five feet and three feet respectively. The bag was of netting one-fourth-inch square mesh, with a lining of muslin at the bottom to form a pocket. Professor Agassiz remarks that they should be moved through the water rapidly.*

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* See foot-note, page 145.

NETTING FOR DREDGES AND TRAWLS.

The netting for the "Blake" was purchased from the American Net and Twine Company, 43 Commercial street, Boston. For the first cruise the main bags of trawls were regularly made in the manufacture, *i. e.*, the round at the bottom was made by gradually decreasing the size of the meshes. For the second cruise, Professor Agassiz purchased the netting in lengths, and the bags were made on board as described heretofore. Our purchases of netting for this cruise were as follows:

For main bag of trawl: web to hang 1,000 feet by twenty feet, mesh one inch square, twenty-one-thread cotton; seven hundred and fifty-nine pounds, at forty-five cents per pound.

For trap and jacket of trawl: web to hang 1,000 feet by six feet, mesh one-half inch square, nine-thread cotton; two hundred and fourteen pounds, at seventy cents per pound.

For bag and trap of dredge: web to hang sixty-seven feet by six feet, mesh one-quarter inch square, $\frac{24}{9}$ tarred cotton; fourteen pounds, at two dollars and fifty cents per pound.

The term "*web to hang*" means when slightly stretched, as when attached to the roping of a seine. The meshes are measured either by the diagonal or by the length of one side. Thus a mesh having each of its four sides one inch in length is called a two-inch mesh or one-inch square mesh. The latter term seems to be the plainer.

Professor Agassiz recommends changes in the above as follows, and these changes have been introduced into the tables of dimensions already given:

For main bag of trawl, web to hang fifteen feet instead of twenty feet.

For trap and jacket of trawl, fifteen-thread cotton instead of nine-thread cotton. The difference in cost and weight is as fifteen to nine.

TUBS AND SIEVES.

The "Blake's" supply of these appliances was very simple: a nest of sieves, from coarse to fine, and several tubs. The tubs were of thick wood, iron bound, and fitted with iron handles. They were about twenty-four inches high, twenty inches in diameter at the top, and somewhat less at the bottom. We found that these answered our purpose well for deep

PLATE 31.

VIEW OF THE "BLAKE'S" DECK, LOOKING AFT FROM THE STARBOARD SIDE OF THE PILOT HOUSE. READY FOR DREDGING

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work, but in the work of the Fish Commission down only to a depth of two hundred fathoms, the hauls being more frequent and the specimens generally less fragile, the special appliances shown in the appendix to this chapter are used with success.

STEEL-WIRE DREDGE-ROPE.

Our rope was made at Trenton, N. J., by the John A. Roebling's Sons Company. It was one and one-eighth inches in circumference, and was composed of six strands laid around a tarred hemp heart. Each of the six strands was composed of seven galvanized steel wires of No. 19 American gauge (No. 20 Birmingham gauge). The ultimate strength of the rope was 8,750 pounds,* weight per fathom 1.14 pounds in air, and approximately one pound in sea-water; price, eight cents per foot.

For the first dredging cruise it was supplied in 3,000-fathom lengths, each length wound upon a separate wooden reel. For the second cruise, the working reel already having 2,700 fathoms upon it, I had the rope supplied on wooden reels, each containing only five hundred fathoms, in which shape it was easier to handle in the event of having to replace losses at sea. One wooden axle common to all these reels formed part of the outfit.

The shortest nip that we gave the rope was over the pulleys of the leading-blocks, the scores of which were eighteen inches in diameter, and this did not break up the zinc enough to give trouble from rusting. We used no preservative on the rope and had no need for it, but that recommended by the Roeblings is raw linseed-oil applied with the fleecy side of a piece of sheepskin, or to the oil may be added equal parts of Spanish brown or lamp-black. To preserve wire rope kept under water they recommend a mixture of mineral or vegetable tar with fresh-slacked lime in the proportion of one barrel of the former to one bushel of the latter; the mixture to be well boiled and applied freely while hot.

At the works wire rope is reeled up under strong tension, and in reeling off for use it should be passed directly from one reel to the other under at least slight tension, and it never should be coiled down or faked by hand. When supplied in a coil, the coil should be rolled along like a wheel and the rope payed off in that way to the working reel.

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* Two lengths tested for strength *in kinks* gave breaking strains as follows: 4,410 pounds, 4,600 pounds. APRIL, 1880.

For joining two lengths of the rope a "long-splice" should be made, at least twenty feet in length. To make an eye-splice at the end of the dredge-rope, turn the end of the rope around an oblong or heart-shaped thimble, and unlay each wire from the thimble to that end. Lay these wires as an untwisted strand along the rope and serve wires and rope together tightly with annealed-iron wire for a distance of eight or ten inches from the thimble. Cut off the free ends of the wires about three-quarters of an inch above the serving and turn down each wire neatly along the serving.

The dredge, trawl, &c., should always be attached to the rope by a shackle. We at first used hooks which we moused with wire, but they always broke adrift, probably by bending. Long shackles should be selected, of a size to slip into the thimbles, and into the eyes in the arms of the dredge. I would call particular attention to this matter, hoping to prevent a resort to makeshifts.

THE DREDGE-REEL.

For dredging in depths no greater than five hundred fathoms, which would require the use of no more than 1,000 fathoms of rope on the working reel, the latter might be made part of the hoisting-engine and be geared to the crank-shaft. The advantage would be in compactness and simplicity. For general work, the plan adopted for the "Blake" is probably better. When the reel takes the full strain on the rope in hauling back great strength is needed to resist the crushing force accumulated upon the drum, and to adapt a reel capable of holding four or five thousand fathoms of rope to this strain would involve an increase in its weight by no means desirable, either for paying out rope or for planting on a vessel's deck.

The "Blake's" reel, which has held 4,200 fathoms of the steel dredge-rope, is best shown on Plate 32. The drum or barrel is of boiler-iron, three feet six inches long, two feet in diameter, and riveted to fillets on the two cast-iron side-plates. The depth of the flanges, above the drum, is one foot. The side-plates are made with spokes, but would be better if solid. The friction-band is of wrought-iron, lined with maple one inch thick.

The standards are of cast-iron and are higher than need be. They were designed when it was intended to wind the rope by means of the

PLATE 32.

THE FORWARD SIDE OF THE DREDGE REEL AND ITS ENGINE. THE REEL HAVING ON IT 2700 FATHOMS OF THE STEEL ROPE RECOMMENDED BY PROFESSOR ALEXANDER AGASSIZ.

Heliotype Printing Co., 220 Devonshire St., Boston

hand-cranks. When a steam-engine is used for winding, the reel should be set as low as possible for security against the rolling of the vessel. In designing standards for a reel it must be remembered that they should be adapted to withstand violent jerks. The axle of the "Blake's" reel is of wrought-iron two and seven-eighths inches in diameter, reduced to two and five-eighths inches in the journal-boxes. The axle should have a bearing on both sides of each journal-box in order that the lateral strain may come upon both standards at each roll of the vessel.

The friction-lever is of the double-acting kind; that is, both ends of the friction strap or band are bolted to the lever, one on each side of the pivot.

Neither the friction-score nor the bearing surface of the friction-band should be lubricated with oil. Water may be used, if necessary, to prevent the wood lining from taking fire, but it should be applied at intervals from the first, and not dashed on when the cast-iron reel is hot and likely to be cracked by a sudden change of temperature.

The "Blake's" reel cost $225, and was made by Messrs. Copeland & Bacon, of New York.

THE STEAM HOISTING AND WINDING ENGINES.

(Plates 32, 33, and others.)

The Hoisting-engine.—There are two trunk cylinders, of the pattern known as Bacon's patent (see Plate 18), each of ten and one-half inches bore and ten inches stroke, firmly secured to the bed-plate at an angle of 45°, thereby avoiding a dead center, both being connected to the same crank-pin. The engine is provided with "link-motion" so that it may be run forward or backward or stopped instantaneously by the operation of the reversing lever, which is fitted to lock in three positions. By its elastic flexure the lever in locking is thrown into jogs cut in the flange of the standard against which it presses. The after lever, working in a vertical plane, as shown on the plates, is the reversing lever.

The crank-shaft is single-geared to the shaft of the winch-head by strong spur-gearing in the proportion of three to one. The winch-head, which is 22.56 inches in its least diameter—to accommodate one fathom of the 1⅛-inch dredge-rope in a single turn—is keyed to its shaft, the latter working within the larger gear-wheel. The winch-head shaft is fitted with a clutch working on a feather and operated by a lever moving in a horizontal plane. This lever may be locked in position by means of a thumb-screw. The winch-head may thus be thrown into gear with the engine, or it may be thrown out of gear and overhauled independently of the engine. The winch-head is provided with a powerful friction-brake, operated by a lever. On Plate 33 this lever is shown thrown up, in which position it is locked or latched in a jog cut in the flange of the forward standard, the friction-band being out of contact. One end of the band sets up with a screw and nut to a lug cast on the standard. The other end of the band is fastened by a pin to an arm projecting from the shaft to which the lever is keyed, the arrangement forming a toggle-joint, by means of which the lever is automatically locked when thrown down to its lowest position—that is, when the greatest stress is upon the band. The ultimate stress may be regulated by the screw and nut at the standing end of the band. This provision is necessary because the wood lining of the band will slowly wear away in use.

Below the brake-lever is the throttle, the wheel of which is made large that it may be turned easily and delicately with the left hand when the right hand is engaged with the brake-lever.

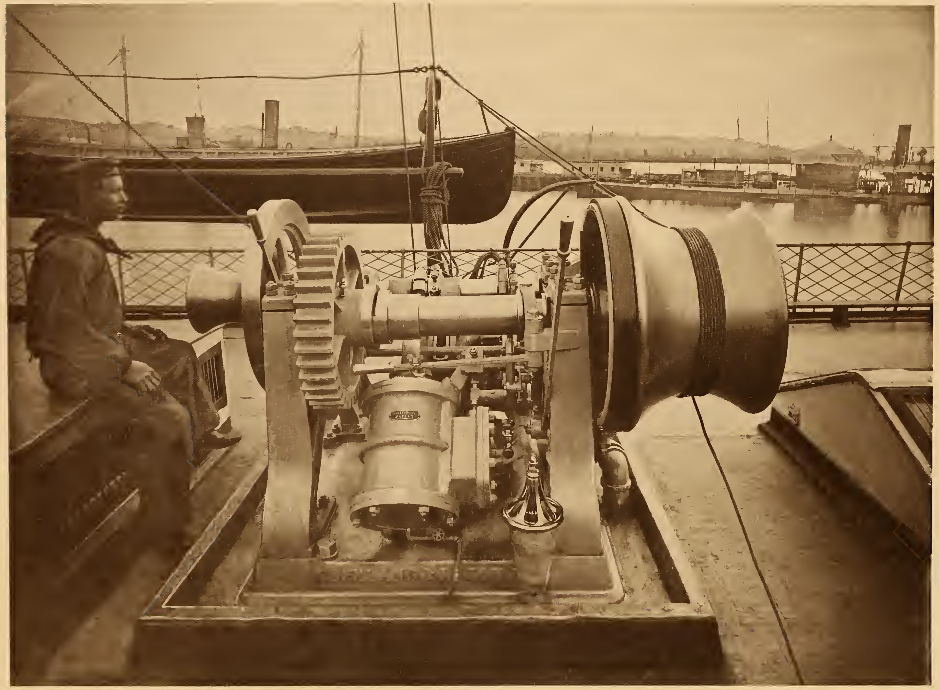
On the hub of the winch-head is a steel worm to engage the gears of a register like that shown on Plate 38. The register gives, approximately, the number of fathoms of dredge-rope payed out.

On the after end of the crank-shaft, outside of the fly-wheel, is a small winch-head for general use. The crank-shaft is forged in one piece, and both this and the winch-head shaft are of the best wrought-iron. The journal-boxes, connecting-rod boxes, and link-blocks are of composition metal. All pins for valve-motion are of steel, and all parts of the engine are made extra strong to withstand violent shocks.

The engine may be run fast or slow according to the work to be done, and under the complete control of one man.

The pressure of steam is usually sixty pounds. The exhaust leads into the condenser of the main engine.

The cost of the hoisting-engine, fitted in place and in running order, was $1,150.



VIEW OF THE MAIN HOISTING ENGINE FROM THE STARBOARD SIDE.

Heliotype Printing Co., 220 Devonshire St., Boston.

The Winding-engine.—This is of the same general description as the hoisting-engine. It has two six-inch cylinders and is single-geared to the axle of the dredge-reel. It is fitted with reversing and clutch levers arranged for locking in position. Engine and reel are under the control of one man.

The cost, placed on board and in running order, was $485.

THE SWINGING BOOM.

This is so clearly shown by the heliotype views that an extended explanation of details is not needed. It was forty-seven feet long and fourteen inches in its greatest diameter. The metal fittings and fastenings were of wrought-iron. The topping-lift was of three-inch manila, rove through iron-strapped blocks made extra strong. The pendant was of 4½-inch manila. The small block at the boom-end was of a well-known commercial pattern, extra fastened under my direction. The pendants of the guys were of two-inch iron-wire rope, and the falls for the same of 2½-inch manila.

THE ACCUMULATOR OR DYNAMOMETER.

(Fig. 3, Plate 34.)

The accumulator for dredging is made of a number of rubber buffers, A, A, &c., arranged for compression on a rod, B. The buffers are separated from each other and from the rod B by the guide-plates C, C, &c. The upper end of the accumulator being secured at D, and a strain applied to the lower end at E, the compression of the buffers will permit the cross-head F to travel along the rod B, and the rods G G to travel through the guide-plate H and the cross-head I. In this manner the accumulator elongates under strain, and when released from strain it is restored to its former length by the elastic force of the buffers.

The buffers are three inches deep, four and a half inches wide, and have a cylindrical hole through them of one and a quarter inches diameter. They were purchased of the New York Rubber Belting Company, of Park Row, New York, at a cost of about $2 each. The material of which they are composed is known by that company as compound No. 24, the constituents of which are as follows:

Ten pounds fine Para rubber, cleaned.
One pound white lead.
One pound litharge.
One pound whiting.
Ten ounces sulphur—about.
Vulcanizing heat, about 260° Fahrenheit.

The rods B and G, G, the nuts, the cross-heads F and I, and the large guide-plate H are of steel; the guide-plates C, C, C, &c., are of brass; all other metal parts are of wrought-iron.

The guide-plates C, C, C, &c., are one-eighth inch thick throughout the flanges. Their hubs are made to fit loose on the rod B, but tight within the buffers.

The edges of the metal around all holes in the guide-plates and cross-heads should be slightly beveled to obviate friction and planing.

The rod B accommodates thirty-two buffers without compression, but seven more are forced on that the accumulator may not extend for a light strain. Neither an accumulator nor a dynamometer is of use excepting for a severe strain. Plates 13 and 14 show the accumulator lowered into view: Plates 1 and 24 show it in its proper place, suspended from the mast-head. It is very elastic, and seems to have answered the purpose for which it was intended. Its maximum extension is about six feet. If I were to suggest any improvement at present occurring to my mind, it would be to make the buffers of a compound which would offer a greater resistance to compression.

The total cost of the apparatus was about $130.

The only really novel feature given by me to this accumulator is the peculiar shape of the brass guide-plates C, C, C, &c., the hubs or fillets of which keep the buffers from coming in contact with the rod B when the buffers are compressed.

If fears were entertained of the accumulator giving way in use, a toggle might be put in the pendant somewhere above the heel of the boom.

FIG. 1.

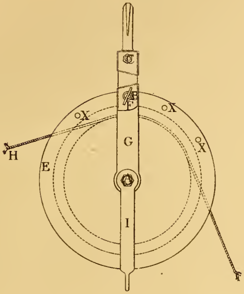


FIG. 2

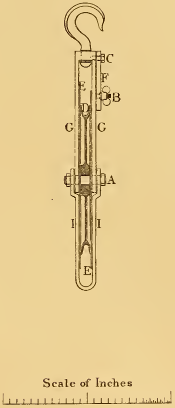
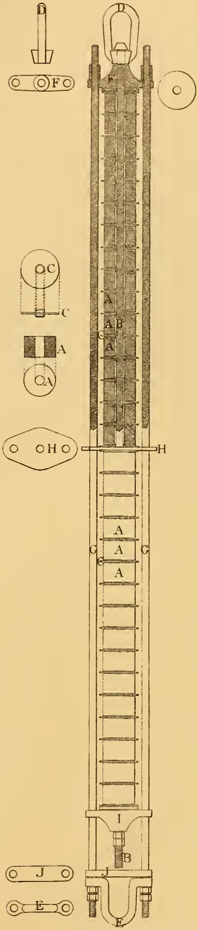


FIG. 3.



FIG'S. 1 & 2. IRON SNATCH-BLOCK FOR DREDGING ROPE.
FIG. 3 IMPROVED ACCUMULATOR FOR DREDGING.

THE IRON SNATCH-BLOCKS.

(Figs. 1 and 2, Plate 34.)

These are the blocks through which the dredge-rope leads. The pins or bolts A, B, C should be of steel, the sheave D of cast-iron, the side-plates E, E of thin plate-iron, and the flap or hook F and the straps G and I of wrought-iron. In the deck-blocks the side-plates are free to revolve, but on the pendant-block at the boom end they are pinned to the strap G, and are connected by socket-bolts at the points X, X, X. The socket-bolts are to prevent the dredge-rope from getting between the side-plates and the strap G. In setting up the socket-bolts care should be taken not to bind the side-plates against the sheave. The dimensions given on Plate 34 are those of the deck-blocks; the pendant-block has a sheave one inch wider. Plate 31 gives a view of the deck-blocks.

APPENDIX TO CHAPTER V.

DESCRIPTION OF SOME OF THE APPARATUS USED BY THE UNITED STATES COMMISSION OF FISH AND FISHERIES IN DREDGING OFF THE NEW ENGLAND COAST.

By Prof. A. E. Verrill.

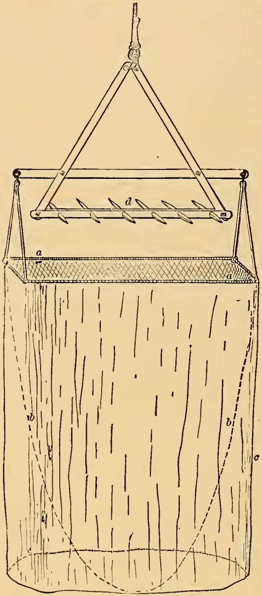
THE RAKE-DREDGE.

This instrument was devised in 1871, by the writer, for the special purpose of obtaining deep-burrowing species of bivalves, annelids, holothurians, crustacea, &c. It can be used only on muddy or sandy bottoms, and, of course, requires considerable force to draw it through compact mud or sand. In its original form, which is still in use, it consists of a strong A-shaped frame, made of flat bar-iron, and so bolted together that it can be folded up compactly when not in use or for convenience in transportation. The rakes consist of two flat bars of iron, furnished with strong iron teeth (steel would perhaps be better), about a foot in length, with thin, sharp edges and sharp point. The two rake-bars, when in use, are placed back to back and bolted to the ends of the side-pieces of the A-shaped frame. The cross-bar of the A projects beyond the side-pieces, and has a hole at each end, by which the arms of the dredge-frame are attached, so that the dredge follows the rake at a distance of about two feet. The dredge-frame for this instrument is made entirely of round iron, and as light as is consistent with the stiffness necessary to support the bag full of mud when being hoisted on deck. The length of the frame should be equal to, or somewhat exceed, that of the rake-bars. In the one now used by the Commission it was originally considerably larger, but owing to the too great weight of the load of mud it brought up, it has been made smaller, so that it is now of about the same length as the rake-bars. The net is similar to that of the common dredge, but deeper and with somewhat larger meshes, in order that a part of the mud may pass through more rapidly. The vast quantity of annelid tubes often encountered in using the rake-dredge frequently clogs the net so as to prevent even the fine mud from passing through the meshes. As this form of dredge can only be used on smooth bottoms, there is not so much need of a canvas protection as in the case of the common dredge, and we have often dispensed with it, but the net will doubtless last longer if protected with the canvas bag.

The dimensions of the rake-dredge used by the Fish Commission are as follows:

		Inches.
Side-pieces of the A-shaped frame:	Length	30
	Width	2
	Thickness	3/8
	Hole for ring	3/4
	Bolts	5/8

		Inches.
Cross-bar:	Length	42
	Width	2½
	Thickness	⅜
Rake-bars (*d*):	Length	36
	Width	2½
	Thickness	⅜
Teeth of rake:	Length	8
	Width	1¼
	Thickness	⅜
Ring for drag-rope:	Diameter	3½
	Size of iron	⅝
Dredge-frame (*a*):	Length	38
	Breadth	7
	Length of arms	20
	Size of iron (round)	½
Depth of net (*b*)		48

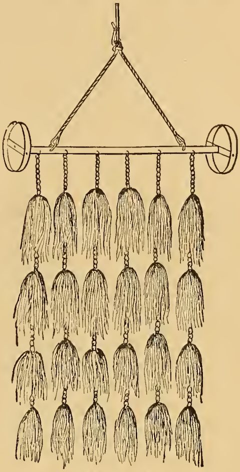


H.—THE RAKE DREDGE.

These dimensions might be improved by making the teeth ten inches long, and at least one-half inch thick if of soft iron, and they might have a slight forward curvature. The head passing through the bar should be square, and about three-fourths of an inch thick. They might be fewer and farther apart without detriment—say, five teeth on a bar three feet long, leaving the spaces about six inches each. The use of steel of low temper would be better still. The round iron for the dredge-frame should be at least five-eighths of an inch in diameter for the size of net given.

THE TANGLES.

