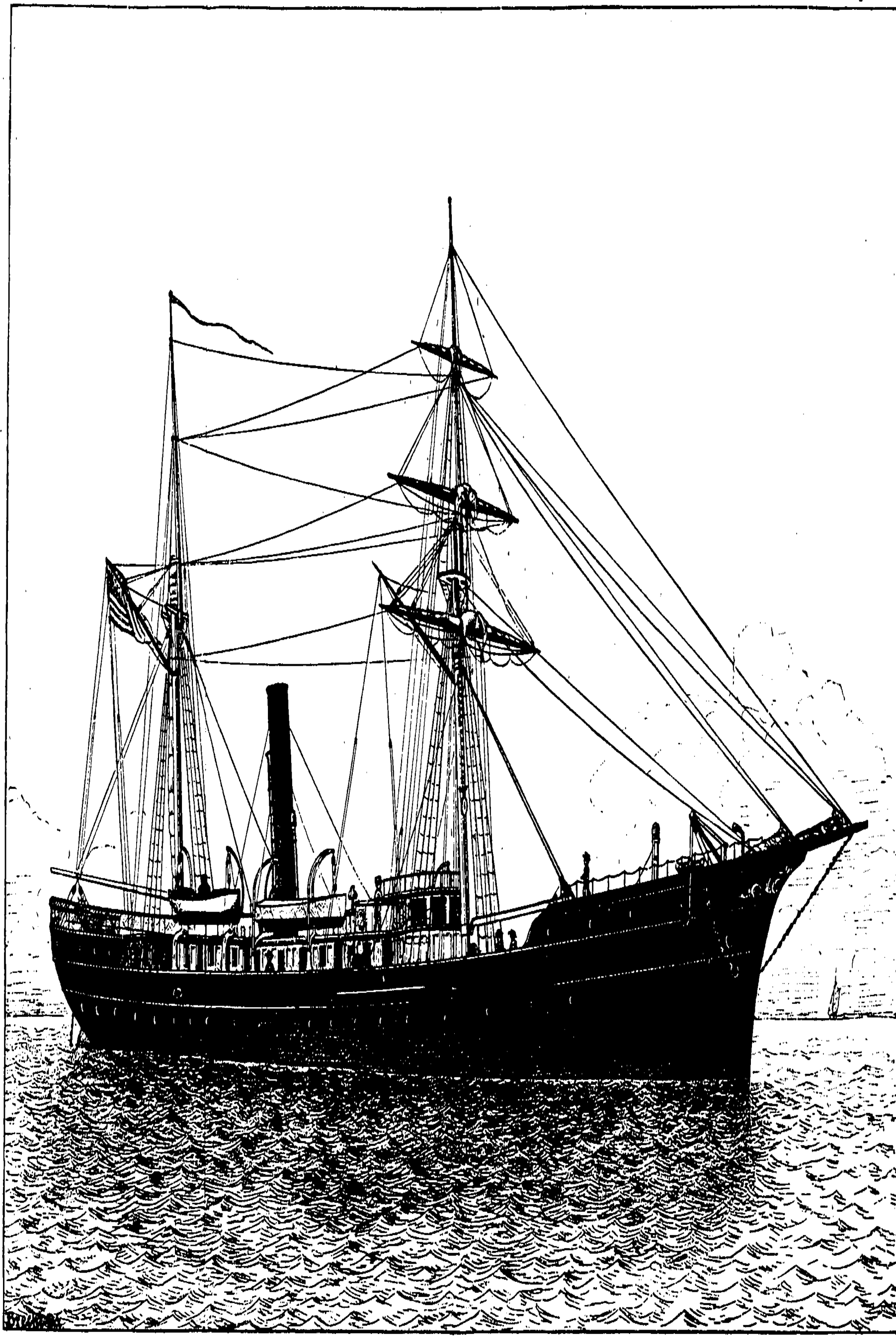


U. S. Fish Commission steamer Albatross.

# I.—REPORT ON THE CONSTRUCTION AND OUTFIT OF THE UNITED STATES FISH COMMISSION STEAMER ALBATROSS.

BY LIEUTENANT-COMMANDER Z. L. TANNER, U. S. N.

CONTENTS.



## A.—PREFACE BY THE COMMISSIONER.

The alleged decrease of the food-fishes along the sea-coasts and in the lakes of the United States induced the passage by Congress, in 1871, of an act authorizing the appointment by the President, with confirmation by the Senate, of a Commissioner of Fish and Fisheries to investigate the subject and report the facts as ascertained, with any recommendations that might seem desirable; and Prof. Spencer F. Baird, the then Assistant Secretary of the Smithsonian Institution, received the appointment.