The original form of tangles constructed by the writer for the United States Fish Commission, in 1871, consisted of a bar of iron to which several small iron chains were attached, each about fifteen feet in length. Along these chains, at intervals of about three feet, the bundles of unraveled hemp rope were attached, as shown in the figure. The bar of iron carrying the chains was attached to the cross-bar of the A-shaped frame forming part of the rake-dredge, the rake-bars being removed. In 1873 a further improvement was made by the writer. This consisted in supporting each end of the chain-bar in the center of a stout iron hoop or wheel by bolting it to a central cross-bar firmly bolted to the inner side of the wheel. The wheels are not intended to revolve, but merely to serve as runners and supports for the iron bar, in order to keep it off the bottom and diminish the chances of its getting caught among the rocks, as well as to keep it from breaking and destroying the specimens before the tangles themselves can touch them. An oval or elliptical form for these runners would answer the same purpose, but the circular form was adopted as the simplest, and, perhaps, the least liable to become caught among the rocks. In practice we have found the tangle-frame hitherto used too light for use on the larger vessel now employed, for when rocks are encountered the chain-bar often comes up badly bent. In constructing new ones, I should recommend a round or square bar of iron at least twice as heavy as the one we have hitherto used. Our present size was first devised for use on a steam-launch. It was also used on the "Bluelight," a tug of eighty tons, with good success. We have used tangles of this form with profit on the roughest cod-fishing ledges off the coasts of Maine and Massachusetts, where the dredge could not be used with safety. It is particularly useful in capturing star-fishes and sea-urchins, which frequent rocky bottoms. Several years ago the writer suggested the use of tangles of this or similar form to capture star-fishes on oyster-beds, where they so often prove very destructive.



I.—THE TANGLE-BAR.

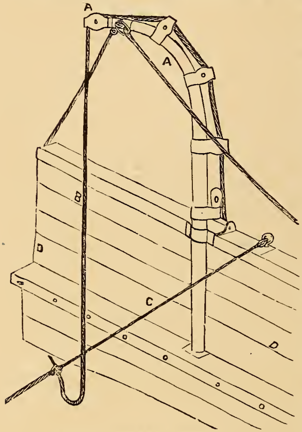
DIMENSIONS OF TANGLES.

	Present form.	Improved design.
Diameter of wheels outside	12 inches.	14 inches.
Breadth of rim of wheels	2 inches.	2½ inches.
Thickness of rim of wheels	½ inch.	½ inch.
Width of cross-bar of wheels	2 inches.	2½ inches.
Thickness of cross-bar of wheels	⅝ inch.	¾ inch.
Length of chain-bar	48 inches.	60 inches.
Width of chain-bar	2 inches.	2½ inches.
Thickness of chain-bar	½ inch.	1 inch.
Size of rings for drag-rope	3 inches.	4 inches.
Size of iron of rings	⅝ inch.	⅝ inch.
Size of iron of chains	¼ inch.	⅜ inch.
Length of iron chains	14 feet.	15 feet.
Length of hemp tangles	2½ feet.	3 feet.

The drag-rope for the tangles should be very strong, to resist the frequent and sudden strains when using them on rough bottoms.

THE CHECK-STOP.

This arrangement was devised by Capt. L. A. Beardslee, for use on board the "Bluelight," in 1873. Its purpose is to put the strain of the drag-rope (B) upon a weaker rope (C), which may be so easily broken in case the dredge or trawl catches upon rocks as not to cause damage to the apparatus, and at the same time to give sufficient warning to allow the slack of the drag-rope to be payed out before the headway of the vessel can be stopped. It has proved to be a very useful and simple expedient for these purposes. The figure shows the arrangement so well that no further description is necessary.

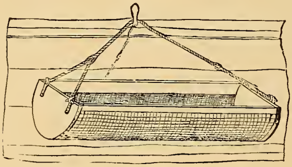


J.—Beardslee's Check-Stop.

THE CRADLE-SIEVE.

This form of sieve was devised by the writer in 1872. It was so constructed as to afford the means of rapidly washing out the large quantities of mud often brought up by the dredge and rake-dredge, and at the same time to keep the mud and water off the deck as much as possible.

It consists of two wooden end-pieces, in shape forming rather more than half a circle, united by two narrow wooden side-pieces set into the end-pieces so as to leave a flush surface. The outside covering consists of two thicknesses of wire netting, the inner one with meshes of one-twelfth inch or less; the outer one of stout galvanized-iron wire with one-half-inch meshes. The outer netting is only to afford support and protection to the inner one. The netting is nailed to the edges of the wooden end-pieces and to the side-pieces, and is further secured by a strip of hoop-iron nailed over the edges all around. A strip of wood, nailed across the bottom from end to end, affords additional strength and protection from injury. Two stout iron straps, fastened across each end-piece by wood screws, and terminating above the edge in a ring, furnish the means of suspending this sieve against the side of the vessel outside the rail. The mud is then placed in it, often filling it more than half full, and a gentle stream of water from the force-pump is turned upon it. In this way several bushels of mud may be washed out in a few minutes with little trouble. Another sieve, with straight wooden sides about six or seven inches high—just large enough to set partially into the



K.—The Cradle-Sieve.

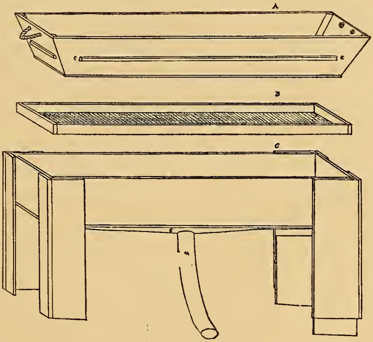
frame of the cradle-sieve and rest upon wooden cleats, provided for that purpose—has been sometimes used in connection with the cradle-sieve. Its bottom is made of strong galvanized-wire netting, with meshes of one-half inch. It serves to separate the coarser specimens and stones from the smaller and more delicate species.

In our own work the table-sieve described below has, to a considerable extent, superseded the cradle-sieve. The latter is still used, however, when there is only a moderate quantity of mud or when the table-sieve is already full of specimens.

DIMENSIONS OF CRADLE-SIEVE.

	Inches.
Length	36
Breadth	18
Depth	12
Width of side-pieces	3½
Thickness of side-pieces and ends	1

THE TABLE-SIEVE.



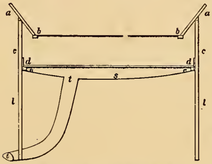
L.—The Table-Sieve.

This piece of apparatus is the result of several successive improvements. In fundamental principle it is like the cradle-sieve much enlarged and raised on legs, but the form is entirely different.

The sieve-foundation consists of a large, rectangular, wooden frame (C, Fig. L), with wide side-pieces made of inch boards, supported on stout legs at a convenient height. The bottom of this frame consists of stout galvanized-wire netting with one-half-inch or three-fourths-inch meshes. Below this is a funnel-shaped stout canvas bag (*s*), which terminates in a large canvas tube (*t*). This serves to conduct the waste water to the scuppers. A light frame of wood (B) is made to fit loosely inside of the main frame, and its under surface is covered with fine wire netting of one-twelfth-inch meshes. This constitutes the real bottom of the sieve, the coarse netting below serving only as a support for it. It is fastened to a movable frame, so that it can be taken out and its contents emptied upon the assorting-table. This also allows the wire netting to be more easily renewed when it becomes worn. The upper or coarse sieve (A) is made with wide, flaring, or hopper-shaped, wooden sides, upon which, at about the middle, there are cleats (*e*, *e*) that rest upon the edges of the main frame. The bottom of the "hopper" is formed of strong galvanized-wire netting of three-fourths-inch meshes (Fig. M, *b*, *b*).

DIMENSIONS OF TABLE-SIEVE.

		Inches.
Main frame:	Height to upper edge	30
	Length	66
	Breadth	38
	Width of side-pieces	11
	Thickness of side-pieces	1
Hopper-frame:	Width of side-pieces	13
	Length at bottom	56
	Length at top	66
	Breadth at bottom	27
	Breadth at top	37



M.—The Table-Sieve.

This form of sieve, in its primary form, was invented by Capt. H. C. Chester and the writer in 1877, but it was soon afterwards much improved by the addition of the canvas bag and pipe beneath it, which were devised by Mr. Smith, the executive officer of the "Speedwell."

The original use of this sieve was to receive the contents of the trawl, instead of emptying it on deck, as had been done previously; but its advantages were soon found to be so great that it has also been used for washing the contents of the dredge whenever the quantity of mud was considerable. The legs are made of unequal lengths, to correspond with the curvature of the deck.

CHAPTER VI.

NAVIGATION AND RECORDS.

DEVISING A SYSTEMATIC RECORD.

Until the records of the "Blake's" work were systematized in the manner to be described in this chapter, deep-sea parties of the Coast Survey had not been required to render to the office a detailed record of navigation; the work having been more or less desultory, there had been no general conformance to a fixed system of record analogous to that demanded of inshore parties, and the results of the navigator's observations and computations for determining positions had usually been accepted as correct. On joining the vessel I was the bearer of instructions from the Superintendent to my predecessor in command to submit to the office, with other records, the data used by the navigator in fixing the positions of soundings. While Commander Howell was still in charge forms for computation, containing the arrangement of data shown below the headings of Forms 7, 11, and 12, were drawn up by Robert G. Peck, Master, one of the watch officers of the "Blake," and were approved by the commanding officer. The system of navigation record, as set forth herein, was then gradually developed during my first and second seasons in the Gulf of Mexico, some preliminary points having been discussed before Commander Howell left the vessel. In the astronomical methods employed to determine positions we made no advance; it was only in combining in a comprehensive system the work of navigation, plotting, and record, to admit of a revision of the whole navigating work at any future time, that we afterwards made any improvement in the department of navigation. From the impetus and scope given to the work by the adoption of wire for sounding purposes it followed, not unnaturally, that the arrangement of the General Record Form (Form 3), *i. e.*, the record of soundings, temperatures, &c., needed to be changed, and as additional forms became necessary we from time to time drew up and introduced all others shown in this book. Our efforts in this direction were, in the main, simply responsive to the new requirements.

Merely to plot a ship's positions for the times of observation is easily done by a navigator, but when the position of every sounding and of every change of the course must also be plotted, and *all the processes clearly explained and submitted to the judgment of others*, the work becomes complicated, and inevitably suggests the necessity for system to a person plotting in a maze of right lines, and surrounded, perhaps, by sixty, eighty, or one hundred Navigation Forms and other papers. While my written description is undoubtedly very dry reading, the system itself is nevertheless so simple that with the opportunity for verbal explanation it was only the work of a few hours to qualify a new officer reporting for assignment as executive and navigator.

WHAT CONSTITUTED THE RECORD.

On fitting out for each season the party was provided by the office with one or more Projections or Sounding-Sheets (Fig. 2, Plate 35) covering the whole ground to be worked over. They were on a scale of either $\frac{1}{400,000}$ or $\frac{1}{600,000}$, and on them were located all the prominent landmarks likely to be needed for beginning or closing the inshore ends of lines of soundings. The various forms used in our work were also provided as required.

The record of the work consisted of the following:

For the Coast Survey Office.—The General Record, Form 3, and the Supplementary Record, Form 4, with which were bound in one volume the following: List of officers of the vessel, copy of the Superintendent's letters of instruction, diary of events, special tabulated statements, deviation tables, description of apparatus and methods, &c.

The Navigation Record, Forms 6 to 12, bound in one or more volumes, and showing the data and methods employed in fixing the positions on the lines of soundings and in determining chronometer errors.

The Sounding-Sheets, represented herein by Fig. 2, Plate 35, containing, besides the plotted work, tabulated statistical statements of the amount of work done during each season.

Temperature Curves or Sections, Form 15.

For the Archives of the Vessel.—The original, or rough sheets, of everything sent to the office, excepting the Sounding-Sheet, of which a tracing was kept.

The Sounding Time Book, Form 1.
The Serial Temperature Book, Form 2.
The Plotting Form, Form 13 (B).
The Plotting-Tracing, Fig. 1, Plate 35.
The Rough Book of Observations, Form 5.

EXPLANATION OF RECORD FORMS.

For an explanation of our system, it is well to describe the record—in all the essential points—of some particular line of soundings, and I have selected for this purpose the record of a part of line S, of 1875–'76, in the Gulf of Mexico, carrying it through one day only. As this line was run from South Pass, Mississippi River, to the Yucatan Bank, nearly on the meridian of 89°, to continue the record along the whole line would be simply to repeat the first day so far as the purpose in view is concerned.

As a preparatory measure an explanation of some features of the forms will be given.

The General Record, Form 3.—Columns A, B, C show the time when the sinker reached bottom, which is regarded as the *time of the sounding*, and that on which the position of the sounding should be based.

Column D shows the serial number of the sounding, to which number are referred all the specimens taken at the cast. At sounding No. 10, for example, we obtained and saved for examination a bottom-soil specimen and six water specimens, all of which received the number 10, on the bottle labels. In referring any specimen to its corresponding sounding on the General Record, the serial number on the label would show beyond question—and without reference to the latitude and longitude—at which sounding the specimen was secured, even had two or more successive soundings shown equal depths. See bottle labels on page 90.

Columns E, F, G, H are arranged to give continuity to the data required by the draughtsman at the office in plotting soundings on the office sheets; that is, the data for chart-making.

Columns I and J show the *corrected* water temperatures (the readings of the instruments and the corrections to be applied are kept on Form 2, page 104). These columns are not filled by the recorder during the work on deck, but the entries are made afterwards when the instrumental errors have been applied.

Column K shows the temperature of the water specimen at the instant of reading the density from the areometer in order that the density of each specimen may be reduced for a common temperature. The depth whence the specimen came is referred to the column of depths under the head of "*water temperatures.*"

Columns L, M, N, O.—A comparison of these columns gives the whole time occupied at a sounding station, which it is well to know for various reasons, and gives also the figures for Columns P and Q.

Columns P and Q show the time taken to make the run from the preceding sounding or change of the course, and are of use, in connection with column T, in giving the officer of the deck an idea of the time required to run the distance from the station last occupied to the one next in order. For example: Master M. F. Wright relieved the deck at 4 a. m., May 10, and, seeing that it had taken the vessel, in Lieut. W. O. Sharrer's watch, $1^h\ 10^m$ to make 9.7 miles, from sounding No. 4 to sounding No. 5, it appears that he allowed $1^h\ 12^m$ from sounding No. 5 to sounding No. 6, hoping in that time to make the exact sounding-interval of ten miles.

Column R shows at each sounding or change of the course the vessel's course by the standard compass from the preceding sounding or change of the course, and is the column to be filled by the officer of the deck, leaving the corrections to be applied afterwards by the navigator.

Column S shows the reading of the patent-log at each sounding and at each change of the course.

Surface currents recorded on the General Record do not necessarily apply to the plotting; each is obviously only the true current at one observation spot and for one short interval of time.

It will be seen that the arrangement of the General Record Form is designed to give, so far as space will permit, a general grouping of the data needed for scientific investigation on one page and that for the navigating purposes of the vessel on the other.

The Supplementary Record, Form 4.—This is of use in making up the statistics of lines of soundings, in preparing detailed reports of operations, and for general reference. It shows what instruments and appliances were employed, and if their working was satisfactory. The categorical style of the headings of some of the columns was suggested by experience, and after its adoption we were free from ambiguities of expression, such as "bottom saved," "got bottom," "bottom specimen," and the like, which left one in doubt as to whether a specimen of the bottom had been *saved for examination* in every case or only in certain instances.

Column F of the General Record points out, by the absence of abbreviations or by special statement, if no specimen was brought to the surface.

The Rough Book of Observations, Form 5.—Books containing fifty leaves, having these forms printed on each page, were bound in suitable style for the pocket, and the navigators used them in all astronomical observing. It was the custom of the "Blake's" navigators to take one or more observations at each sounding during the day and frequently between soundings also, while at twilight, both morning and evening, they continued to get them as long as the twilight gave a bright star above a distinct horizon. The intention was not, necessarily, to compute all, but to have them available should those which were computed fail to give good results.

With Form 5 is given the label for the cover of the Rough Book of Observations.

The Navigation Forms, Forms 6, 7, 11, and 12.—These are the only forms used on board the "Blake" for the computation of astronomical observations, and, with the remarks written upon them, they constitute the whole navigation record sent to the office, excepting the data contained on the General Record Form.

Form 6 is for computing chronometer errors by Equal Altitudes, for recording positions by bearings, and for all computations for which the arrangement of Forms 7, 11, and 12 is not adapted.

Sumner's Method by Moon, Planet, or Star may be worked on Form

7; Sumner's Method by the Sun on Form 11; and the Meridian Altitude of Sun, Moon, Planet or Star on Form 12.

The occasion was very rare that required the use of Form 6 when working on our lines. Forms 7, 11, and 12 were employed almost exclusively, full advantage being taken of the comprehensive scope of Sumner's Method.

The Plotting Form, Form 13 (A and B).—This is not indispensable, but its use systematizes the work of plotting and thereby very much lessens the probability of making errors. It was regarded by us as a great convenience, and its use will become apparent when the plotting of the work is explained.

SCHEME OF NAVIGATION RECORD.

When at work on a line of soundings the navigators arrange the computed observations in order of time, for convenience of reference. After the arrival of the vessel in port, and when the chronometer errors have been ascertained, the chronometer rates are worked back for each day on the line. Then each observation, beginning with the first of the series, undergoes a verification by the assistant navigator, the new chronometer rates being introduced. The executive officer, who is also the navigator, beginning with the line first run, and keeping each line distinct, selects such observations as are deemed worthy of consideration, and, still preserving the order of time, numbers them in a regular series by *numeral letters* as they come from the assistant navigator. After a few observations have been verified the navigator begins the plotting, and the work of verification and plotting go on together, usually keeping pace with each other.

After the plotting has been completed the *accepted* observations—those not rejected as the plotting advances—are renumbered in a new series by order of time, and are designated by the *numeral figures*. The rough copies of the Navigation Forms retain the symbols of the first numbering, and receive also those of the second series, but the smooth copies sent to the office bear only the numeral figures—that is, the revised numbers. Thus we have the selected observations numbered in two series, one series embracing all that were selected and considered, and the other series only those that were finally accepted in the plotting.

The utility of numbering in a series *all* the observations to be considered is, I think, apparent, and it is probably equally clear that a renumbering or a rearrangement of the *accepted* observations in a second series is necessary in order to restore the continuity of a first series that has been broken by the rejection of some of its component parts. Since an observation may have a different number in the second series from that which it had in the first, to escape confusion a distinct notation or symbolization must be adopted for each series; hence the employment of both numeral letters and numeral figures. Throughout the Navigation Record no other use is made of the Roman numerals than that already specified.

Each line of soundings of any season is designated by a *letter* according to alphabetical order and order of time, and all specimens, soundings, stations, observations, positions, &c., on a line are referred to the *line letter*. On the Navigation Forms the various *positions* established by astronomical observations or by bearings of objects on shore are also marked serially in order of time, and on the Sounding-Sheet are designated by symbols such as S_1, S_2, S_3, &c., for line S. The use of the symbols will be appreciated when it is called to mind that upon the Sounding-Sheet may be plotted many intersecting lines of soundings, each line exhibiting a number of Definite Positions obtained by observation. On board the "Blake" a person would be readily understood were he to say that Sounding 13, on Line S of 1875–'76, was taken at Position 10, or S_{10}, determined by Observations 8, 9, and 10.

HOW TO KEEP THE PLOTTING FORM; ITS USE.

In plotting a line of deep-sea soundings, as in plotting an inshore line, the line itself is first laid down by fixing and connecting the successive positions obtained by observation, after which the soundings are located on the line as thus laid down.

It is very confusing in plotting to be obliged to refer, forward and back, repeatedly to the General Record and the many Navigation Forms, on which there is a vast deal of data of no use in plotting; but with the Plotting Form this necessity is obviated, for on the latter, by a preliminary operation, all the necessary data, and no more, are arranged and combined in such a way as to facilitate subsequent selection and comparison. Form 13 A shows the Plotting Form fully prepared for beginning the plotting of line S, while Form 13 B shows its condition when the plotting has been completed.

All the bearings, angles, and astronomical observations to be considered in plotting the work are arranged on the Plotting Form (Form 13 A) in order of time; the observations are numbered in Roman numerals in a regular series, and the data for laying down the lines of position, together with the courses and distances that have been made to each observation or change of the course from the preceding observation or change of the course, are correctly placed in their appropriate columns. A change of the course, when there is no corresponding observation, is designated by the letters C, C in the "*object*" column, and to secure a proper spacing it should be entered as soon as its place has been reached, and not after all the data from the various Navigation Forms have been first entered throughout the whole Plotting Form.

The courses and distances are obtained by an inspection of the "*course*" and "*patent-log*" columns of the General Record Form in comparison with the patent-log readings on the Navigation Forms. Confusion may arise herein if it be not borne in mind that the courses and distances are arranged on the General Record in their relation to the *soundings*, while on the Plotting Form they are arranged in their relation to the *observations*.

As an example of a case in which a mistake might be made if care were not exercised, it will be shown how the courses and distances are entered on the Plotting Form between Observations IV and V.

There are given herewith specimens of only seven of the completed Navigation Forms. Their serial numbers happening to be the same by both numeral letters and numeral figures, they have been marked on the headings with the numeral figures only as being smooth copies. After entering these specimen observations on the Plotting Form, the results of others, of which no specimen copies are thought necessary, have also been entered in order to complete the record for one day.

Observation IV was taken between Soundings 5 and 6 (shown by the back of the Navigation Form, or by a comparison of the reading of the patent-log on the General Record with that on the Navigation Form). From the time of the observation, when the patent-log read 46.4 miles, the

General Record shows that the vessel continued on a S. ⅞ E. course until Sounding 6, when the patent-log read 50.4 miles—a distance of 4 miles. Immediately after Sounding 6 the course was changed to south (see General Record, Sounding 7, "*course from last sounding*"), and remained unchanged at Sounding 8, when the patent-log read 70.2 miles—a distance of 19.8 miles.

Observation V was taken at Sounding 8, as the patent-log readings at once show, and thus it should be entered on the Plotting Form, between the records of Observations IV and V, that the course was changed at $5^h\ 25^m$ a. m. (assumed to have been changed from the time the sinker touched bottom at Sounding 6), when the patent-log read 50.4 miles, and after the vessel had steered S. ⅞ E., 4 miles, since Observation IV; and for Observation V it should be recorded that the vessel had steered south, 19.8 miles, since the change of course mentioned.

As the plotting of the work progresses and the location of the Definite Positions are determined, the method followed in getting each of these positions from the observations is stated in the second column of "*remarks*" on the Plotting Form. It should be borne in mind by the person who plots the work that while his memory is charged with many important facts concerning the navigation of the vessel, these facts will be altogether out of the reach, excepting through the records, of those who may in the future revise his work. His aim should be, therefore, to prepare the "*remarks*" for the benefit of persons who understand plotting, but who are unfamiliar with the circumstances attending the work itself. A similar principle should be applied to all the records.

The first column of "*courses and distances*" on the Plotting Form is made to show, at each observation or change of the course, the run from the preceding observation or change of the course with reference to all the observations which were placed under consideration. The second column of "*courses and distances*" is used to rearrange the traverse data to suit the *accepted* observations only. Thus, for example, Observations VIII and IX (Form 13 B) having been rejected in the plotting, the columns are made to show in the simplest form the run to the *accepted* Observation 8 from the *accepted* Observation 7 (to Observation X from Observation VII). By the first column of "*courses and distances*" the run to Observation X (*accepted* Observation 8) from Observation VII (*accepted* Observation 7) reads S. by E. ¾ E., 10.3 miles, S. ⅝ E., 5 miles, and S. ⅝ E., 5.3 miles, while in the second column it is stated compactly as S. by E. ¾ E., 10.3 miles, and S. ⅝ E., 10.3 miles.

When the plotting has been completed, the "*remark*" column filled out, the second numbers given to the observations, and the latitude, longitude, and serial number of each Definite Position recorded, we have on the Plotting Form, exclusive of the computations of observations, all the information needed to effect a replotting of the Definite Positions on the line of soundings by either series of observations.

There should be transcribed from the Plotting Form to the rough Navigation Forms all the explanatory remarks from the second column of "*remarks*"; also, the latitudes, longitudes, and serial numbers of the Definite Positions. I will again state that the rough Navigation Forms, both on the headings and in the remarks, should give the observation numbers in both series; but the smooth copies, for transmission to the office, should give only the numbers in the second series. The forms of those observations which are thrown out in the plotting are marked "*Rejected*," in large letters across the face, with red or blue pencil, and may be filed away in the Archives with the rough forms of the accepted observations or by themselves. We never sent the Plotting Form nor the Plotting-Tracing to the office because, the "Blake's" work being continuous, the party on board could always be called on by the office for a replotting; but with a brief explanation on the Plotting Form, to show the use of the first and second arrangement of numbers, courses, and distances, that Form and the Tracing might form very useful additions to the office records.

THE ARCHIVES.

The establishment of the Archives was by no means a caprice; on the contrary, it was a legitimate consequence of the many embarrassing circumstances which suggested it; and it can be stated with confidence that, by taking a great number of observations, by recording them with full information in the systematically arranged Rough Book of Observations, and by preserving all of them for future reference, many miles on lines of soundings were saved which otherwise would have been lost.

THE PLOTTING-TRACING AND THE SOUNDING-SHEET.

It grew to be our custom to plot, not directly on the Sounding-Sheet, but on a piece of tracing-paper laid over it and upon which were traced the parallels, meridians, compasses, and graduated scales required to plot the line of soundings in hand (Fig. I, Plate 35). By pricking through the Tracing positions could afterwards be transferred readily to the Sounding-Sheet. The finished Sounding-Sheet (Fig. 2, Plate 35) contained on each line the Definite Positions, the points where the course was changed, the soundings, the character of the bottom-soil specimens, occasional surface currents by dead-reckoning or by actual observation with floats, and the direction of the wind at frequent intervals.

When the transfer had been made the Tracing was cleared of all *superfluous* pencil-marks, and filed away in the Archives on board the vessel, where it remained from year to year for reference.

In case lines of soundings subsequently run did not intersect consistently with lines already plotted, the Plotting-Tracing was taken from the Archives and the plotting work subjected to a careful revision. This Tracing, besides greatly facilitating revision, saved the Sounding-Sheets from much of the wear that would have defaced them during the successive seasons that they were used on board the vessel.

Although the Sounding-Sheets were sent to the office at the end of each season, they were usually returned, after being copied, to serve for further work in the same locality.

Fig. 1, Plate 35, shows the Plotting-Tracing of Line S cleared of superfluous pencil-marks and ready for the Archives.

DETAILS OF THE PLOTTING OF LINE S.

Establishing the Positions (Fig. 1, Plate 35).—By reference to the Plotting Form it is seen that the "*departure*" on line S was taken from South Pass and Pass à l'Outre Lights at $8^h\ 40^m$ p. m. on May 9. A plotting of the bearings gives the first Definite Position, which is designated by a circle of one-eighth-inch radius, and marked S_1. At $9^h 37^m$ p.m. bearings were again taken of the same lights, by which we get Position S_2.

The course and distance by dead-reckoning from Position S_1 to the time of Position S_2—S. ⅝ E., 5.1 miles—is represented by a dotted line. It is well to draw the line of course and distance after the manner shown—*i. e.*, from a Definite Position—when this can be done without producing a confusion of lines on the Tracing, but it may be laid off as shown from Position S_7, or from any part of a line of position, instead of from a Definite Position on that line. The requirement is simply to make it clear between which Definite Positions, or lines of positions, the run by dead-reckoning was made. If drawn on one side, the parallel rule and the dividers will carry it up to any place where it may be needed.

With a line of soundings of no very great length it is a good plan to lay down all the Sumner and other lines of position, and to mark each with its appropriate legend before plotting positions other than those obtained by bearings of objects on shore. We generally drew lines of position and Definite Position circles and symbols in red ink.

From Observation I to Observation II the vessel made 1.1 knots, S. ⅞ E., by dead-reckoning. To find the Definite Position on Observation II, lay off the run from any part of Observation I, and from the lower extremity of the line thus projected draw another line parallel to Observation I, which will intersect Observation II in the position sought—that is, Position S_4.

When referring to the plotting the term "*observation*" will, for brevity and convenience, often be used instead of "*line of position*" or "*Sumner-line.*"

From Position S_4 lay back the run made, by dead-reckoning, between Observation I and Observation II; the line representing the run will cut Observation I in Position S_3; or carry back Observation II, by course and distance, to an intersection with Observation I. In getting Position S_3 and Position S_4 no current nor drift was allowed for in the run. A line drawn from the point A—the dead-reckoning position at the time of Observation I—to Position S_3, would represent the current or drift from the time the vessel was at Position S_2 to the time of Observation I—S. E. ¼ E., 2.4 miles in the elapsed time of 3^h 4^m, a velocity per hour of 0.8 mile. From this it seems plain that the Positions S_3 and S_4 need not be revised to allow for current, since Observation II was taken only six minutes after Observation I.

It is seldom that any dead-reckoning current need be allowed in such short runs between observations. What from custom is here styled *current,* is evidently sometimes very different from the true current, and results from current, headway, and sternboard during soundings, imperfect steerage; and leeway, if it has not been allowed for in correcting the courses. During the operation of sounding a vessel is so constantly manœuvring to keep the wire vertical that no accurate run can be kept of her drift over the ground on such occasions. Since the stoppages vary in time—because the soundings vary in depth, and from other circumstances—the dead-reckoning current between two widely-separated positions—as S_2 and S_3—does not, by any means, always give a measure of the drift at each intermediate point; hence it would be of no avail in plotting to strive for a degree of exactness unattainable from the nature of the work. I have no intention to encourage laxity; on the contrary, I would insist on accuracy wherever it is possible; but it is useless to accord to results involving speculation more than their merited value.

As each Definite Position is determined, explain in the second "*remark*" column of the Plotting Form the method adopted in its determination; and if any allowance for current has been made, the fact should be stated, mentioning if the current was by dead-reckoning or by observation with floats. The wind and current between positions are indicated by arrows, as shown on the plate. The velocity per hour of the current, in knots and tenths, is designated by figures, and the force of the wind is expressed by the figures of the usual weather notation. The arrows, on the whole, present a very good general indication of the direction of the currents. By reference to those plotted in previous years we were enabled, in 1878, to run a series of lines of soundings in various directions in the Straits of Florida and the Yucatan Channel, across the swiftest currents of the Gulf of Mexico, with such precision as to elicit the special commendation of the Superintendent of the Coast and Geodetic Survey.

Positions S_5 and S_6 are obtained from Observations III and IV after the manner of getting Positions S_3 and S_4 from Observations I and II—*i. e.*, by carrying Observation III forward, by course and distance, to an intersection with Observation IV, and Observation IV back to an intersection with Observation III.

From Observation V, which gives a Sumner-line of position by the forenoon sun, we could get at once a position close enough for ordinary navigation by referring it to the Definite Positions S_5 and S_6; but for our purpose it is necessary to take into consideration, likewise, the noon and afternoon observations, Nos. VI and VII, the first step being to determine the Definite Position on the noon parallel, Observation VI.

The forenoon observation, No. V, carried forward to an intersection with the noon parallel, Observation VI—which is done by simply prolonging the Sumner-line, because the course is directly along that line—gives a position at B, while the afternoon observation, No. VII, carried back gives another position at C. To determine Definite Position S_8, it is assumed that from the time of Observation V until the time of Observation VII the current remained unchanged in direction and velocity, and that the vessel's drift in a true westerly direction is represented by the distance from B to C, without regard to any possible northing or southing.

It is evident that this assumption is not strictly true, for had simultaneous observations of two objects on different bearings been taken at the time of getting Observation V, their lines of position would not have worked to an intersection with Observation VI at exactly the same point on the parallel. To avoid misunderstanding, we usually called the distance from B to C *discrepancy;* but we treated it as true drift, unless there were reasons to the contrary.

If, therefore, from $9^h\ 15^m$ a. m. until $2^h\ 58^m$ p. m., an interval of $5^h\ 37^m$ (remembering that the clock was set ahead 6^m at noon), the drift was 1.7 miles—as represented by the distance from B to C—from $9^h\ 15^m$ a. m. until noon, an interval of $2^h\ 39^m$ (clock set ahead 6^m), it was 0.8 mile. The distance 0.8 mile laid off on the noon parallel from B toward C gives Position S_8. This is the method usually followed in getting the position on a noon parallel by means of one forenoon and one afternoon observation; but should there be doubts of its correctness in certain instances, the dead-reckoning currents found by working forward or back to noon from the morning or evening twilight positions will probably point out if the method be admissible. With several forenoon and several afternoon observations worked to noon there can be no great uncertainty of getting a trustworthy position, provided all the observations are good.

Having determined the noon position we are prepared for a return to the Definite Position on Observation V. Observation V makes so small an angle with the meridian that it will give a close approximation to the correct longitude for any latitude likely to be assumed; hence it is with the determination of the latitude that we need most concern ourselves. The course and distance carried forward from the *Definite Position* S_6 gives a dead-reckoning latitude at D, and by working back in the same way from the *Definite Position* S_8 we get another dead-reckoning latitude at E. Interpolating for time-intervals we get a mean latitude between the points D and E, which, laid off on Observation V, gives Position S_7.

It is interesting to note that when carried to intersection with Observation V, Observation III gives a position at F, Observation IV at G, and Observation VI at H, and that a mean of these positions differs but little from Position S_7 already found.

The true position of the vessel when the course was changed at $5^h\ 25^m$ a. m.—after she had steered S. $\frac{7}{8}$ E., 4 miles, from Position S_6—should next be sought. If in $4^h\ 40^m$, the time from Position S_6 to Position S_7, she drifted E. N. E. $\frac{1}{4}$ E., 1.2 miles, as represented by a line drawn from D to Position S_7, in 50^m (the time from Position S_6 to the changing of the course), she must have drifted E. N. E. $\frac{1}{4}$ E., about 0.2 mile, assuming the drift to have been invariable from Position S_6 to Position S_7. The true position is therefore marked at a point 0.2 mile E. N. E. $\frac{1}{4}$ E. from the dead-reckoning position, and designated by a circle of $\frac{1}{16}$-inch radius.

For finding the correction to be applied to the dead-reckoning position of the vessel at changes of the course, in order to locate the true position, it might prove convenient, in extended plotting, to make use of a diagram similar to that shown in the right upper corner of Fig. 1, Plate 35. One of these could be constructed in some vacant corner on each Sounding-Sheet, and by having the scale of miles on the diagram the same as that of the projection the correction, as taken from the former with a pair of dividers, could be applied directly to the dead-reckoning position. Any expansion or contraction of the paper from time to time would probably equally affect the diagram and the projection.

Example: If in $8^h\ 45^m$ the drift was 2.5 miles, how much was it in $3^h\ 40^m$? The dotted line *a b* on the diagram represents the drift sought, which by computation is 1.04 miles.

Before seeking a Definite Position on Observation VII, Position S_1 should be determined. Observations X and XII were taken only 20^m apart, during which interval the vessel was engaged in sounding and manœuvring. From this it appears that we can do no better than to locate Position S_{10} at the intersection of Observations X, XI, and XII.

The Sumner-lines corresponding to Observations VIII and IX, which were originally accepted, have been purposely shifted 4′ in longitude to the eastward, that they may be found unfit for acceptance, and so give an opportunity to show in what manner *rejected* observations are treated in the record, or, perhaps more strictly, how the records are amended for rejected observations.

Position S_9 on Observation VII is obtained by running the course and distance forward from Definite Position S_8 and back from Definite Position S_{10} for a dead-reckoning latitude, after the manner of proceeding in the case of Position S_7.

If, instead of getting Position S_9 by the method just stated, the noon observation and the evening twilight observations were to be carried to intersections with Observations VII, the several points of intersection would be as follows: By Observations VI at J, and by Observations X, XI, and XII at K, L, and M, respectively. The lines of position of Observations X and XI, making only the small angle of 18° with the line of position of Observation VII, give untrustworthy results, but that of Observation XII, making an angle of 42°, would give a a tolerably good position if coupled with Observation VI.

It is well to take plenty of time for consideration when plotting, and to make a practice of running courses and distances forward and back, and of carrying the lines of position to intersections by various combinations, as a means of detecting those observations which, through one cause or another, are least worthy of acceptance.

The position where the course was changed between S_9 and S_{10} should now be found, the successive positions connected by right lines, and the winds and currents along the whole line of soundings ascertained and designated by arrows. Then the Plotting Form should be completed in every particular; after which it may be laid aside and the General Record Form taken up for the purpose of plotting the soundings. Unless the independent points where courses were changed are known, it would not be possible to plot the soundings correctly. While these points are determined and specially marked to serve a necessary purpose, they are not classed with the Definite Positions, so called, because they do not occur on any astronomical line of position nor on any line of bearing of a shore object. It might be convenient to call them *Secondary Positions.*

DETAILS OF THE PLOTTING OF LINE S—(CONTINUED).

Plotting the Soundings.—All the soundings taken between any two successive Definite Positions are generally plotted on a right line connecting those positions, but if an unusually prolonged delay has been made at any cast, making it evident that an exceptional allowance for drift or current should be applied in that instance, then it may not be practicable to adhere to the right-line method, and the case becomes one of special judgment, dependent on circumstances. When such cases arise, it should be remembered that, the method by right lines being the one usually followed, all deviations therefrom should be specially mentioned in the column of "*remarks*" on the Plotting Form, to be transcribed to the proper Navigation Forms. It is desirable that the navigation record should not be encumbered by such supplementary remarks, and they may often be avoided by taking observations at short intervals along the line of soundings, especially at different times during the long stoppages. When working over gentle slopes like the Great Florida Bank, where for more than one hundred miles seaward the water is of less depth than one hundred fathoms, greater exactness is called for than is absolutely required in the deep basin beyond, as it is probable that navigators at large will turn to good account the soundings shown on their charts within the curve of one hundred fathoms. Line S, part of which has just been plotted, crossed very strong currents as we approached the Yucatan Bank, and on line T, run soon after from Alacran Reef to Tortugas, we experienced on leaving the Bank such a strong head wind and heavy sea, and such a swift current setting up through the Yucatan Channel, that the dead-reckoning current was five miles per hour at right angles to the direction of the line of soundings. On each of these lines we had, as a result of our astronomical observations (thirty-eight observations on Line S and sixty on Line T), as many Definite Positions as there were soundings, although the position by observation was not always that of a sounding. The right-line method was followed in plotting, but with so many Definite Positions the location of the soundings on our Sheets cannot be much in error, notwithstanding the rapid drifting of the vessel.

Fig. 3, Plate 35, illustrates the plotting of the soundings between Positions S_2 and S_3. Sounding 2 (one hundred and twenty-seven fathoms) was taken after a run, by patent-log, of 4.9 miles from Position S_2, and Sounding 3 (three hundred and eighty-six fathoms) after a run of 10.3 miles from Sounding 2, or of 15.2 miles from Position S_2. In the present case these intervals might be laid off on the dotted line representing the run from S_2 to S_3, and thence might be carried to the line proper, but frequently the line of the course and the line of soundings coincide so nearly in direction that other means must be adopted, and the manner of working may be as follows: Draw at any convenient angle with the line of soundings a right line S_2 P, equal to the distance by patent-log from Position S_2 to Position S_3—equal to S_2 A, or 16.2 miles. Lay off on the right line S_2 P the sounding-intervals S_2 N (4.9 miles), and N O (10. 3 miles), as given by the patent-log readings on the General Record Form. From the points N and O draw parallels to the right line S_3 P, intersecting the right line connecting the Positions S_2 and S_3. The points of intersection are the positions to be assigned to the respective soundings. The right line S_2 P may be drawn at discretion, but the method of obtaining the most convenient angle possible is shown by Fig. 3. From Position S_2 as a center, with a radius equal to S_2 A, describe the arc of a circle as shown. From Position S_3 draw a tangent to the circle. The right line S_2 P, touching the circle at the point of contact with the tangent, gives the best angle that can be obtained.

There are other ways of plotting the soundings on right lines joining positions, but they need not be explained here.

When a change of the course is marked between two Definite Positions, the soundings are plotted from the first position to the change of the course, and then from the latter to the second position.

REMARKS AND SUGGESTIONS ON PLOTTING AND NAVIGATION.

If the sun pass the meridian near the zenith, equal altitudes of that body give a quick and trustworthy means of finding the longitude for noon; but the conditions which are favorable for that method also greatly increase the value of the Sumner-line of position for the same purpose. Although the advantage of easy computation is on the side of the equal altitudes, it is more than probable that on the arrival of the time which would be selected to take the ante-meridian observations of the set there will have been already computed, for positions intermediate between twilight and noon, two or more Sumner-lines, which, with scarcely any additional labor, may be carried forward to be considered in connection with the afternoon Sumner-lines for finding the noon longitude. When we observed equal altitudes on board the "Blake" it was chiefly for securing a check, or for providing a substitute in case of the loss of the usual forenoon observations, or to insure a noon longitude against the failure of the afternoon Sumners.

The cases shown on Fig. 1, Plate 35, of getting the daylight positions—S_7, S_8, and S_9—are of a simple character. Were it advisable in this chapter to discuss the management of Sumner-lines in general, a different line of soundings would be chosen for illustration—one that would involve some perplexities in the plotting work. The mode of finding the Definite Positions on the forenoon and afternoon Sumner-lines changes with the conditions, even when the data is complete. Thus in the cases already plotted the latitude at the time of observation was most in doubt, but had the latitude of the vessel and the declination of the sun been widely different it might have been that the longitude was least well defined by the Sumner-lines in point, and this would probably have caused us to arrive at the Definite Positions by other steps. It sometimes happens, when the same course has been held between a twilight and a noon position, that a right line connecting these two positions will intersect the forenoon or afternoon Sumner-lines in the most rational points for the position of the vessel on those Sumner-lines at the respective times of observation. This is the easiest of all cases for solution. When there has been hazy or cloudy weather the difficulty in the plotting work which follows is greatly increased. On one occasion three days were spent by me in determining a single Definite Position on a line of soundings that had been run in a heavy sea with a dim horizon. This was troublesome, but in the end there was satisfaction in feeling that my conclusions were sound. The troubles are not confined to the forenoon and afternoon positions only, but may arise anywhere. On occasions there are no forenoon or no afternoon observations, or perhaps both sets are missing; at other times the meridian altitude has failed, or morning, evening, or all twilight observations likewise; and, again, some observations are presumably much more trustworthy than others, calling for careful comparison and discrimination in plotting. The way out of difficulties in plotting, as I have stated before, is to seek for current or drift, or *discrepancy*, by working runs forward and backward, by one disposition or another, until the errors of observation become apparent.

There are a number of methods of taking a departure on a line of soundings. The best, doubtless, is that of measuring with sextants, from the vessel, the angular distance between three established objects on shore. Two objects in range with their angle at the vessel from a third object gives a fine position. A good way—for want of a better—is to begin the line of soundings at the outer bar-buoy or sea-buoy if leaving a harbor or roadstead. Cross compass-bearings on two land objects are almost always worthy of acceptance when the vessel is quiet; but with us, when they were taken in a rough sea or heavy swell, we could seldom get good results from them—*i. e.*, when the bearings were projected on a chart the hydrography of which had been executed by the most approved methods of inshore work, they would not always intersect in the depth found by an actual sounding taken at the time of observation. Such a dilemma may possibly be escaped by getting a compass-bearing of one of the objects and a sextant angle between the two. When this does not succeed, and there is at hand a trustworthy chart of the place, showing the slope of the bottom to be regular and tolerably steep, a compass-bearing of only one shore object—several times repeated to make sure—may be projected on the chart and the position of the vessel marked where the line of bearing cuts a depth corresponding to the sounding taken at the time of observation. When admissible, the most suitable line of bearing on which to place the vessel for this purpose would, doubtless, be one taking a direction normal to the curves of equal depths. Sometimes we were compelled to take a departure from an isolated light-house, or other object, where the circumstances were such that to accept a position by one bearing and a sounding was out of the question. In such cases we generally managed to approach the object so as to get the possible advantage of what is known as the bow and beam-bearing problem. With the vessel steadied on her course, a bearing was taken of the landmark when it bore four points on the bow and another when it was abeam, holding the same course between, and reading the patent-log at each bearing. When there was no current the distance from the landmark at the second bearing was equal to the distance run between the two bearings. If the existence of current was suspected, then, at the second bearing, an observation was made by means of floats from a boat anchored to the sounding-rope. Any current thus found was applied to the run, and if it proved to have been at an angle with the course steered the character of the problem was changed, and the case was solved by projection on the Sounding-Sheet in accordance with the data. A check on the above is to leave a buoy at the spot where the second bearing was taken, and then, continuing the same course, to get a third bearing and a patent-log reading when the object bears four points on the quarter. By returning to the buoy a departure may be taken at pleasure.

Methods that are adapted to taking a departure on a line of soundings are alike suited to closing the inshore end of a line.

Changing the course between observations should be avoided as much as possible when on the lines, that the plotting work may not be complicated. Very often at evening twilight it is known that no more observations will be obtained until morning twilight, and that a course must be shaped for all night. We learned, after a few severe disappointments in the strong surface flow of some parts of the Gulf of Mexico, to shape the course for the night directly along the projected line of soundings, unless quite sure that we could predict the general direction and approximate velocity of the current. It was very unpleasant to find by the morning twilight position that the course had helped the current to carry the vessel away from her line. While five miles of deflection might not give great concern, ten miles in the same case might be thought to detract very seriously from the appearance or the adequacy of the work.

For positions we placed our dependence chiefly on the twilight observations, as giving us, practically, the latitude and the longitude at the same time. A twilight horizon is, in general, a very fine one, the bright sky beyond throwing it out black and distinct, thus offering the best of conditions for accurate contact in measuring altitudes at sea. To get fine intersections like that given by Observations X, XI, and XII (Fig. 1, Plate 35), was by no means an unusual occurrence with our navigators.

By always knowing in advance the names, approximate bearings, and altitudes of the stars that each wished to observe, our navigators never lost opportunities when the time for observing had arrived. Since with Sumner's Method the line of position is always at right angles to the line of true bearing of the body observed, the angles which the several lines of position would make with each other could be foretold at once from the compass-bearings of the objects at the time of observation; hence, in selecting the planets or stars for our purpose a due regard was had to their relative bearings. Eight points evidently gives the perfect intersection, while one of two points is hardly acceptable for good work. When there was so little clear sky at twilight that the constellations were indistinguishable, the altitude of the first bright star that presented itself favorably was turned to account, for with the altitude, and the bearing that we habitually took simultaneously therewith, a reference to our handy little celestial globe rarely failed to give us the name of the star. While a globe was not exactly a necessity, hardly a day passed at sea that it was not put to good use for instruction or amusement. We did not often attach paramount importance to meridian altitudes of stars at twilight, for, in the time given up to watching for the culmination, opportunities for fine altitudes for Sumner-lines might have escaped notice, and the advantage of observing at the very best phase of the twilight horizon might have been lost to us. The records of the "Blake" show nevertheless that a large number of meridian altitudes of stars were taken during the period covering the whole work, thereby proving that we were not neglectful of them when they served our purpose best.

Whenever an observation is needed and can be secured, the navigators should be cautious about deferring it in anticipation of a better chance, for the prospective chance may come to nothing, and they will then have only regrets instead of "salted" observations, as we called those taken for precaution. Occasionally, good altitudes of stars or planets may be had on moonlight nights—at times when the moon is not too high—by observing such bodies as will come to a contact just at the limit of the illuminated portion of the horizon. Such opportunities should not be neglected, especially when by embracing them any good purpose may be served, because it is often the case that a sky which has been clear all night becomes temporarily overcast toward the break of day. Our old hands were always alive to these points, and the new-comer quickly worked his own cure, for he was sure to find that diligence in observing lessened the perplexities of plotting.

When the navigators were in danger of being overworked, we found it a good plan on moonlight nights to leave with the officer of the deck a memorandum showing the watch-time of the meridian-passage of the moon or of some of the stars or planets. If the officer of the deck succeeded during the night in getting any meridian or other altitudes they were computed by the navigators on the day following.

If the weather became overcast or foggy at a time when further progress on the line of soundings without observations was thought to be a serious disadvantage, we would, when working in water less than two hundred fathoms in depth, plant a buoy, or anchor the vessel, and await clearing weather. By anchoring at intervals, we once executed successfully a line of considerable length, the whole of which would otherwise have been lost.

SECTIONS AND TEMPERATURE CURVES.

Forms 14 and 15 are given as specimens of what may probably be considered the most important graphic methods of arranging for study the data obtained at the observations for serial temperatures, while Form 15 serves at the same time for presenting in a simple and comprehensive manner other useful information.

Our instructions did not require us to submit anything of this kind to the office, but after our first season in the Gulf of Mexico we began to add Form 15 to our records, and in time a continuance of the practice was expected of us. Form 14 never formed part of our records; it is chiefly because of its special importance to a party when actually engaged in the work that it is given here.

Form 14.—With a piece of cross-section paper at hand, the curve may be constructed from the data in a few minutes. The horizontal or upper scale represents degrees of temperature, and the vertical or side scale fathoms of depth. The point corresponding to any depth of a series is plotted at the intersection of the vertical and the horizontal lines representing, respectively, the temperature and the depth. The successive points are then connected by right lines, or all the points may be embraced in a consistent curve.

This Form may be made to exhibit the relation between depth and temperature for a single station or for a number of stations. In the latter case, the results obtained at the several stations may be compared. The gradients of a curve, by showing the rate of change in temperature between successive points of observation, give evidence of the existence of currents; but if any gradient show an abrupt divergence from the general aspect of the curve it may be found that this results from an instrumental error, and thus a curve will point out the necessity for a repetition of an observation.

The heavy vertical line represents the temperature of 39½° Fahr., the lowest temperature of the deep waters of the Gulf of Mexico, and that which we always found there below a depth of six or seven hundred fathoms.

Form 15.—It is usual to make sections of this kind on profile paper, which gives a clear exhibit of the lines, but cross-section paper being more convenient in our special case was always used by us. The scales are arbitrary, that at the top representing miles and that at the side fathoms. The depth is generally so small in proportion to the distance run that it is necessary to greatly exaggerate the former in order to present the data in a shape available for inspection.

The data was plotted on Form 15 as follows: From the position of each sounding on the Sounding-Sheet (Fig. 2, Plate 35) a perpendicular was drawn to a right line connecting the positions of the first and the last sounding on the Sheet. The several distances of the new or projected positions from the first sounding of the series were then set off on the scale of miles on Form 15, and, from the corresponding elements of depth and distance, the curve or profile of the bottom was constructed as shown. The further construction of the lines shown on the Form is so apparent as hardly to need special description. In drawing the lines of equal temperature it was our practice to first join such points on adjacent lines of descent as were shown, by actual observation, to have equal temperatures. The figures on the line representing the surface of the water denote temperature of the surface water.

ABBREVIATIONS OF BOTTOMS.

M. for	*Mud.*	*bk. for*	*black.*	*hrd. for*	*hard.*
S. "	*Sand.*	*wh.* "	*white.*	*sft.* "	*soft.*
G. "	*Gravel.*	*yl.* "	*yellow.*	*fne.* "	*fine.*
Sh "	*Shells.*	*gy.* "	*grey.*	*crs.* "	*coarse.*
P. "	*Pebbles.*	*bu.* "	*blue.*	*brk.* "	*broken.*
Sp. "	*Specks.*	*dk.* "	*dark.*	*stk.* "	*sticky.*
C. "	*Clay.*	*gn.* "	*green.*	*rky.* "	*rocky.*
St. "	*Stones.*	*br.* "	*brown.*		
R. "	*Rock.*	*rd.* "	*red.*		
Co. "	*Coral.*				

Note.—The principal materials and their qualities are represented by larger letters than the subsidiary.

† *signifies sunk rock.* * *rock awash at low water.*

WEATHER SYMBOLS.

b.—Clear blue sky.
c.—Cloudy weather.
d.—Drizzling or light rain.
f.—Fog or foggy weather.
g.—Gloomy or dark, stormy looking weather.
h.—Hail.
l.—Lightning.
m.—Misty or hazy weather.
o.—Overcast.
p.—Passing showers of rain.
q.—Squally weather.
r.—Rainy weather or continuous rain.
s.—Snow, snowy weather, or snow falling.
t.—Thunder.
u.—Ugly appearances or threatening weather.
v.—Variable weather.
w.—Wet or heavy dew.

4′ 35″.

ING.

, 1876.

SYMBOLS FOR APPEARANCES OF CLOUDS.

Cir., Cirrus	*Primary form.*
Cir. Cum., Cirro-Cumulus	*Secondary form.*
Cir. Str., Cirro-Stratus	" "
Cum., Cumulus	*Primary form.*
Cum. Str., Cumulo-Stratus	*Secondary form.*
Nimb., Nimbus	*Primary form.*
Str., Stratus	" "

SYMBOLS FOR STATE OF SEA.

B.—Broken or irregular sea.
C.—Chopping, short or cross sea.
G.—Ground swell.
H.—Heavy sea.
L.—Long rolling swell.
M.—Moderate sea or swell.
R.—Rough sea.
S.—Smooth sea.
T.—Tide-rips.

occupied aking distance from sounding.	*COURSES.*				*DISTANCES.*		*Initials of officer of the deck.*	*REMARKS.*
M.	*Compass course from last sounding.*	*Compass correction.*	*Leeway.*	*Correct magnetic course from last sounding; or from intermediate change of course, as may be.*	*Reading of patent-log.*	*Distance from last record of patent-log.*		*Mention matters of special importance connected with the columns, particularly all matters affecting the navigation of the vessel; such, for instance, as setting the clock back or ahead.*
					Set at 0.		W. E. S.	South Pass Light bore (cor mag.) W. S. W. ⅞ W.; Pass à l'Outre Light, N. ⅝ W.
	S. ½ E	⅛ W.		S. ⅝ E	5.1	5.1	W. E. S.	South Pass Light bore (cor. mag.) N. W. by W. ¼ W.; Pass à l'Outre Light, N. ⅛ W.
15	S. ¾ E	⅛ W.		S. ⅞ E	10.	4.9	W. E. S.	
15	S. ¾ E	⅛ W.		S. ⅞ E	20.3	10.3	W. O. S.	
15	S. ¾ E	⅛ W.		S. ⅞ E	30.5	10.2	W. O. S.	
10	S. ¾ E	⅛ W.		S. ⅞ E	40.2	9.7	W. O. S.	
12	S. ¾ E	⅛ W.		S. ⅞ E	50.4	10.2	M. F. W.	
12	South	0		South	60.7	10.3	M. F. W.	
12	South	0		South	70.2	9.5	W. E. S.	
14	South	0		South	80.4	10.2	W. E. S.	
19	South	0		South	90.4	10.	W. O. S.	Set watch ahead 6^m at noon.
15	South	0		South	100.1	9.7	W. O. S.	
16	S. by E. ½ E	¼ W.		S. by E. ¾ E	110.4	10.3	M. F. W.	
16	S. ½ E	⅛ W.		S. ⅝ E	120.7	10.3	W. E. S.	
Q	R				S	T		

STATISTICS OF THE LINE.

Time occupied on line, **0** *days* **22¾** *hours.*
Soundings taken: With wire **11**, *with rope* **2**, *total* **13.**
Length of sounding line in nautical miles, **124.**
Air temperatures observed: Wet bulb **0**, *dry bulb* **13.**
Water temperatures observed: Surface **13**, *intermedial* **39**, *bottom* **5**, *total* **57.**
Number of serial temperature stations occupied, **5.**
Water densities observed: Surface **5**, *intermedial* **14**, *bottom* **5**, *total* **24.**
Current stations occupied (using floats), **0.**
Astronomical observations considered in plotting **12**, *accepted* **10**, *bearings* **4.**
Definite positions established by observations and bearings, **10.**
Bottom soil specimens saved for examination, **7.**
Water specimens saved for examination. Surface **5**, *intermedial* **14**, *bottom* **4**, *total* **23.**

(On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.)

Form 3.

U. S. COAST SURVEY.

Off-Shore Soundings, Gulf of Mexico.

GENERAL RECORD.

LINE 8, *FROM* .... near South Pass, Mississippi River. *TO* .... latitude 26° 58′ 25″, longitude 89° 04′ 35″.

IN STEAMER .... "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N., Assistant C. S., ... *COMMANDING.*

BEGUN AT 8 *HOURs* 40 *MINs.* p. m., *DATE* May 9th, 1876. *ENDED AT* 7 *HOURs* 24 *MINs.* p. m., *DATE* May 10th, 1876.

ABBREVIATIONS OF BOTTOMS.

M.	*for Mud.*	bk	*for black*	hrd.	*for hard*
S.	" *Sand.*	wh.	" *white*	sft.	" *soft*
G.	" *Gravel.*	yl	" *yellow*	fne.	" *fine*
Sh	" *Shells.*	gy	" *grey*	crs	" *coarse.*
P.	" *Pebbles.*	bu	" *blue*	brk	" *broken*
Sp.	" *Specks.*	dk.	" *dark.*	stk	" *sticky*
C.	" *Clay.*	gn	" *green.*	rky	" *rocky*
St.	" *Stones*	br	" *brown.*		
R	" *Rock*	rd	" *red*		
Co.	" *Coral*				

Note.—The principal materials and their qualities are represented by larger letters than the subsidiary

† *signifies sunk rock.* * *rock awash at low water*

SYMBOLS FOR APPEARANCES OF CLOUDS.

Cir., Cirrus	*Primary form*
Cir. Cum., Cirro-Cumulus	*Secondary form.*
Cir. Str., Cirro-Stratus	" "
Cum., Cumulus	*Primary form*
Cum. Str., Cumulo-Stratus	*Secondary form*
Nimb., Nimbus	*Primary form*
Str., Stratus	" "

WEATHER SYMBOLS.

b—*Clear blue sky*
c.—*Cloudy weather.*
d.—*Drizzling or light rain.*
f.—*Fog or foggy weather.*
g.—*Gloomy or dark, stormy looking weather.*
h—*Hail*
l—*Lightning*
m.—*Misty or hazy weather.*
o—*Overcast.*
p—*Passing showers of rain.*
q—*Squally weather*
r—*Rainy weather or continuous rain.*
s—*Snow, snowy weather, or snow falling.*
t—*Thunder.*
u—*Ugly appearances or threatening weather*
v—*Variable weather*
w.—*Wet or heavy dew.*

SYMBOLS FOR STATE OF SEA

B.—*Broken or irregular sea.*
C.—*Chopping, short or cross sea*
G.—*Ground swell.*
H.—*Heavy sea*
L.—*Long rolling swell.*
M—*Moderate sea or swell*
R—*Rough sea.*
S—*Smooth sea.*
T.—*Tide-rips*

DATE.	*Time of sinker striking bottom.*			*THE SOUNDING.*					*Air temperatures.*		*Water temperatures (corrected).*			*Water densities.*		*Currents observed with floats.*			*Barometer.*		*WIND.*		*State of the weather by symbols.*	*Forms of clouds by symbols.*	*Proportion of clear sky in tenths.*	*State of the sea by symbols.*	*Time of stopping to sound.*		*Time of starting ahead after sounding.*		*Time occupied in making distance from last sounding.*		*COURSES.*				*DISTANCES.*		*Initials of officer of the deck.*	*REMARKS.*
Month and Day.	*Hour.*	*Min.*	*A. M. or P. M.*	*Serial No. of sounding and of specimens.*	***Depth in fathoms.***	*Character of the bottom soil by symbols.*	*Position of vessel when sinker struck bottom. Latitude.* ° ′ ″	*Longitude.* ° ′ ″	*Wet bulb.*	*Dry bulb.* °	*Serial depths in fathoms.*	*Min.* °	*Max.*	*Density.*	*Corresponding temp of spec.* °	*Correct magnetic direction setting towards.*	*Velocity per hour in knots and tenths.*	*Depth of current observed, in fathoms.*	*Inches.*	*Attached thermometer.* °	*Magnetic direction from.*	*Force*					*H*	*M.*	*H.*	*M.*	*H.*	*M.*	*Compass course from last sounding.*	*Compass correction.*	*Leeway.*	*Correct magnetic course from last sounding; or from intermediate change of course, as may be*	*Reading of patent-log*	*Distance from last record of patent-log.*		*Mention matters of special importance connected with the columns, particularly all matters affecting the navigation of the vessel, such, for instance, as setting the clock back or ahead*
May 9	8	40	P. M.	1	**25**	dk. br. M	29 01 40	89 02 35		70	Surface.	70		1.0190	70				30.12	73	S. W	1	w	Cum	5	S	8	40	8	59							Set at 0		W E S.	South Pass Light bore (cor. mag.) W. S. W. ¼ W; Pass à l'Outre light, N ¾ W
											10	70		1.0214	70																									
											25	68		1.0253	68																									
May 9	9	37	P. M.			**Changed the course**																											S. ¾ E	¼ W		S ½ E	5 1	5.1	W. E. S.	South Pass Light bore (cor. mag.) N. W. by W. ¼ W., Pass à l'Outre Light, N. ¾ W
May 9	10	18	P. M	2	**127**	dk. br. M	28 51 00	89 02 20		71	Surface.	70		1.0190	70				30.15	73	S. W	3	w	Cum	6	S	10	14	11	00	1	15	S ¾ E	¼ W		S. ½ E	10.	4.9	W E S.	
											10	69																												
											25	67		1.0261	72																									
											50	65		1.0282	66																									
											75	60½																												
											100	58½		1.0273	68																									
											127	55¾		1.0268	69																									
May 10	12	23	A M	3	**386**	dk. gy. M	28 39 35	89 00 25		71	Surface.	73							30.15	72	North	3	w	Cum	9	S.	12	15	12	35	1	15	S. ¾ E	¼ W.		S. ½ E	20.3	10.3	W. O. S	
May 10	1	58	A. M.	4	**493**	dk. gy. M	28 28 55	88 59 25		72	Surface	73							30.15	72	North	4	w	Cum	9	S	1	50	2	14	1	15	S. ¾ E	¼ W.		S ½ E	30.5	10.2	W. O. S	
May 10	3	36	A. M.	5	**648**	dk. gy. M	28 18 45	88 58 35		73	Surface.	74							30.15	72	North	3	b	Cum	8	S.	3	24	3	54	1	10	S. ¾ E	¼ W.		S. ½ E	40.2	9 7	W. O. S	
May 10	5	25	A. M.	6	**676**	dk. gy. M	28 08 25	88 57 35		79	Surface.	74		1.0262	74				30.16	76	N. E. by N	3	bc	Cum	3	S.	5	06	6	10	1	12	S. ¾ E	¼ W.		S. ½ E	50 4	10 2	M. F. W.	
											10	73																												
											25	70																												
											50	68																												
											75	65½																												
											100	60½		1.0262	73																									
											150	55																												
											200	50¾																												
											300	46																												
											400	42¾		1.0266	72																									
											500	41																												
											600	40																												
											676	39½		1.0266	74																									
May 10	7	36	A. M.	7	**739**	dk. gy. M	27 58 20	88 58 35		78	Surface.	75							30.20	77	N. E. by N	4	bc	Cir. Cum	6	S	7	22	7	54	1	12	South	0		South	60 7	10 3	M. F. W	
May 10	9	20	A M	8	**802**	yl. M	27 48 55	88 59 25		81	Surface.	76							30 21	79	N. E. by N.	3	bc	Cir. Cum	6	S.	9	06	9	35	1	12	South	0		South	70.2	9.5	W E S	
May 10	10	59	A. M	9	**890**	yl. M	27 39 10	89 01 35		83	Surface.	76½							30.21	78	N. E. by N	3	bc	Cir. Cum	6	S.	10	49	11	16	1	14	South	0		South	80.4	10.2	W. E. S.	
May 10	12	48	P. M	10	**971**	dk. bu. M	27 29 20	89 03 40		83	Surface.	77		1.0262	77				30.22	80	N. E. by N	3	bc	Cir. Cum	6	S.	12	35	1	35	1	19	South	0		South	90.4	10.	W. O. S.	Set watch ahead 6^m at noon.
											10	75½																												
											25	75																												
											50	73																												
											75	68																												
											100	65		1.0264	75																									
											150	60																												
											200	55		1.0264	74																									
											300	48½																												
											400	44		1.0264	72																									
											500	42																												
											600	39¼		1.0270	71																									
											971	39½		1.0270	70																									
May 10	3	02	P. M.	11	**1077**	Gas-pipe rod; spec. barely visible.	27 19 15	89 05 30		90	Surface.	77							30.21	79	S. E.	1	bc	Cum	7	S.	2	50	3	19	1	15	South	0		South	100 1	9.7	W. O. S.	
May 10	4	51	P. M.	12	**1195**	rd. C	27 09 00	89 03 45		92	Surface.	77							30.20	79	S. E	1	bc	Cum	7	S.	4	35	5	17	1	16	S. by E. ¾ E	¼ W.		S. by E. ½ E.	110.4	10.3	M. F. W.	
May 10	6	55	P. M.	13	**1312**	bu. M	26 58 25	89 04 35		84	Surface.	76		1.0270	73				30.20	75	S. E	1	bc	Cum	7	S	6	33	7	24	1	16	S ¾ E	¼ W.		S. ½ E	120 7	10 3	W. E. S.	
											10	73																												
											25	70½																												
											50	68½																												
											75	61																												
											100	58		1.0270	71																									
											150	51¾																												
											200	48		1.0268	70																									
											300	44½																												
											400	41¾		1.0268	71																									
											500	41																												
											600	39¼		1.0267	68																									
											1312	39¼		1.0266	67																									
	A	B	C	D	E	F	G	H				I	J		K												L	M	N	O	P	Q	R				S	T		

Serial number of sounding and of specimens.	*Depth of the bottom in fathoms.*	*ssel's rolling motion.*	*REMARKS.* *Mention accidents, losses, failures of gear or apparatus to work satisfactorily, giving probable causes; give reason for unusual delays; mention, generally, matters of importance or interest connected with the work.*
		Pitching.	
1	**25**	uiet	
2	**127**	do	
3	**386**	do	
4	**493**	do	
5	**648**	do	
6	**676**	ightly	Water-cups at other depths failed because valves had not been adjusted.
7	**739**	do	
8	**802**	do	
9	**890**	do	
10	**971**	do	
11	**1077**	do	
12	**1195**	do	
13	**1312**	do	

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

Form 4.

U. S. COAST SURVEY.

Off-Shore Soundings, Gulf of Mexico.

SUPPLEMENTARY RECORD.

LINE 8, *FROM* ....near South Pass, Mississippi River. *TO*............ latitude 26° 58′ 25″, longitude 89° 04′ 35″.

IN STEAMER..........“Blake,” Lieutenant-Commander C. D. Sigsbee, U. S. N., Assistant C. S.,..........*COMMANDING.*

BEGUN AT 8 *HOUR*s 40 *MIN*s. p. m., *DATE* May 9th, 1876, *ENDED AT* 7 *HOUR*s 24 *MIN*s. p. m., *DATE* May 10th, 1876.

Serial number of sounding and of specimens.	*Depth of the bottom in fathoms.*	*Was a specimen of the bottom soil saved for examination? Yes or no.*	*What sounding-rod or specimen-cup was used to get the specimen of bottom soil?*	*What sinker was used? Give weight.*	*Was sinker hauled back (H. B.) or detached (Det.)?*	*Was sounding taken with wire or rope?*	*What sounding-machine was used to take the sounding?*	*Were any water specimens saved for examination? Yes or no. If saved, from what depths?*	*What water-cups or instruments were used to get water specimens?*	*What thermometers were used to get temperatures below the surface?*	*What instrument was used to get water densities?*	*State extent of vessel's rolling and pitching motion.*		*REMARKS. Mention accidents, losses, failures of gear or apparatus to work satisfactorily, giving probable causes; give reason for unusual delays; mention, generally, matters of importance or interest connected with the work.*
												Rolling.	*Pitching.*	
1	25	Yes	Stellwagen Spec. Cup	50-pound lead	H. B	Rope	None	Yes; surface, 10 and 25 fathoms	Coast Survey Cup, 3 hauls	Miller-Casella	Special areometer	Quiet	Quiet	
2	127	No	do	do	H. B	Rope	None	Yes; surface, 25, 50, 100, and 127	Coast Survey at 25 fathoms; Sigsbee's at other depths.	do	do	do	do	
3	386	Yes	do	34-pound lead	H. B	Wire	Sigsbee's Experimental Machine	No				do	do	
4	493	No	do	do	H. B	Wire	do	No				do	do	
5	648	No	do	do	H. B	Wire	do	No				do	do	
6	676	No	Belknap No. 3, modified	57-pound shot	Det	Wire	do	Yes; surface, 100 and 400	Sigsbee Cups	Miller-Casella	Special areometer	Slightly	Slightly	Water-cups at other depths failed because valves had not been adjusted.
7	739	Yes	do	do	Det	Wire	do	No				do	do	
8	802	Yes	do	do	Det	Wire	do	No				do	do	
9	899	No	do	do	Det	Wire	do	No				do	do	
10	971	Yes	do	do	Det	Wire	do	Yes; surface, 100, 200, 400, 600, 971.	Sigsbee Cups	Miller-Casella	Special areometer	do	do	
11	1977	No	Gas-pipe Rod, Sigsbee's Detacher	do	Det	Wire	do	No				do	do	
12	1195	Yes	Belknap No. 3, modified	do	Det	Wire	do	No				do	do	
13	1312	Yes	do	do	Det	Wire	do	Yes; surface, 100, 200, 400, 600, 1195.	Sigsbee Cups	Miller-Casella	Special areometer	do	do	

NOTE.—The above line crossed others on which much of the same kind of data had been obtained. From this fact, and the desire to progress rapidly on a long line while pleasant weather lasted, we did not adhere closely to schedule.

FORM 5.

LINE ______

DATE, ______, 18 .	TIMES.	DIFF.	ALTITUDES.	DIFF.	CHARACTER OF OBSERVATION.
	H. M. S. Ths.		° ′ ″		

Time: a. m., p. m ______

Object ______

Compass-bearing ______

Ship's head ______

Patent-log ______

Obs'n at sounding No. ______

Obs'n shortly before sound'g No.

Obs'n shortly after sound'g No.

Obs'n between sound'gs Nos.

Index correction ______

REMARKS.

	Very good.	Moderately good.	Barely acceptable.
Object ___			
Horizon _			
Value of Obs'n __			

	H.	M.	S.	Ths.
C.				
W.				
C—W.				
C. C.				

	H.	M.	S.	Ths.
C.				
W.				
C—W.				
C. C.				

U. S. COAST SURVEY,

CARLILE P. PATTERSON, *Superintendent.*

◆

SECTION ______

◆

OBSERVATIONS.

GENERAL LOCALITY:

______

Rough Book of Observations No. ______

From ______, 18 , *Line* ______

To ______, 18 , *Line* ______

Vessel, ______

Chief Com'dg Hyd. Party:

Observer:

______

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

FORM 6.

U. S. COAST SURVEY. OFF-SHORE WORK, GULF OF MEXICO.

(Bearings of objects on shore.)

LINE FROM *LAT.* 29° 01′ 40″, *LONG.* 89° 02′ 35″, *TO* *LAT.* 26° 58′ 25″, *LONG.* 89° 04′ 35 .
COAST SURVEY STR. "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N., *COMMANDING.*
DATE. May 9th, 1876, ———*A. M.* ———*P. M.* *NO. OF POSITION*, **1 & 2.** *NO. OF OBSERVATION*, Bearings. *LINE LETTER*, **S.**

At 8^h 40^m P. M., May 9th, took our departure on Line S.
South Pass Light, Mississippi River, bearing (correct magnetic), W. S.W. $\frac{7}{8}$ W.
Pass à l'Outre " " " " " " N. $\frac{5}{8}$ W.
Patent-log, 0; Sounding No. 1.

DEFINITE POSITION BY ABOVE BEARINGS:

LATITUDE. **29° 01′ 40″.** LONGITUDE. **89° 02′ 35″.**

POSITION **1.**

At 9^h 37^m P. M., May 9th, took following bearings:
South Pass Light, Mississippi River (correct magnetic), N.W. by W. $\frac{1}{4}$ W.
Pass à l'Outre " " " " " N. $\frac{1}{2}$ W.
Patent-log, 5.1; Between soundings Nos. 1 and 2.

DEFINITE POSITION BY ABOVE BEARINGS:

LATITUDE. **28° 56′ 20″.** LONGITUDE. **89° 03′ 15″.**

POSITION **2.**

REMARKS—(Continued).

OBSERVER--Lieut. J. E. Pillsbury, U. S. N.
COMPUTER--

TIMES.	*ALTITUDES.*	*CHRO. COMP.*		*REMARKS.*
		C.		
		W.		
		C—W.		
		C. C.		
		C.		
		W.		
		C—W.		
		C. C.		

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

FORM 7.

U. S. COAST SURVEY. OFF-SHORE WORK, GULF OF MEXICO.

×

SUMNER'S METHOD BY MOON, PLANET ( ), STAR (Altair).

Line from *Lat.* 29° 01′ 40″, *Long.* 89° 02′ 35″, *to* *Lat.* 26° 58′ 25″, *Long.* 89° 04′ 35″.

Coast Survey Str. "Blake." Lieutenant-Commander C. D. Sigsbee, U. S. N., *Commanding.*

Date. May 10th, 1876. 12h 41m *A. M.* / *P. M.* *No. of Position.* **3.** *No. of Observation,* **1.** *Line Letter,* **S.**

	° ′ ″		h. m. s.		° ′ ″			h. m. s.	
S. D.		*W. T.*	12-39-11.4	*DEC.* (+)	8 32 20.1	*M. D.*	*R. A.*	19-44-45.6	*M. D.*
AUG.		*C—W.*	5-58-07.5	*COR.*			*COR.*		
I. C.	— 1 50	*C. F.*	18-37-18.9	*COR. DEC.*			*COR. R. A.*		
DIP.	— 4 03	*C. C.*	+ 1-19.4		*90° 00′ 00″*				
REF.	— 1 28	*G. M. T.*	18-38-38.3	*P. D.*	81 27 40				
1st COR.	— 7 21	*G. D.*	+	*R. A. M. S.*	h. m. s. 3-10-33.71	*For G. M. NOON*	*DIP—BY ANGLE WITH SEXTANT.*		
OBS. ALT.	32 57 29			*Cor. G. M. T.*	3-03.659	*FOR H. & M.*			
				"	.105	*For SECONDS.*	*2 Z. D. HOR.*	*180° 00′ 00″*	
2d COR.				*R. A. M. S.*	3-13-37.474	*LOCAL.*	*DIFF.*		
							½ DIFF.= DIP.		

T. ALT.	° ′ ″ 32 50 08			*T. ALT.*	° ′ ″ 32 50 08			*HOR. PAR.*	
LAT.	28 20 00	*L. SEC.*	.05542	*LAT.*	28 40 00	*L. SEC.*	.05679	*TAB. XIX.*	
P. D.	81 27 40	*L. COSEC.*	.00484	*P. D.*	81 27 40	*L. COSEC.*	.00484		
SUM.	142 37 48			*SUM.*	142 57 48				
½ SUM.	71 18 54	*L. COS.*	9.50565	*½ SUM.*	71 28 54	*L. COS.*	9.50189	*SUM.*	
T. ALT.				*T. ALT.*				*CONST.*	*59′ 42″*
REM.	38 28 46	*L. SIN.*	9.79395	*REM.*	38 38 46	*L. SIN.*	9.79554	*2d COR.*	
		2	19.35986			***2***	19.35906		
H. A.	h. m. s. 3-48-43.7	*L. SIN. ½.*	9.67993	*H. A.*	h. m. s. 3-48-30	*L. SIN. ½.*	9.67953		
R. A.	19-44-45.6			*R. A.*	19-44-45.6				
R. A. MER.	15-56-01.9			*R. A. MER.*	15-56-15.6				
R. A. M. S.	3-13-37.5			*R. A. M. S.*	3-13-37.5				
L. M. T.	12-42-24.4			*L. M. T.*	12-42-38.1				
G. M. T.	18-38-38.3			*G. M. T.*	18-38-38.3				
LONG. T.	5-56-13.9			*LONG. T.*	5-56-00.2				
LONG. A.	89° 03′ 28″	*WEST.*		*LONG. A.*	89° 00′ 03″	*WEST.*			

CHARACTER OF OBSERV'N.

	Very good.	*Mod'rt'ly good.*	*Barely acceptable.*
OBJECT.		×	
HORIZON.		×	
VALUE OF OBS'N.		×	

DEFINITE POSITION ON THE ABOVE LINE AT THE TIME OF OBSERVATION:
Latitude **28° 38′ 35″** *North.* *Longitude* **89° 00 15″** *West.*

REMARKS.

Patent-Log, ...21.35.

Carried Observation 2 back, by course and distance, to an intersection with Observation 1, for Definite Position on Observation 1.

[OVER.]

REMARKS—(Continued).

OBSERVER.. Robert G. Peck, Master, U. S. Navy.
COMPUTER.. same.

PRELIMINARY WORK.

TIME AS PER SOUNDING-SHEET 12^{h} 41^{m} *A. M.* ——— *P. M.*

TIMES.	*ALTITUDES.*	*CHRO. COMPS.*		*REMARKS.*
h. m. s.	° ′ ″			
12 - 37 - 13	32 31 40	*C.*		*OBJECT*..........................mod. good.
48	38 20	*W.*		*HORIZON*.......................... " "
38 - 27	46 00	*C—W.*		*COMP. BEARING OF OBJECT*..........S^{d} & E^{d}.
39 - 13	58 50	*C. C.*		*SHIP'S HEAD.*
55	07 20			*PATENT-LOG*..........................21. 35.
40 - 28	14 10			*Taken during Sounding No.*
41 - 16	26 00	*C.*		*Taken shortly before Sounding No.*
80	402 20	*W.*		*Taken shortly after Sounding No.*
12 - 39 - 11.4	32 57 29	*C—W.*		*Taken between Soundings Nos.* .... 3 & 4.
		C. C.		

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

FORM 8.

U. S. COAST SURVEY. OFF-SHORE WORK, GULF OF MEXICO.

SUMNER'S METHOD BY MOON, PLANET (× *), STAR* (Vega).

Line from *Lat.* 29° 01′ 40″, *Long.* 89° 02′ 35″, *to* *Lat.* 26° 58′ 25″ *Long.* 89° 04′ 35″.

Coast Survey Str. "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N., *Commanding.*

Date, May 10th, 1876, $12^h\ 47^m$ *A. M.* ~~*P. M.*~~ *No. of Position,* **4.** *No. of Observation,* **2.** *Line Letter,* **S.**

	° ′ ″		h. m. s.		° ′ ″			h. m. s.	
S. D.		*W. T.*	12-45-13.1	*DEC.* (+)	38 39 49	*M. D.*	*R. A.*	18-32-46.2	*M. D.*
AUG.		*C—W.*	5-58-07.8	*COR.*			*COR.*		
I. C.	— 1 50	*C. F.*	18-43-20.9	*COR. DEC.*			*COR.R.A.*		
DIP.	— 4 03	*C. C.*	+ 1-19.4		*90° 00′ 00″*				
REF.	— 36	*G. M. T.*	18-44-40.3	*P. D.*	51 20 11				
					h. m. s.		*DIP—BY ANGLE WITH SEXTANT.*		
1st COR.	— 6 29	*G. D.*	9^d +	*R. A. M. S.*	3-10-33.71	*For G. M. NOON*			
OBS. ALT.	57 28 46			*Cor. G. M. T.*	3-04.645	*FOR H. & M.*		*180° 00′ 00″*	
				"	.110	*For SECONDS.*	*2. Z. D. HOR.*		
2d COR.				*R. A. M. S.*	3-13-38.46	*LOCAL.*	*DIFF.*		
							½ DIFF.= DIP.		

	° ′ ″				° ′ ″				
T. ALT.	57 22 17			*T. ALT.*	57 22 17			*HOR. PAR.*	
LAT.	28 20 00	*L. SEC.*	.05542	*LAT.*	28 40 00	*L. SEC.*	.05679	*TAB. XIX.*	
P. D.	51 20 11	*L. COSEC.*	.10744	*P. D.*	51 20 11	*L. COSEC.*	.10744		
SUM.	137 02 28			*SUM.*	137 22 28				
½ SUM.	68 31 14	*L. COS.*	9.56368	*½ SUM.*	68 41 14	*L. COS.*	9.56046	*SUM.*	
T. ALT.				*T. ALT.*				*CONST.*	*59′ 42″*
REM.	11 08 57	*L. SIN.*	9.28638	*REM.*	11 18 57	*L. SIN.*	9.29274	*2d COR.*	
		2	19.01292			**2**	9.01743	*CHARACTER OF OBSERV'N.*	
	h. m. s.				h. m. s.				
H. A.	2-29-46.3	*L. SIN. ½.*	9.50646	*H. A.*	2-30-35	*L. SIN. ½.*	9.50871		
R. A.	18-32-46.2			*R. A.*	18-32-46.2				
R. A. MER.	16-02-59.9			*R. A. MER.*	16-02-11.2				
R. A. M. S.	3-13-38.5			*R. A. M. S.*	3-13-38.5				
L. M. T.	12-49-21.4			*L. M. T.*	12-48-32.7				
G. M. T.	18-44-40.3			*G. M. T.*	18-44-40.3				
LONG. T.	5-55-18.9			*LONG. T.*	5-56-07.6				
LONG. A.	88° 49′ 43″	*WEST.*		*LONG. A.*	89° 01′ 54″	*WEST.*			

	Very good.	*Mod't'y good.*	*Barely acceptable.*
OBJECT.		×	
HORIZON.		×	
VALUE OF OBS'N.		×	

DEFINITE POSITION ON THE ABOVE LINE AT THE TIME OF OBSERVATION:

Latitude **28° 37′ 25″** *North.* *Longitude* **89° 00′ 10″** *West.*

REMARKS.

Patent-Log, ________ 22.4.

Carried Observation 1 forward, by course and distance, to an intersection with Observation 2, for Definite Position on Observation 2.

REMARKS—(Continued).

OBSERVER Robert G. Peck, Master, U. S. Navy.
COMPUTER same.

PRELIMINARY WORK.

TIME AS PER SOUNDING-SHEET 12^h 47^m *A. M.* *P. M.*

TIMES.	*ALTITUDES.*	*CHRO. COMPS.*		*REMARKS.*
h. m. s. 12 - 43 - 03	° ′ ″ 57 04 30	*C.*		*OBJECT* mod. good.
54	14 10	*W.*		*HORIZON* " "
44 - 34	21 00	*C—W.*		*COMP. BEARING OF OBJECT* N^d & E^d.
45 - 08	26 30	*C. C.*		*SHIP'S HEAD.*
53	27 30			*PATENT-LOG* 22. 4.
46 - 37	44 30			*Taken during Sounding No.*
47 - 23	53 10	*C.*		*Taken shortly before Sounding No.*
92	201 20	*W.*		*Taken shortly after Sounding No.*
12 - 45 - 13.1	57 28 46	*C—W.*		*Taken between Soundings Nos.* 3 & 4.
		C. C.		

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

FORM 9.

U. S. COAST SURVEY. OFF-SHORE WORK, GULF OF MEXICO.

×

***SUMNER'S METHOD BY MOON, PLANET* (Saturn), *STAR* (——————).**

Line from *Lat.* 29° 01′ 40″, *Long.* 89° 02′ 35″, *to* *Lat.* 26° 58′ 25″, *Long.* 89° 04′ 35″.

Coast Survey Str. "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N.:, *Commanding.*

Date, May 10th, 1876, $4^h\ 25^m$ *A. M.* / *P. M.* *No. of Position,* **5.** *No. of Observation,* **3.** *Line Letter,* **S.**

	°	*′ ″*		h. m. s.		° ′ ″				° ′ ″	
S. D.			*W. T.*	4-23-16.5	*DEC.* (—)	10 23 40.1	*M. D.*	— 2.9	*R. A.*	22 36 46.56	*M.D.* +.583
AUG.			*C—W.*	5-58-09.2	*COR.*	+ 4.6		— 1.6	*COR.*	— .94	—.162
								29		h. m. s.	583
I. C.	—	1 50	*C. F.*	9-21-25.7	*COR. DEC.*	10 23 45		17	*COR. R. A.*	22-36-45.62	350
DIP.	—	4 03	*C. C.*	+ 1-19.3		*90° 00′ 00″*		4.6			11
REF.	—	1 27	*G. M. T.*	22-22-45	*P. D.*	100 23 45					.944
1st COR.	—	7 20	*G. D.*	9ᵈ +	*R. A. M. S.*	h. m. s. 3-14-30.27	*For G. M. NOON.*		*DIP—BY ANGLE WITH SEXTANT.*		
OBS. ALT.	32 43 45				*Cor. G. M. T.*	— 15.935	*FOR H. & M.*			*180° 00′ 00″*	
					"	— .041	*For SECONDS.*		*2 Z. D. HOR.*		
					R. A. M. S.	3-14-14.3	*LOCAL.*		*DIFF.*		
2d COR.									*½ DIFF.= DIP.*		

T. ALT.	° ′ ″ 32 36 25			*T. ALT.*	° ′ ″ 32 36 25			*HOR. PAR.*	
LAT.	28 00 00	*L. SEC.*	.05407	*LAT.*	28 20 00	*L. SEC.*	.05542	*TAB. XIX.*	
P. D.	100 23 45	*L. COSEC.*	.00718	*P. D.*	100 23 45	*L. COSEC.*	.00718		
SUM.	161 00 10			*SUM.*	161 20 10				
½ SUM.	80 30 05	*L. COS.*	9.21755	*½ SUM.*	80 40 05	*L. COS.*	9.20993	*SUM.*	
T. ALT.				*T. ALT.*				*CONST.*	*59′ 42″*
REM.	47 53 40	*L. SIN.*	9.87035	*REM.*	48 03 40	*L. SIN.*	9.87149	*2d COR.*	
		2	19.14915			*2*	19.14402		
H. A.	h. m. s. 2-56-25.7	*L. SIN. ½.*	9.57457	*H. A.*	h. m. s. 2-55-20	*L. SIN. ½.*	9.57201		
R. A.	22-36-45.6			*R. A.*	22-36-45.6				
R. A. MER.	19-40-19.9			*R. A. MER.*	19-41-25.6				
R. A. M. S.	3-14-14.3			*R. A. M. S.*	3-14-14.3				
L. M. T.	16-26-05.6			*L. M. T.*	16-27-11.3				
G. M. T.	22-22-45.0			*G. M. T.*	22-22-45.0				
LONG. T.	5-56-39.4			*LONG. T.*	5-55-33.7				
LONG. A.	89° 09′ 51″	*WEST.*		*LONG. A.*	88° 53′ 25″	*WEST.*			

CHARACTER OF OBSERV'N.

	Very good.	*Mod'tly good.*	*Barely acceptable.*
OBJECT.		×	
HORIZON.		×	
VALUE OF OBS'N.		×	

DEFINITE POSITION ON THE ABOVE LINE AT THE TIME OF OBSERVATION:

Latitude **28° 14′ 15″** *North.* *Longitude* **88° 58 05″** *West.*

REMARKS.

Patent-Log,........44.6.

Carried Observation 4 back, by course and distance, to an intersection with Observation 3, for Definite Position on Observation 3.

[OVER.]

REMARKS—(Continued).

OBSERVER .... Robert G. Peck, Master, U. S. Navy.
COMPUTER .... same.

PRELIMINARY WORK.

TIME AS PER SOUNDING-SHEET 4^{h} 25^{m} *A. M.* ——— *P. M.*

TIMES.	*ALTITUDES.*	*CHRO. COMPS.*		*REMARKS.*
h. m. s. 4 - 22 - 56	° ' " 32 40 10	*C.*		*OBJECT* .... mod. good.
23 - 37	47 20	*W.*		*HORIZON* .... " "
33	87 30	*C—W.*		*COMP. BEARING OF OBJECT* .... S^{d} & E^{d}.
4 - 23 - 16.5	32 43 45	*C. C.*		*SHIP'S HEAD.*
				PATENT-LOG 44.6
				Taken during Sounding No.
		C.		*Taken shortly before Sounding No.*
		W.		*Taken shortly after Sounding No.*
		C—W.		*Taken between Soundings Nos.* .... 5 & 6.
		C. C.		

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

FORM 10.

U. S. COAST SURVEY. OFF-SHORE WORK, GULF OF MEXICO.

×

SUMNER'S METHOD BY MOON, PLANET (Jupiter), *STAR (   ).*

Line from *Lat.* 29° 01′ 40″, *Long.* 89° 02′ 35″, *to* *Lat.* 26° 58′ 25″, *Long.* 89° 04′ 35″.

Coast Survey Str. "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N., *Commanding.*

Date, May 10th, 1876, 4h 35m *A. M.* / *P. M.* *No. of Position,* **6.** *No. of Observation,* **4.** *Line Letter,* **S.**

	° ′ ″		h. m. s.		° ′ ″	*M. D.* — 4.01		h. m. s.	*M.D.*—1.285
S. D.		*W. T.*	4-33-10.2	*DEC.* (—)	18 40 45.5	— 1.45	*R. A.*	15-44-11.71	—1.45
AUG.		*C—W.*	5-58-09.8	*COR.*	+ 5.8	4.01	*COR.*	+ 1.86	1.285
I. C.	— 1 50	*C. F.*	10-31-20	*COR. DEC.*	18 40 51.3	1.60	*COR. R. A.*	15-44-13.6	514
DIP.	— 4 03	*C. C.*	+ 1-19.4		*90° 00′ 00″*	.20			64
REF.	— 3 35	*G. M. T.*	22-32-39.4	*P. D.*	108 40 51	+ 5.81			+1.863
1st COR.	— 9 28	*G. D.*		*R. A. M. S.*	3-14-30.27	*For G. M. NOON.*	*DIP—BY ANGLE WITH SEXTANT.*		
OBS. ALT.	14 17 50			*Cor. G. M. T.*	— 14.29	*FOR H. & M.*		*180° 00′ 00″*	
				"	— .06	*For SECONDS.*	*2. Z. D. HOR.*		
2d COR.				*R. A. M. S.*	3-14-15.9	*LOCAL.*	*DIFF.*		
							½ DIFF.= DIP.		

T. ALT.	14° 08′ 22″			*T. ALT.*	14° 08′ 22″		
LAT.	28 00 00	*L. SEC.*	.05407	*LAT.*	28 20 00	*L. SEC.*	.05542
P. D.	108 40 51	*L. COSEC.*	.02350	*P. D.*	108 40 51	*L. COSEC.*	.02350
SUM.	150 49 13			*SUM.*	151 09 13		
½ SUM.	75 24 36	*L. COS.*	9.40123	*½ SUM.*	75 34 36	*L. COS.*	9.39635
T. ALT.				*T. ALT.*			
REM.	61 16 14	*L. SIN.*	9.94295	*REM.*	61 26 14	*L. SIN.*	9.94295
		2	19.42175			*2*	19.42175
H. A.	h. m. s. 4-07-23.2	*L. SIN. ½.*	9.71087	*H. A.*	h. m. s. 4-06-29.5	*L. SIN. ½.*	9.71087
R. A.	15-44-13.6			*R. A.*	15-44-13.6		
R. A. MER.	19-51-36.8			*R. A. MER.*	19-50-43.1		
R. A. M. S.	3-14-15.9			*R. A. M. S.*	3-14-15.9		
L. M. T.	16-37-20.9			*L. M. T.*	16-36-27.2		
G. M. T.	22-32-39.4			*G. M. T.*	22-32-39.4		
LONG. T.	5-55-18.5			*LONG. T.*	5-56-12.2		
LONG. A.	88° 49′ 37″	*WEST.*		*LONG. A.*	89° 03′ 03″	*WEST.*	

HOR. PAR.	
TAB. XIX.	
SUM.	
CONST.	*59′ 42″*
2d COR.	

CHARACTER OF OBSERV'N.

	Very good.	*Mod'ty good.*	*Barely acceptable.*
OBJECT.	×		
HORIZON.		×	
VALUE OF OBS'N.		×	

DEFINITE POSITION ON THE ABOVE LINE AT THE TIME OF OBSERVATION:

Latitude **28° 12′ 25″** *North.* *Longitude* **88° 58′ 00″** *West.*

REMARKS.

*Patent-Log,*________46.4.

Carried Observation 3 forward, by course and distance, to an intersection with Observation 4, for Definite Position on Observation 4.

[over.]

REMARKS—(Continued).

OBSERVER..Robert G. Peck, Master, U. S. Navy.
COMPUTER.. same.

PRELIMINARY WORK.

TIME AS PER SOUNDING-SHEET 4^h 35^m *A. M.* ——— *P. M.*

TIMES.	*ALTITUDES.*	*CHRO COMPS.*		*REMARKS.*
h. m. s. 4-31-39	° ′ ″ 14 34 10	*C.*		*OBJECT*..........good.
32-18.5	26 40	*W.*		*HORIZON*.......... "
33-02	20 20	*C—W.*		*COMP. BEARING OF OBJECT*..........S^d & E^d.
33-57.5	09 20	*C. C.*		*SHIP'S HEAD.*
34-54	13 58 40			*PATENT-LOG*..........46. 4.
51	89 10			*Taken during Sounding No.*
4-33-10.2	14 17 50	*C.*		*Taken shortly before Sounding No.*
		W.		*Taken shortly after Sounding No.*
		C—W.		*Taken between Soundings Nos.*..........5 & 6.
		C. C.		

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

FORM 11.

U. S. COAST SURVEY. OFF-SHORE WORK, GULF OF MEXICO.

SUMNER'S METHOD BY SUN.

Line from *Lat.* 29° 01′ 40″, *Long.* 89° 02′ 35″, *to* *Lat.* 26° 58′ 25″, *Long.* 89° 04′ 35″.

Coast Survey Str. "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N., *Commanding.*

Date, May 10th, 1876, $\frac{9^h\ 15^m}{\quad}$ *A. M.* / *P. M.* *No. of Position,* **7.** *No. of Observation,* **5.** *Line Letter,* **S.**

		′ ″		h. m. s.		° ′ ″				h. m. s.	
S. D.	+	15 52	*W. T.*		*DEC.* (+)	17 47 17	*H. D.*	+ 38.7	*EQ. of T.*	0-34-7.75	*H. D.* + .09
PARX.	+	06	*C—W.*		*COR.*	2 06		+ 3.27	*COR.*	.29	+3.27
I. C.	—	1 50	*C. F.*	3-15-02.5	*COR. DEC.*	17 49 23		11.61 77	*COR. EQ. OF T.*	3-48.04	+ .2943
REF.	—	43	*C. C.*	1-19.5		*90° 00′ 00″*		27			
DIP.	—	4 03	*G. M. T.*	3-16-22	*P. D.*	72 10 37		+ 126.5			
COR.	+	9 22	*G. D.*	10^d +							
OBS. ALT.		52 45 00									

	° ′ ″				° ′ ″		
T. ALT.	52 54 22			*T. ALT.*	52 54 22		
LAT.	27 40 00	*L. SEC.*	.05273	*LAT.*	28 00 00	*L. SEC.*	.05407
P. D.	72 10 37	*L. COSEC.*	.02136	*P. D.*	72 10 37	*L. COSEC.*	.02136
SUM.	152 44 59			*SUM.*	153 04 59		
½ SUM.	76 22 29	*L. COS.*	9.37212	*½ SUM.*	76 32 29	*L. COS.*	9.36688
T. ALT.				*T. ALT.*			
REM.	23 28 07	*L. SIN.*	9.60015	*REM.*	23 38 07	*L. SIN.*	9.60305
		2	9.04636			**2**	19.04536
	h. m. s.				h. m. s.		
L. A. T.	9-24-07	*L. SIN.* ½.	9.52318	*L. A. T.*	9-24-18.2	*L. SIN.* ½.	9.52268
EQ. OF T.	3-48			*EQ. OF T.*	3-48		
L. M. T.	9-20-19			*L. M. T.*	9-20-30.2		
G. M. T.	3-16-22			*G. M. T.*	3-16-22		
LONG. T.	5-56-03			*LONG. T.*	5-55-51.8		
LONG. A.	89° 00′ 45″	*WEST.*		*LONG. A.*	88° 57′ 57″	*WEST.*	

DIP—BY ANGLE WITH SEXTANT.

	180° 00′ 00″
2 Z. D. HOR.	
DIFF.	
½ DIFF. = DIP.	

CHARACTER OF OBS'N.

	Very good.	*Mod't'y good.*	*Barely acceptable.*
OBJECT.	×		
HORIZON.	×		
VALUE OF OBS'N.	×		

DEFINITE POSITION ON THE ABOVE LINE AT THE TIME OF OBSERVATION:

Latitude, **27° 48′ 55″** *North.* *Longitude,* **88° 59′ 25″** *West.*

REMARKS.

Patent-Log, ...70.2

Found Dead-reckoning positions at time of Observation 5 by running course and distance forward from Position S_6, and back from Position S_8. For a Definite Position on Observation 5 accepted a mean of the latitudes thus found, allowing for time-intervals.

[OVER.]

REMARKS—(Continued).

OBSERVER .... Robert G. Peck, Master, U. S. Navy.
COMPUTER .... same.

PRELIMINARY WORK.				
TIME AS PER SOUNDING-SHEET, 9^h 15^m *A. M.* _____ *P. M.*				
TIMES.	*ALTITUDES.*	*CHRO. COMPS.*		*REMARKS.*
h. m. s.	° ′ ″			
3-14-39.5	52 40	*C.*		*SUN* ---------- good.
15-02.5	45	*W.*		*HORIZON* ---------- “
25.5	50	*C-W.*		*COMP. BEARING OF SUN* ---------- E^{d}.
07.5		*C. C.*		*SHIP'S HEAD.*
3-15-02.5	52 45 00			*PATENT LOG* ---------- 70.2
				Taken during Sounding ---------- *No.* 8
		C.		*Taken shortly before Sounding No.*
		W.		*Taken shortly after Sounding No.*
		C-W.		*Taken between Soundings Nos.*
		C. C.		

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

FORM 12.

U. S. COAST SURVEY. OFF-SHORE WORK, GULF OF MEXICO.

×
MERIDIAN ALTITUDE OF SUN, MOON, PLANET (——), STAR (——).

Line from Lat. 29° 01′ 40″, *Long.* 89° 02′ 35″, *to Lat.* 26° 58′ 25″, *Long.* 89° 04′ 35″.

Coast Survey Str. "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N., *Commanding.*

Date, May 10th, 1876, —— *A. M.* × *Noon.* —— *P. M.* *No. of Position,* **9.** *No. of Observation,* **6.** *Line Letter,* **S.**

FORM FOR SUN OR STAR.

	° ′ ″		′ ″		° ′ ″			*CHARACTER OF OBS'N.*			
OBS. ALT.	80 06 50	*S. D. +*	15 52	*DEC. (+)*	17 47 14.6	*H. D. +*	38.6				
COR.	9 52	*PARX. +*	02	*COR.*	3 48.8	*LONG T. +*	5.93		*Very good.*	*Mod't'ly good.*	*Barely acceptable.*
							193.0				
T. ALT.	80 16 42	*I. C. —*	1 50	*COR. DEC.*	17 51 03.4		34.7				
							1.1				
	90° 00′ 00″	*REF. —*	09				+ 222.8	*SUN.*	×		
Z. D.	9 43 18	*DIP. —*	4 03	*DIP—BY ANGLE WITH SEXTANT.*				*HORIZON.*	×		
DEC.	17 51 03	*COR. +*	9 52		*180° 00′ 00″*			*VALUE OF OBS'N.*	×		
LAT.	27 34 21			*2 Z. D. HOR.*							
				DIFF.							
				½ DIFF. = DIP.							

FORM FOR MOON OR PLANET.

(*When using this Form record "Dip with Sextant," and "Character of Observation" on upper Form.*)

OBS. ALT.		*S. D.*		*H. P.*		*G. M. PASS.*		*H. RET.*	
1st COR.		*AUG.*		*TAB. XIX.*		*COR. LONG.*		*LONG.*	
		I. C.				*L. M. PASS.*			
2d COR.		*REF.*				*LONG.*			
T. ALT.		*DIP.*		*SUM.*		*G. M. T.*			
	90° 00′ 00″	*1st COR.*		*CONST.*	*59′ 42″*	*DEC. ( )*		*M. D.*	
Z. D.				*2d COR.*		*COR.*			
DEC.						*COR. DEC.*			
LAT.									

DEFINITE POSITION ON THE ABOVE PARALLEL AT THE TIME OF OBSERVATION:

Latitude **27° 34′ 21″** *North.* *Longitude* **89° 02′ 30″** *West.*

REMARKS.

Patent-Log, ...85.4

By courses and distances, carried Observation 5 forward and Observation 7 back to an intersection with Observation 6. For Definite Position on Observation 6 accepted a mean of the longitudes thus found, allowing for time-intervals.

[OVER.]

REMARKS—(*Continued*).

OBSERVER.................... Robert G. Peck, Master, U. S. Navy.
COMPUTER.................... same.

REMARKS.

TIME AS PER SOUNDING-SHEET	*A. M.*	*P. M.*	Noon.
OBJECT			Good.
HORIZON			"
COMP. BEARING OF OBJECT			S.
SHIP'S HEAD.			
PATENT-LOG			85.4
TAKEN DURING SOUNDING NO.			
TAKEN SHORTLY BEFORE SOUNDING NO.			
TAKEN SHORTLY AFTER SOUNDING NO.			
TAKEN BETWEEN SOUNDINGS NOS			9 & 10.

5″.

G.

76.

DATE.	*Second column of remarks.* *(Describing the manner of getting each position, &c.)*
May 9	
May 9	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	
May 10	

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

Form 13 *(A).*

U. S. COAST SURVEY.

Off-Shore Soundings, Gulf of Mexico.

PLOTTING FORM.

LINE 8, *FROM* ....near South Pass, Mississippi River. *TO*............latitude 26° 58′ 25″, longitude 89° 04′ 35″.

IN STEAMER..........“Blake,” Lieutenant-Commander C. D. Sigsbee, U. S. N., Assistant C. S.,..........*COMMANDING.*

BEGUN AT 8 *HOUR*s 40 *MIN*s. p. m., *DATE* May 9th, 1876, *ENDED AT* 7 *HOUR*s 24 *MIN*s. p. m. *DATE* May 10th, 1876.

DATE.	*Time of the observation.*			*THE OBSERVATION.*						*Readings of patent-log.*	*Courses and distances from previous observation or change of the course.*				***DEFINITE POSITIONS.***			*First column of remarks (to guide in plotting).*	*Second column of remarks. (Describing the manner of getting each position, &c.)*
	Hour.	*Min.*	*A. M or P. M.*	*Objects observed.*	*Presupposed value of observation*	*First serial numbers of observations.*	*Second serial numbers of observations.*	*Terminal latitudes of lines of position (for plotting).*	*Terminal longitudes of lines of position (for plotting).*		*First arrangement of courses.*	*First arrangement of distances.*	*Second arrangement of courses.*	*Second arrangement of distances.*	***Serial numbers of the positions.***	***Latitude.***	***Longitude.***		
								° ′ ″	° ′ ″							° ′ ″	° ′ ″		
May 9	8	40	P. M.	Bearings	V. G					0								South Pass Light bore (cor. mag.) W. S. W. ¾ W. Pass à l'Outre Light bore (cor. mag.) N. ⅜ W. South Pass Light bore (cor. mag.) N. W. by W. ¼ W. Pass à l'Outre Light bore (cor. mag.) N. ⅛ W.	
May 9	9	37	P. M.	Bearings	V. G					5.1	S. ⅛ E	5.1							
May 10	12	41	A. M.	Altair	M. G	I		28 20 00 28 40 00	89 03 28 89 00 03	21.3	S. ⅞ E	16.2							
May 10	12	47	A M	Vega	M. G	II		28 20 00 28 40 00	88 49 43 89 01 54	22.4	S ⅞ E	1.1							
May 10	4	25	A. M.	Saturn	M. G	III		28 00 00 28 20 00	89 09 51 88 53 25	44.6	S. ⅞ E	22 2							
May 10	4	35	A. M.	Jupiter	M. G	IV		28 00 00 28 20 00	88 49 37 89 03 03	46.4	S ⅛ E	1.8							
May 10	5	25	A. M.	C. C						50.4	S. ⅞ E	4.0							
May 10	9	15	A. M.	Sun	V. G	V		27 40 00 28 00 00	89 00 45 88 57 57	70.2	South	19.8							
May 10	Noon			Sun	V. G	VI		27 34 21		85.4	South	15.2						Clock set ahead 6^{m}	
May 10	2	58	P. M	Sun	V. G	VII		27 10 00 27 30 00	89 05 05 89 06 05	100.1	South	14.7							
May 10	4	40	P. M.	Sun	V. G	VIII		27 00 00 27 20 00	89 01 40 88 58 25	110.4	S. by E. ¾ E	10.3							
May 10	5	55	P. M.	Sun	V. G	IX		27 00 00 27 20 00	89 01 43 88 55 10	115.4		5.0							
May 10	6	56	P. M.	Venus	V. G	X		26 50 00 27 10 00	89 06 50 89 01 35	120.7	S. ⅛ E	5.3							
May 10	7	06	P. M.	Procyon	V. G	XI		26 50 00 27 10 00	89 01 00 89 09 40	120.7	Sounding St'n.	0							
May 10	7	16	P. M	Capella	V. G	XII		26 50 00 27 10 00	89 12 30 88 53 18	120.7	Sounding St'n.	0							

D	*Second column of remarks.* *(Describing the manner of getting each position, &c.)*
May 9	
May 9	
May 10	and distance, to an intersection with Obs. I (1) for Def. Pos. on Obs. I (1).
May 10	se and distance, to an intersection with Obs. II (2) for Def. Pos. on Obs. II (2).
May 10	and distance, to an intersection with Obs. III (3) for Def. Pos. on Obs. III (3).
May 10	rse and distance, to an intersection with Obs. IV (4) for Def. Pos. on Obs. IV (4).
May 10	
May 10	bs. V (5) by running course and distance forward from Pos. S_6 and back from Pos. S_8. ted a mean of the latitudes thus found, allowing for time-intervals.
May 10	Obs. V (5) forward and Obs. VII (7) back to an intersection with Obs. VI (6). pted a mean of the longitudes thus found, allowing for time-intervals.
May 10	bs. VII (7) by running course and distance forward from Pos. S_8 and back from Pos. S_{10}. pted a mean of the latitudes thus found, allowing for time-intervals.
May 10	
May 10	
May 10	(8), XI (9), and XII (10), gives Def. Pos. on Obs. X (8).
May 10	(8), XI (9), and XII (10), gives Def. Pos. on Obs. XI (9).
May 10	(8), XI (9), and XII (10), gives Def. Pos. on Obs. XII (10).

[On this form the Italics show the printed matter of the blank form, while the written or recorded matter is represented by Roman.]

Form 13 *(B).*

U. S. COAST SURVEY.

Off-Shore Soundings, Gulf of Mexico.

PLOTTING FORM.

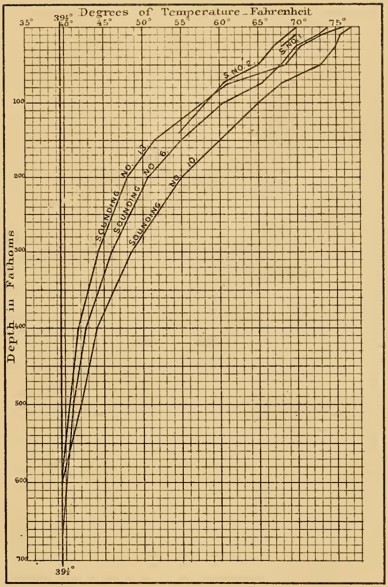
LINE 8, *FROM* .... near South Pass, Mississippi River. *TO*............latitude 26° 58′ 25″, longitude 89° 04′ 35″.

IN STEAMER.......... "Blake," Lieutenant-Commander C. D. Sigsbee, U. S. N., Assistant C. S.,..........*COMMANDING.*

BEGUN AT 8 *HOURs* 40 *MINs.* p. m., *DATE* May 9th, 1876, *ENDED AT* 7 *HOURs* 24 *MINs.* p. m., *DATE* May 10th, 1876.

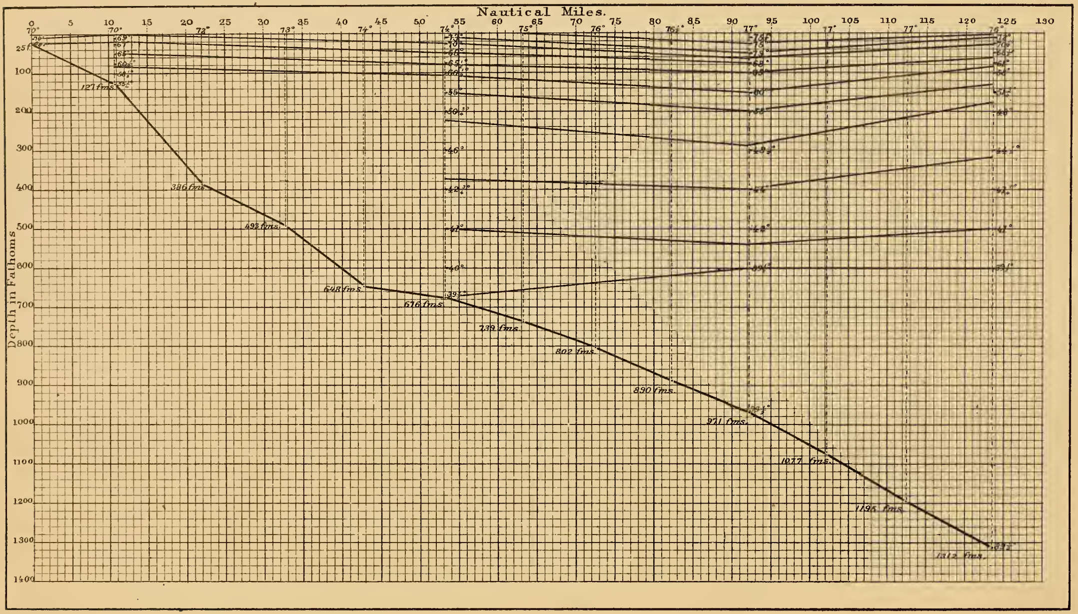
DATE.	*Time of the observation.*			*THE OBSERVATION.*						*Readings of patent-log.*	*Courses and distances from previous observation or change of the course.*				*DEFINITE POSITIONS.*			*First column of remarks (to guide in plotting).*	*Second column of remarks. (Describing the manner of getting each position, &c.)*
	Hour.	*Min.*	*A. M. or P. M.*	*Objects observed.*	*Presupposed value of observation.*	*First serial numbers of observations*	*Second serial numbers of observations*	*Terminal latitudes of lines of position (for plotting)*	*Terminal longitudes of lines of position (for plotting).*		*First arrangement of courses.*	*First arrangement of distances.*	*Second arrangement of courses.*	*Second arrangement of distances.*	*Serial numbers of the positions.*	*Latitude.*	*Longitude.*		
								° ′ ″	° ′ ″							° ′ ″	° ′ ″		
May 9	8	40	P. M.	Bearings	V. G					0					1	29 01 40	89 02 35	South Pass Light bore (cor. mag.) W. S. W. ½ W. Pass à l'Outre Light bore (cor. mag.) N. ⅜ W.	Position obtained by the bearings.
May 9	9	37	P. M.	Bearings	V. G					5.1	S. ⅝ E.	5.1	S. ⅝ E	5.1	2	28 56 20	89 03 15	South Pass Light bore (cor. mag.) N. W. by W. ¼ W. Pass à l'Outre Light bore (cor. mag.) N. ½ W.	Position obtained by the bearings.
May 10	12	41	A. M.	Altair	M. G	I	1	28 20 00 28 10 00	89 03 28 89 00 03	21.3	S. ¾ E	16.2	S. ¾ E	16.2	3	28 38 35	89 00 15		Carried Obs. II (2) back, by course and distance, to an intersection with Obs. I (1) for Def. Pos. on Obs. I (1).
May 10	12	47	A. M.	Vega	M. G	II	2	28 20 00 28 10 00	88 49 13 89 01 54	22.4	S. ¾ E	1.1	S. ¾ E	1.1	4	28 37 25	89 00 10		Carried Obs. I (1) forward, by course and distance, to an intersection with Obs. II (2) for Def. Pos. on Obs. II (2).
May 10	4	25	A. M.	Saturn	M. G	III	3	28 00 00 28 20 00	89 09 51 88 53 25	44.6	S. ¾ E	22.2	S. ¾ E	22.2	5	28 14 15	88 58 05		Carried Obs. IV (4) back, by course and distance, to an intersection with Obs. III (3) for Def. Pos. on Obs. III (3).
May 10	4	35	A. M.	Jupiter	M. G	IV	4	28 00 00 28 20 00	88 49 37 89 03 03	46.4	S. ⅞ E	1.8	S. ¾ E	1.8	6	28 12 25	88 58 60		Carried Obs. III (3) forward, by course and distance, to an intersection with Obs. IV (4) for Def. Pos. on Obs. IV (4).
May 10	5	25	A. M.	C. C						50.4	S. ⅞ E	4.0	S. ⅞ E	4.0					
May 10	9	15	A. M.	Sun	V. G	V	5	27 10 00 28 00 00	89 00 45 88 57 57	70.2	South	19.8	South	19.8	7	27 48 55	88 59 25		Found D. R. positions at time of Obs. V (5) by running course and distance forward from Pos. S_6 and back from Pos. S_8. For Def. Pos. on Obs. V (5) accepted a mean of the latitudes thus found, allowing for time-intervals
May 10	Noon			Sun	V. G	VI	6	27 31 21		85.4	South	15.2	South	15.2	8	27 34 21	89 02 30	Clock set ahead 6m	By courses and distances, carried Obs. V (5) forward and Obs. VII (7) back to an intersection with Obs. VI (6). For Def. Pos. on Obs. VI (6) accepted a mean of the longitudes thus found, allowing for time-intervals
May 10	2	58	P. M.	Sun	V. G	VII	7	27 10 00 27 30 00	89 05 05 89 06 05	100.1	South	11.7	South	14.7	9	27 19 15	89 05 30		Found D. R. positions at time of Obs. VII (7) by running course and distance forward from Pos. S_8 and back from Pos. S_{10}. For Def. Pos. on Obs. VII (7) accepted a mean of the latitudes thus found, allowing for time-intervals.
May 10	4	40	P. M.	Sun	V. G	VIII		27 00 00 27 20 00	89 01 40 88 58 25	110.4	S. by E. ¾ E	10.4	S. by E. ¾ E	10.4				Becomes a "change of the course"	Rejected. Filed in the Archives.
May 10	5	55	P. M.	Sun	V. G	IX		27 00 00 27 20 00	89 01 43 88 55 10	115.4	S. ⅜ E	5.0							Rejected. Filed in the Archives.
May 10	6	56	P. M.	Venus	V. G	X	8	26 50 00 27 10 00	89 06 50 89 01 35	120.7	S. ½ E	5.3	S. [illegible] E	10.3	10	26 58 25	89 04 35		The intersection of Observations X (8), XI (9), and XII (10), gives Def. Pos. on Obs. X (8).
May 10	7	06	P. M.	Procyon	V. G	XI	9	26 50 00 27 10 00	89 01 00 89 09 40	120.7	Sounding St'n.	0	Sounding St'n.	0	10	26 58 25	89 04 35		The intersection of Observations X (8), XI (9), and XII (10), gives Def. Pos. on Obs. XI (9).
May 10	7	16	P. M.	Capella	V. G	XII	10	26 50 00 27 10 00	89 12 30 88 53 18	120.7	Sounding St'n.	0	Sounding St'n.	0	10	26 58 25	89 04 35		The intersection of Observations X (8), XI (9), and XII (10), gives Def. Pos. on Obs. XII (10).

FORM 14.



TEMPERATURE CURVES AT EACH STATION
ON LINE S. OF 1875 - 6., GULF OF MEXICO.

FORM 15.



PROFILE OF THE BOTTOM, AND TEMPERATURE CURVES ON LINE S. 1875-6., GULF OF MEXICO.

SUPPLEMENT.

SUPPLEMENT.

THE SIGSBEE MACHINE FOR SOUNDING WITH WIRE; PATTERN OF 1881.

During the year 1881 a Sigsbee Sounding-Machine was made for each of the following-named organizations: U. S. Navy, U. S. Coast and Geodetic Survey, and Imperial German Navy. Another is now being made for the U. S. Commission of Fish and Fisheries. The leading object in this supplement is to point out such improvements in these machines as are not embraced in the machine shown on Plate 8, &c., of the original volume to which the supplement pertains.

The references herein relate to the original volume. In the views shown on the two accompanying Plates the scale of dimensions is the same throughout the set.

In the construction of the new machines metal only has been employed, a cast-steel bed, in two parts, replacing the wooden bed formerly used. The new style of bed allows the machine to be more compactly folded than before.[1] The strain-pulley has been abandoned and its former place on the bed is now occupied by the steam-engine and a special form of tightening-pulley.[2] An auxiliary brake has been placed beneath the reel; a single spur buffer only is used at the foot of the guide-pipes, and the outriggers to which the side-stays are set up, and the casting which supports the fairleader and swivel pulley, are now hinged or pivoted.[3] The intention is to adapt the machine for folding with the removal of so few parts that, in inexperienced hands, there need be no doubt as to the position which each part should occupy when the machine is set up for use. Steel castings are used wherever they can be utilized.

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[1] Comp. Plate 12.

[2] Page 62, ¶ 4, and p. 72, ¶ 1.

[3] Page 64, ¶¶ 7 and 8.

Plate 42 shows the right side of the machine. In Fig. 1 the machine is rigged for reeling in by steam, the reel being connected with the engine by means of a belt of round leather on one part of which rests the tightening-pulley.[1] The swivel-pulley is down in the position it would have when reeling in while the ship has headway.[2] Fig. 2 shows the machine in temporary disuse, as in port, for instance. The reel, being unshipped, is supposed to be in the tank containing preservative.[3] The register is thrown back out of the way.[4] The fairleader arrangement is thrown back on its pivot and the swivel-pulley is carried still farther to the rear on another pivot; neither are unshipped. The side stays are slacked and their outriggers are thrown up on pivots into a snug position.[5] The two parts of the back brace or stay are disconnected, and the upper section of the guide-pipes is thrown back where it remains supported, all parts of the machine thus being accessible for cleaning.

Plate 43 shows the left side of the machine. In Fig. 1 it is rigged for paying out.[6] The belt is disconnected and the friction-line is applied. The swivel-pulley is laid aside, resting on the left outrigger. The clamp is in use in the fairleader as if the reel had been stopped temporarily to repair a defect in the wire.[7] Fig. 2 shows the machine folded for transportation or stowage, the reel being in the tank. The cross-head pulley has been removed, but the cross-head itself remains in place.[8] In folding the machine the reel and this pulley are the only parts that do not remain hinged or otherwise attached to their proper places; such bolts or screws as are necessarily removed are again replaced, after the machine has been folded, to secure them against loss or error in future adjustments. The front part of the bed has been thrown upward, carrying with it the guide-pipes. The guide-pipes are folded in a reverse way from that shown in Fig. 2, Plate 42, while the outriggers, fairleader arrangement, and swivel-pulley are folded as shown in that figure. For inclosing the machine when folded, a box is placed over it and screwed to the wooden piece shown by the figures of Plates 42 and 43. This wooden piece forms the

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[1] Comp. Plates 7 and 13.
[2] Page 81, ¶ 2.
[3] Page 34, ¶ 5.
[4] Page 62, ¶ 3.
[5] Comp. Plate 12.
[6] Page 67, ¶ 5.
[7] Page 77, ¶ 2.
[8] Page 63, ¶ 2.

PLATE 42.

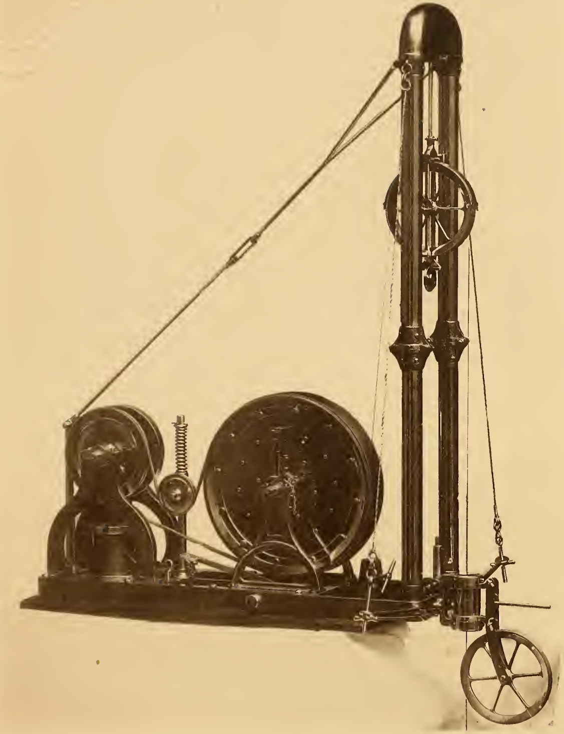

Fig. 1.

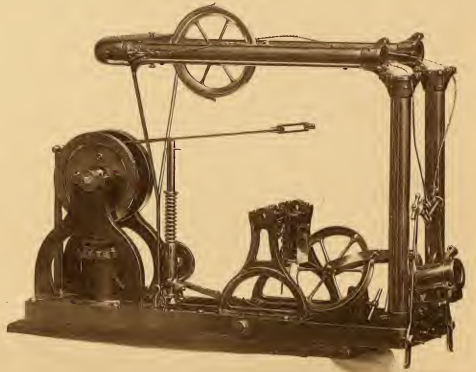

Fig. 2.

HELIOTYPE PRINTING CO.

BOSTON.

SIGSBEE MACHINE FOR SOUNDING WITH WIRE: PATTERN OF 1881. FIG. 1—RIGGED FOR REELING IN BY STEAM. FIG. 2.—IN TEMPORARY DISUSE.

bottom of the box, but, for convenience, it is permanently attached to the steel bed. The outside dimensions of the box, when it is made of heavy stuff, are as follows: length, 4 feet 5 inches; breadth, 1 foot 8 inches; height, 3 feet. In this space are stowed such conveniences as the steam-engine, tightening-pulley, accumulator, dynamometer, governor, swivel-pulley, auxiliary brake, etc.[1]

The bed is well shown in the several figures of Plates 42 and 43. It is composed of two skeleton frames of steel, hinged together by bolts. The steel bed does away with the warping sometimes experienced with the wooden bed when exposed to a hot sun. Warping of the bed throws the standards of the reel out of alignment, which makes the axle of the reel bind in its bearings.

The engine does not differ essentially from that shown on Plate 18, with the exception of being vertical instead of inclined.[2]

The tightening-pulley.[3] A collar, sliding on the vertical shaft shown in the plates, has a stud on one side which forms the axle for the pulley. The tension on the belt is maintained by the elastic pressure of a spiral spring. Along the shaft are bored holes at regular intervals, into any one of which the pin shown near the top of the shaft may be inserted according to the amount of pressure which it is desired the spring shall exert. When the tightening-pulley is not in use the shaft is turned on its axis, carrying the pulley to the left side of the machine, giving place for the standing part of the friction-line, or the spring scales—Fig. 2, Plate 42, and Figs. 1 and 2, Plate 43. A pin at the foot of the shaft keeps the latter from turning when it should remain immovable.

The outriggers are of cast-steel; each is fastened or hinged to the bed by a bolt going through a longitudinal slot in the outrigger.[4] In use the inner ends of the outriggers rest upon studs projecting from the bed.

The auxiliary brake and its use.—The brake is a lever of the first order, pivoted on a block screwed to the board shown on the plates. The end of the lower arm, which is fitted with a wedge-shaped piece of wood, may be pressed into the **V**-groove of the reel by force applied to the other arm,

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[1] Comp. p. 67, ¶¶ 2 and 3. [2] Page 87, ¶ 2. [3] Comp. p. 86, ¶ 3. [4] Comp. Plates 8 and 12.

but, in the absence of such force it is held out of action by a spring. The auxiliary brake serves for immediate and temporary use in the event of the friction-line or the connecting-belt parting, and in unusually heavy seas and under adverse circumstances it may be used in lieu of the toggle tucked into the friction-line—described in the original volume. The office of the toggle—although it is rarely used—is to impose upon the reel a small amount of friction which will not be lessened by the action of the governor,[1] the object being to permit in heavy seas a rapid rate of paying out.[2] The occasional advantage which may be derived from this accessory is well illustrated by such an extreme case as would make the use of the auxiliary brake desirable, thus: sounding from the bow; sea heavy; ship pitching violently; a heavy reel in use, and containing a large coil of wire which adds much to its weight at the periphery.[3] Under these conditions, and when the reel is revolving with considerable speed, the vessel rises suddenly, increasing the tension upon the wire which is being payed out; the cross-head is borne down, easing the friction-line, we will assume, more than is desirable, and the heavy reel, thus deprived for a second of nearly all frictional control, is set revolving with great rapidity. At this instant the vessel gives a quick, deep plunge. The reaction of the accumulator acting as a governor is almost instantaneous, and the friction-line is set hard taut; but before the momentum of the heavy reel can be overcome the wire slacks and perhaps flies from the reel. If, in the case stated, the auxiliary brake, which is independent of the governor, had been bearing upon the reel with a constant pressure, maintaining a slight resistance, the undue slacking of the friction-line would not have been followed by such excessive revolution of the reel. To insure an even pressure of the auxiliary brake, the inboard end of the brake-lever—the long arm—might be connected with the bed of the sounding-machine by a spring of rubber or metal which could be set to any desired tension. It must not be inferred that the auxiliary brake is a necessity; it is intended as a convenience on extraordinary occasions, to obviate the necessity for unusual skill or judgment on the part of those

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[1] Page 68, ¶ 6.

[2] Page 70, ¶ 2.

[3] Page 56, ¶ 1.

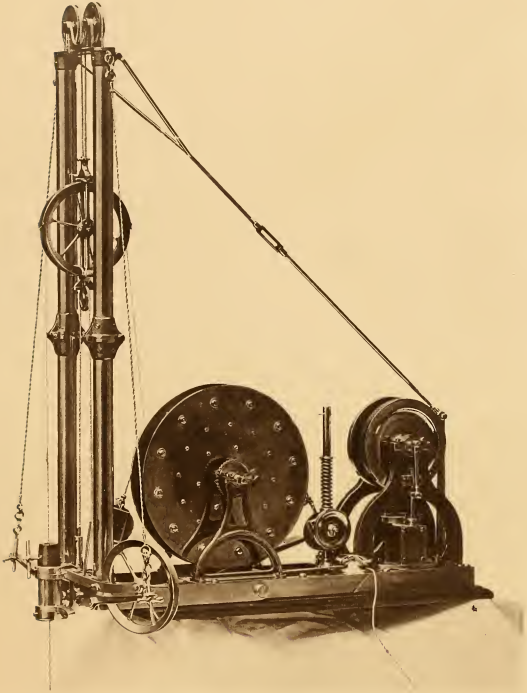


Fig. 1.

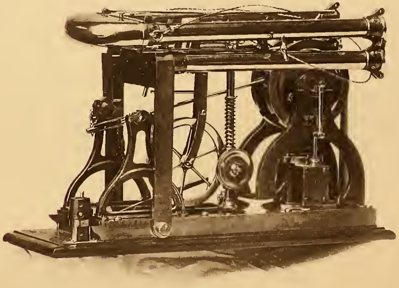


Fig. 2.

HELIOTYPE PRINTING CO. BOSTON.

SIGSBEE MACHINE FOR SOUNDING WITH WIRE: PATTERN OF 1881. FIG. 1—RIGGED FOR PAYING OUT; CLAMP IN USE. FIG. 2.—FOLDED FOR TRANSPORTATION OR STOWAGE.

operating the machine. It has been my purpose to add to the sounding-machine, when warranted by economy, every appliance which may save time or prevent accident. In many localities there is but a small proportion of weather during which astronomical observations can be had for determining the positions of soundings; it is therefore highly important in such localities to make the best use of favorable weather.

GRAVITATING OR COLLECTING TRAP FOR OBTAINING ANIMAL SPECIMENS FROM INTERMEDIATE DEPTHS.

In the original volume, page 144, last paragraph, and page 145, foot-note, reference is made to the invention of an apparatus for collecting animal forms from intermediate depths. The apparatus has now been well tried and a full description of it by myself (accompanied by a drawing), and a statement of the results obtained, by Prof. Alexander Agassiz, is contained in the "Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. VI, Nos. 8 and 9, September, 1880."

I quote a part of my own description contained therein, as follows:

"The old practice of dragging for animal forms at intermedial depths by means of a tow-net, which, during the several operations of lowering, dragging, and hauling back remained open, was not regarded by Prof. Alexander Agassiz as affording acceptable evidence of the habitat of such specimens as were obtained, and he frequently referred to the subject during our association on board the "Blake" in 1878.

"In March, 1880, it having been arranged that Professor Agassiz should make another cruise on board the "Blake," Commander J. R. Bartlett, U. S. N., commanding, he asked my co-operation in devising an apparatus to meet the rigid demands of the work in question. This resulted in the apparatus described herein, which is presented in the precise form used with success by the "Blake," although, as may readily be seen, it is open to great improvement, especially in minor details.

"The 'Challenger' had examined intermediate depths by means of tow-nets trailing from the dredge-rope while hauling the dredge or trawl. In such a practice it must have been that the depths to which the nets were sunk depended in some degree on the amount of slack-rope payed out, and also on the strain upon the dredge-rope due to the resistance encountered by the dredge when dragging; it cannot, therefore, be said that strictly determinate depths were examined by that method, even assuming that the nets gathered nothing while being lowered and hauled back.

"It occurred to me that by using an apparatus in connection with a line and lead, payed out vertically as in sounding, and by dragging vertically, instead of horizontally as formerly, there would be at least as much certainty with regard to depths as in the old method, and that simple mechanical devices could be invented to satisfy the conditions of the work. The scheme has been stated in my volume on 'Deep-Sea Sounding and Dredging' (p. 145, foot-note), as follows:

"'Our plan is to trap the specimens by giving to a cylinder, covered with gauze at the upper end and having a flap-valve at the lower end, a rapid vertical descent between any two depths, as may be desired; the valve during such descent to keep open, but to remain closed during the processes of lowering and hauling back with the rope. An idea of what it is intended to effect may be stated briefly thus: Specimens are to be obtained between the intermediate depths *a* and *b*—the former being the uppermost. With the apparatus in position, there is at *a* the cylinder suspended from a friction *clamp* in such a way that the weight of the cylinder and its frame keeps the valve closed; at *b* there is a friction *buffer*. Everything being ready, a small weight or messenger is sent down, which on striking the clamp disengages the latter and also the cylinder, when messenger, clamp, and cylinder descend by their own weight to *b*, with the valve open during the passage. When the cylinder frame strikes the buffer at *b* the valve is thereupon closed, and it is kept closed thereafter by the weight of the messenger, clamp, and cylinder. The friction buffer, which is four inches long, may be regulated on board to give as many feet of cushioning as desired.'"

The trap was first tried in Narragansett Bay, and soon after was used for the second time at sea, several improvements having been made in the meantime by Professor Agassiz and Commander Bartlett. I quote from the Bulletin again, this time giving Professor Agassiz's words:

"On the 1st of July the Sigsbee cylinder was tried for the second time in Lat. 39° 59′ 16″ N., Long. 70° 18′ 30″ W., in 260 fathoms of water. The surface was carefully explored with the tow-net to see what pelagic animals and others might be found on the surface. There were found Calanus, Sagitta, Annelid larvæ, Hydroid Medusæ, Squillæ embryos, Salpæ, and a few Radiolarians. The cylinder, filled with water which had been carefully sifted through fine muslin, was then attached to the dredging-wire, and lowered, so as to collect the animals to be found between 5 and 50 fathoms. The time occupied by the cylinder in passing through that space was 28 seconds. The cylinder was then brought up, and the sieves and gauze trap carefully washed with water, which had also previously been strained through fine muslin. The water was carefully examined, and we found the very same things which had a short time before been collected at the surface with the tow-net and the scoop-net; nothing different was collected by the cylinder. The Radiolarians (two genera) were perhaps more numerous than at the surface. A slight breeze having sprung up after the surface collections had been examined, the cylinder was then sent down a second time at this same station, so adjusted as to collect any animal life to be found from a depth of 50 to 100 fathoms. Not only in this experiment, but in all the subsequent ones, the same precautions were taken in regard to straining the water which filled the cylinder at the start, as well as that used for washing out the sieve and the gauze trap. The messenger sent down to detach and open the machine occupied 21 seconds in reaching the (50 fathoms) point to which the cylinder was attached, and the cylinder then occupied 30 seconds in passing to the stop at 100 fathoms. On examining the sieves, it was found that the more common surface things, Calanus, Sagitta, Annelid larvæ, Hydroid Medusæ, and Squillæ embryos, were entirely wanting, and there were only two Radiolarians of the same species as those from the upper levels found after a careful scrutiny of the water. Nothing additional was brought up. The cylinder was then sent down a third time, lowered to a depth of 100 fathoms, the messenger sent down to open it (time occupied 45″), and the cylinder traveled from 100 to 150 fathoms (time 45″), so as to collect the animal life to be obtained between these limits. On drawing up the cylinder and washing out the sieve of the trap, not only did we find that the water contained nothing different from what had been brought up by the cylinder from the lesser depth, but it did not contain even a single Radiolarian.

"On the 15th of July, in Lat. 34° 28′ 25″ N., Long. 75° 22′ 50″ W., we tried the Sigsbee cylinder for a third time, in a depth of 1,632 fathoms. With the same precautions before and after using it, the cylinder was sent to collect first between 5 and 50 fathoms (time 30″). The surface was somewhat ruffled, and but little was found on the surface beyond a few Crustacean larvæ and Heteropods. The cylinder contained Hydroids, fragments of Siphonophores, pelagic Algæ, Crustacean larvæ, and Heteropod eggs; forms which differed from these scooped at the surface, but were identical with the species found on previous days at the surface under more favorable surface conditions of the sea. Next, the cylinder was arranged to collect between 50 and 100 fathoms (time of messenger 21″ from surface to 50 fathoms, time of cylinder 40″ to stopper from 50 to 100 fathoms). The water was found to contain only a couple of Squillæ larvæ, similar to those fished up at the surface. The third time the cylinder went down at this station it was lowered to collect from 100 to 150 fathoms (time of messenger from surface to 100 fathoms 45″, time of cylinder in passing from 100 to 150 fathoms 45″). The water when examined contained nothing. No Radiolarians were found at this station, either at the surface or at any depth to which the cylinder was sent (150 fathoms).

"The above experiments appear to prove conclusively that the surface fauna of the sea is really limited to a comparatively narrow belt in depth, and that there is no intermediate belt, so to speak, of animal life, between those living on the bottom, or close to it, and the surface pelagic fauna.

"The experiments of using the tow-net at great depths (of 500 and 1,000 fathoms), as was done by Mr. Murray on the 'Challenger,' were not conclusive, as I have already pointed out on a former occasion, while the so-called deep-sea Siphonophoræ, taken from the sounding-line by Dr. Studer, on the 'Gazelle,' may have come, as I have so often observed in the Caribbean, from any depth. I do not mean, of course, to deny that there are deep-sea Medusæ. The habit common to so many of our Acalephs (Tima, Æquorea, Ptychogena, etc.) of swimming near the bottom is well known; Dactylometra moves near the bottom, and Polyclonia remains during the day turned up, with the disk downward, on the mud bottom. I only wish to call attention to the uncertain methods adopted for ascertaining at what depth they live.

"As far as the pelagic fauna is concerned, those who have been in the habit of collecting surface animals know full well that the least ripple will send them below the reach of commotion; Müller and Baur were the first to adopt the use of a tow-net sunk below the surface to collect pelagic animals when the water was disturbed. It seems natural to presume, as we have found from our experiments with the Sigsbee cylinder, that this surface fauna only sinks out of reach of the disturbances of the top, and does not extend downward to any great depth. The dependence of all the pelagic forms upon food which is most abundant at the surface, or near it, would naturally keep them where they found it in greatest quantity.

"Of course, with the death and decomposition of the pelagic forms, they sink to the bottom fast enough to form an important part of the food supply of the deep-sea animals, as can easily be ascertained by examining the intestines of the deep-water Echinoderms. The variety and abundance of the pelagic fauna, and its importance as food for marine animals, are as yet hardly realized.

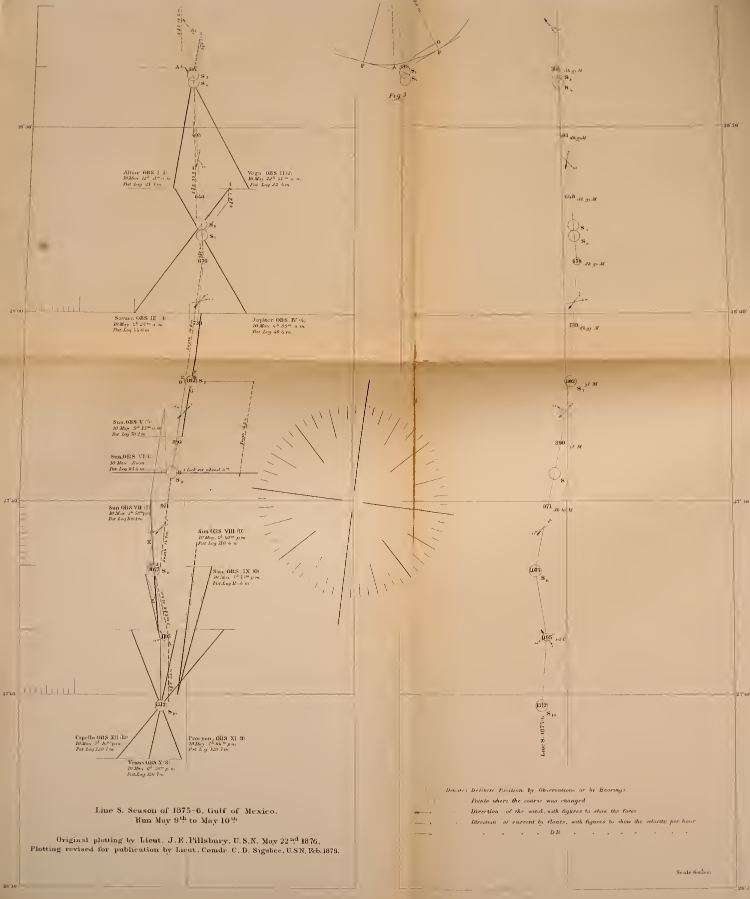
"One must have sailed through miles of Salpæ with the associated Crustacean, Annelid, and Mollusk larvæ, the Acalephs, especially the oceanic Siphonophores, the Pteropods and Heteropods, with the Radiolarians, Globigerinæ, and Algæ, to form some idea how rich a field still remains to be explored. The variety of the pelagic fauna in the course of the Gulf Stream is probably not surpassed by that of any other part of the ocean."

PRESSURE ERRORS OF MILLER-CASELLA THERMOMETERS.

The following report is taken from "*Nature*," issue of April 21, 1881, page 595. It treats of a matter contained in the original volume on Deep-Sea Sounding and Dredging, page 109:

"ROYAL SOCIETY, *April* 4.

"Professor Tait communicated the results of his experiments on the pressure errors of the *Challenger* thermometers, the correction for which, as originally furnished to the expedition, was 0°.5 F. per mile of depth. The mode of experimenting was to subject the thermometers to considerable pressure in a hydraulic press, which was essentially a strong steel cylinder that was warranted to stand a pressure of 25 tons weight on the square inch. It was supported in an upright position upon a strong tripod stand. Water was filled in from above; and into the upper end of the cylinder there was lowered a tight-fitting plug, which was fixed in position by a transverse steel bolt. The lower end of the cylinder was connected through a narrow copper tube to a hydraulic pump, which, by pumping in water to the cylinder, raised the pressure to the required amount. At three tons pressure an average effect of 1°.5 F. was produced upon the inclosed thermometers. Before drawing any conclusions as to the correction to be applied in deep-sea sounding, it was necessary to consider how far this effect could be explained as resulting from the peculiar conditions under which the experiments were made. From the known compressibility of glass it was calculated that the volume of the bore of a thermometer tube, closed at both ends, would be diminished by only one-thousandth part for an increase of pressure of one ton weight on the square inch; and from a direct experiment made with a metre-long tube this was proved to represent very approximately the real effect. Hence it was quite out of the question that this could have any appreciable effect on such comparatively short thermometers as those of the *Challenger*, which were besides subject to much graver errors, such as those arising from the shifting of the indices during the ascent from the depths, or even from the effect of parallax when taking the reading. The direct action of pressure may then be disregarded, and the effect produed upon the thermometers in the compression apparatus must be due to secondary effects of pressure, such as evolution of heat. The various sources of heat were four: 1. Heating of the water by compression. This depends greatly on the original temperature of the water, being *nil* at the point of maximum density (40° F.) and larger for higher temperatures. One-fourth of the total effect is due to this. 2. Heating of the water due to pumping in through the narrow tube. This accounts for three-twentieths of the effect. 3. Heating of the vulcanite frame by compression. This explains another fifth. 4. Heating due to the effect upon the protecting-bulb. This probably explains the remaining two-fifths of the effect. In this last case, however, there is not only compression but distortion; and of the thermal effects of such a strain no one yet knows anything. These four sources of error cannot be supposed to exist under the conditions in which deep-sea temperatures are taken; and the only other possible source, that, namely, due to the direct effect of pressure, gives rise to an error which requires a correction of only 0°.04 F. per mile of depth. In the course of the description of experiments Professor Tait had occasion to describe the various kinds of pressure gauges which he had found it necessary to devise, the ordinary forms of gauge being altogether useless for scientific work."



Line S. Season of 1875-6, Gulf of Mexico.
Run May 9th to May 10th

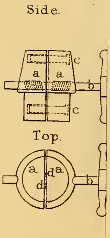
Original plotting by Lieut. J. E. Pillsbury, U.S.N. May 22nd 1876.
Plotting revised for publication by Lieut. Comdr. C. D. Sigsbee, U.S.N. Feb. 1879.

Denotes Definite Position by Observations or by Bearings
Points where the course was changed
Direction of the wind, with figures to show the force
Direction of current by floats, with figures to show the velocity per hour
. . . . DR . . . .

Scale $\frac{1}{600000}$

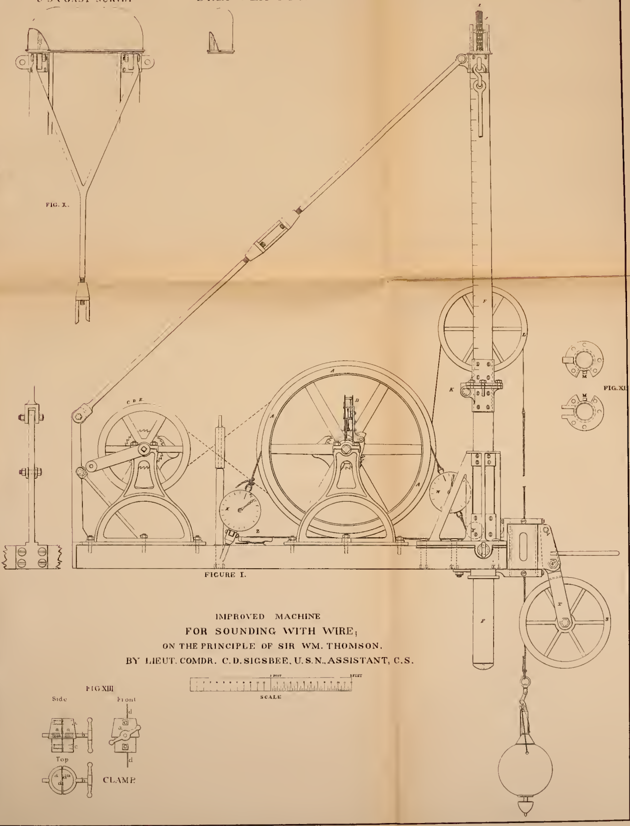
THE PLOTTING OF A LINE OF SOUNDINGS

F



Side.

Top.



IMPROVED MACHINE
FOR SOUNDING WITH WIRE;
ON THE PRINCIPLE OF SIR WM. THOMSON.
BY LIEUT. COMDR. C. D. SIGSBEE, U. S. N., ASSISTANT, C. S.

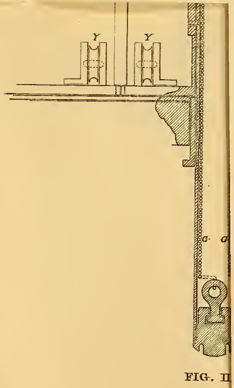


FIG. I

FIG. XII.

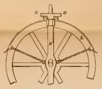


FIG. VII.

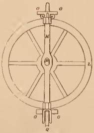


FIG. VIII.

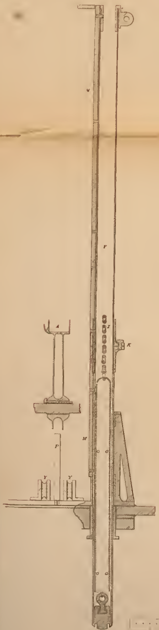
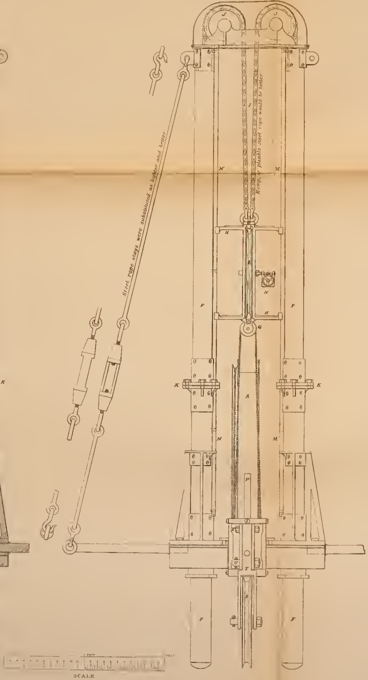


FIG. III.



SCALE

FIG. II.

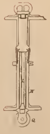
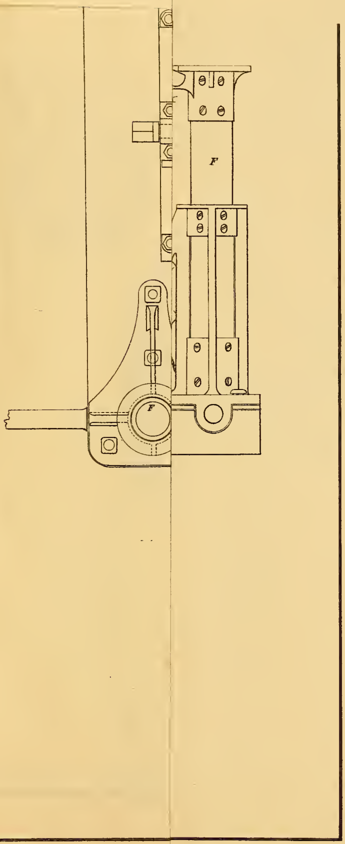


FIG. IX.

CONTINUATION OF PLATE 36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U S COAST SURVEY

DEEP-SEA SOUNDING AND DREDGING

PLATE 38

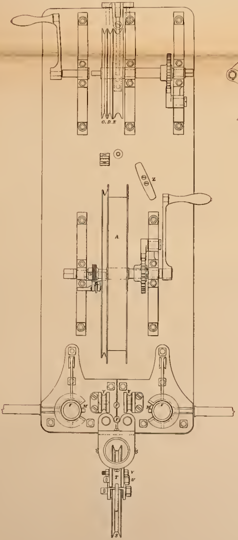
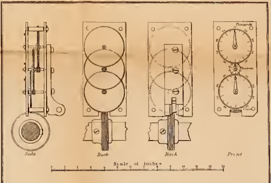
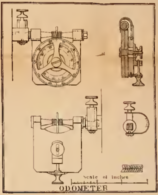


FIG. V.

FIG. VI.



REGISTER



ODOMETER

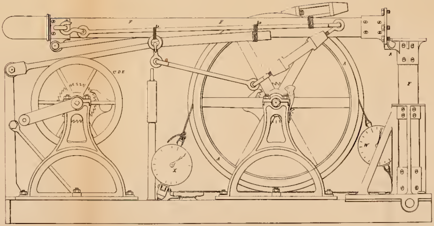


FIG. IV.

CONTINUATION OF PLATES 36 & 37.

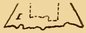


FIG. IV.

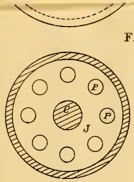


FIG. V.

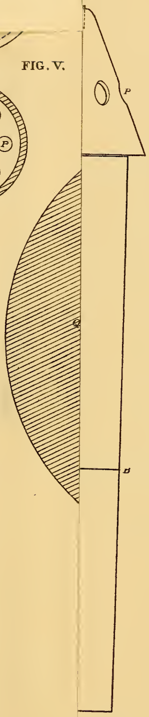


FIG. III.

DEEP-SEA SOUNDING AND DREDGING

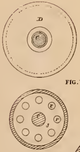


FIG. V.

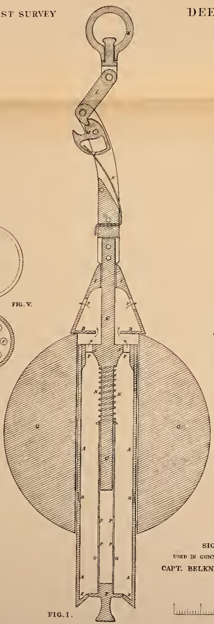


FIG. I.

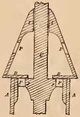


FIG. VI.

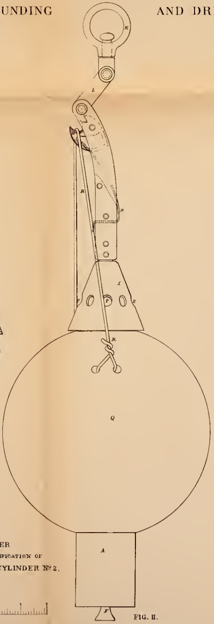


FIG. II.

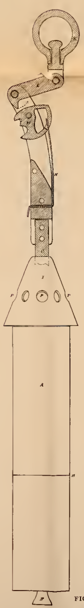


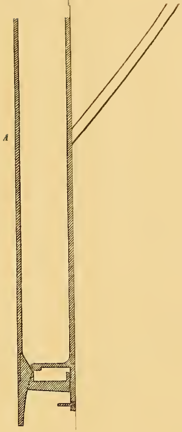
FIG. III.

FIG. IV.

SIGSBEE'S DETACHER

USED IN CONNECTION WITH A MODIFICATION OF

CAPT. BELKNAP'S SOUNDING CYLINDER No 2.



FIG

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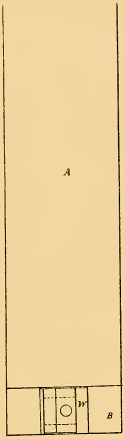


FIG. V.

DEEP-SEA SOUNDING AND DREDGING

FIG. I.

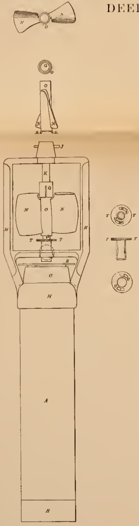


FIG. II.

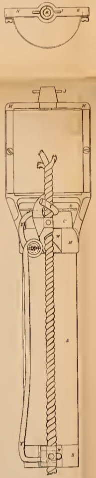


FIG. III.

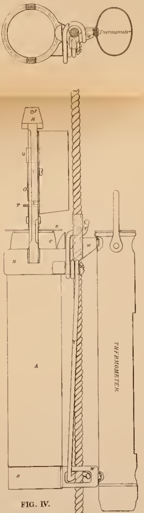
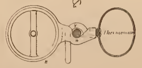


FIG. IV.



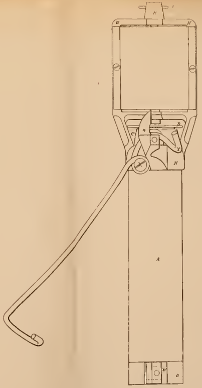
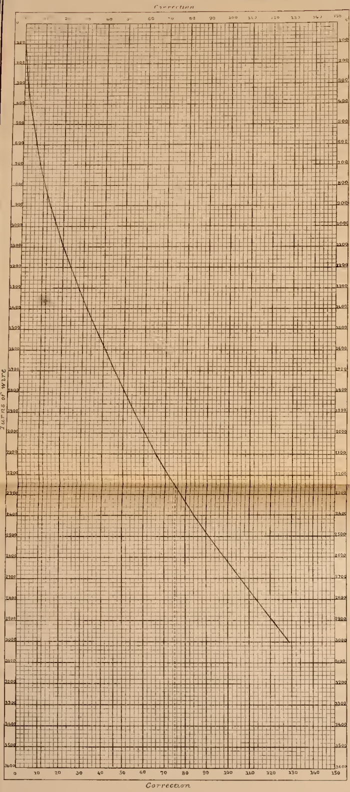


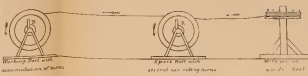
FIG. V.

Water Specimen Cup for getting at one haul specimens of water from various depths by using as many cups as there are specimens desired

Invented by Lieut Comdr C D Sigsbee U S N Assistant Coast Survey in January 1875 and improved at different times up to August 1877

The [illegible] or tong clamp should be made not as shown but L shaped [illegible] corrugated [illegible]





Reeling off Wire to get data for Curve,
R = Register connects with axle of Reel

Turns of Working Reel	Turns of Spare Reel or Fathoms	Difference or Correction	Remarks
100	100	0	Splice at 159 turns W R
200	200 ½	½	
300	301 ½	1½	„ „ 334 „ „
400	403	3	
500	504 ½	4½	„ 550½ „ „
600	606 ½	6½	
700	708 ½	8½	
800	810 ½	10½	
900	913 ½	13½	„ „ 917 „
1000	1016 ½	16½	
1100	1120	20	
1200	1223 ½	23½	„ „ 1272
1300	1327 ½	27½	
1400	1432	32	
1500	1536 ½	36½	
1600	1641	41	„ „ 1632½
1700	1745 ½	45½	
1800	1850 ½	50½	„ „ 1854
1900	1955 ½	55½	
2000	2060 ½	60½	
2100	2165 ½	65½	„ „ 2114
2200	2271 ½	71½	
2300	2377 ½	77½	„ „ 2340 „
2400	2484	84	
2500	2591	91	„ „ 2536 „
2600	2698 ½	98½	
2700	2805 ½	105½	
2800	2913 ½	113½	„ „ 2860 „
2900	3021 ½	121½	
3000	3129 ½	129½	
3100			
3200			
3300			
3400			

Construction of the curve

On a profile sheet as shown let the side column represent the [illegible] working reel, and the top column represent the corrections Opposite each hundred [illegible] side column, set off the proper correction as given by the third column of the above table, and mark the points Connect the various points by a curve

Finding the correction from the curve.

Let T = the number of turns of wire payed out as per register at any sounding and C = correction to be applied to reduce the turns to fathoms
t = whole number of turns of wire in use on working reel and c = [illegible]
t' = number of turns of wire left on working reel when sinker touches bottom and c' [illegible]

then $t' = t - T$
$C = c - c'$
and $T + C$ = number of *fathoms* payed out

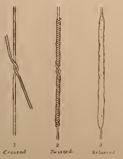
c will evidently remain a constant until wire is lost, or added to the reel when a new constant must be used corresponding to the new quantity t

Example

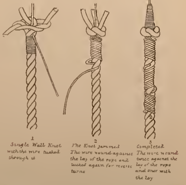
t	wire in use = 2260 turns	cor c	75
T	reading of register = 1420 „		
t'	= diff = wire left on reel = 840 „	cor c'	12
	difference or	C =	63
	add T, or reading of register		1420
	true depth of sounding		1483 fathoms

Note *This particular table and curve are for the Navy brass reel*

Com'dr Howell's method of splicing the wire.



Lieut Com'dr Sigsbee's method of splicing the wire into the "stray line"



SOUNDING WITH WIRE.

CURVE FOR CORRECTING THE READING OF THE REGISTER PLACED ON THE AXLE OF THE SOUNDING REEL;

BY LIEUTENANT COMMANDER C. D SIGSBEE, U. S NAVY, ASSISTANT COAST SURVEY.