The investigations in question were at first restricted to the examination of the inshore waters; but the many questions arising in regard to the movements of the mackerel, the bluefish, the menhaden, and other pelagic species, caused the Commissioner to make application to Congress for means to build a sea-going steamer, by the aid of which the movements of the sea fish could be more readily followed, and their lines of migration and winter habitat determined. An appropriation of $103,000 was accordingly made in 1881 for building such a vessel, which was, however, found insufficient to construct a steamer upon the approved plans of Mr. Charles W. Copeland, of New York. An additional sum having been allowed by Congress, making an aggregate of $145,000, proposals were invited, and Messrs. Pusey & Jones, of Wilmington, Del., being the lowest bidders, and their offer coming within the amount of the appropriation, work was commenced by that firm in March, 1882, and the trial trip was made December 30, 1882.

Some repairs and alterations made it necessary to send the steamer back to the ship-yard of the builders; and in April, 1883, the vessel made her first cruise on the business of the Commission.

Lieut. (now Lieutenant-Commander) Z. L. Tanner was ordered by the Navy Department to superintend the construction of the vessel. He made many important suggestions, and his practical experience was of the utmost benefit in the final determination of the plan of construction. The equipment of the vessel was entirely under his direction, and to his ingenuity is due a large number of the novel and important devices and improvements adopted.

SPENCER F. BAIRD,
*Commissioner.*

## B.—CONSTRUCTION OF THE ALBATROSS.

The United States Fish Commission steamer Albatross is an iron twin-screw vessel, built by the Pusey and Jones Company, of Wilmington, Del. She was launched August 19, 1882 (see frontispiece).

Her general dimensions are as follows:

Length over all, 234 feet.
Length at 12-foot water-line, 200 feet.
Breadth of beam, moulded, 27 feet 6 inches.
Depth from top of floor to top of deck beams, 16 feet 9 inches.
Sheer forward, 5 feet 2 inches.
Sheer aft, 3 feet.
Height of deck-house amidships, 7 feet 3 inches.
Displacement on 12-foot water-line, 1,074 tons.
Registered tonnage (net), 384 tons.

ANCHORS AND CHAINS.

One 1,900 pounds, 120 fathoms, $1\frac{5}{8}$-inch chain.
One 1,288 pounds, 120 fathoms, $1\frac{3}{16}$-inch chain.
One 1,030 pounds.
One 600 pounds, 250 fathoms. Bullivant's.
Elastic steel wire cable, $3\frac{1}{2}$ inches diameter.

She is rigged as a brigantine, carrying sail to a foretop-gallant sail. The spars are of white pine and spruce, and the following are their dimensions, viz:

SPARS.

| Name. | Feet. | Diameter in inches. |
|---|---|---|
| Mainmast above main deck | 56 | 20 |
| Maintop-mast above cap | 32 | $9\frac{1}{2}$ |
| Foremast above deck | 52 | 21 |
| Foretop-mast above cap | 30 | $10\frac{1}{2}$ |
| Fore yard, length | 50 | 11 |
| Foretop-sail yard, length | 40 | 9 |
| Foretop-gallant yard, length | $27\frac{1}{2}$ | $5\frac{1}{2}$ |
| Fore gaff | 27 | $7\frac{1}{4}$ |
| Main boom | 56 | $12\frac{1}{2}$ |
| Main gaff | 36 | $9\frac{1}{2}$ |
| Dredging boom | 36 | 10 |

Bowsprit, 13 inches square, 10 feet outboard to shoulder. Round-top on foremast. Cross-trees on mainmast.

SAILS.

| Name. | Canvas. | Square feet. |
|---|---|---|
| Mainsail | No. 2 | 1,488 |
| Gaff-topsail | No. 7 | 578 |
| Foresail (27-foot drop) | No. 2 | 1,156 |
| Fore trysail | No. 2 | 872 |
| Foretop-sail (24¾-foot hoist) | No. 4 | 934 |
| Foretop-gallant sail (14½-foot hoist) | No. 6 | 389 |
| Fore staysail | No. 2 | 660 |
| Jib | No. 5 | 918 |
| Flying jib | No. 6 | 526 |
| Total sail area | | 7,521 |

*Index to the detailed plans of the steamer Albatross.*

| No. | Articles. |
|---|---|
| | POOP-HOUSE AND FORECASTLE DECKS (PLATE II). |
| 1 | Forecastle. |
| 2 | Wooden bitts. |
| 3 | Fish-davit. |
| 4 | Capstan (connected with steam windlass). |
| 5 | 3-inch rifled howitzer. |
| 6 | Sigsbee deep-sea sounding machine. |
| 7 | Top of pilot-house. |
| 8 | Top of deck-house. |
| 9 | Bridge. |
| 10 | Skylight over chart-room and laboratory. |
| 11 | Whale-boat. |
| 12 | Seine-boat. |
| 13 | Standard compass. |
| 14 | Smoke-stack. |
| 15 | Ventilator to fire-room. |
| 16 | Skylight over drum-room and galley. |
| 17 | Steam-gig (Herreshoff). |
| 18 | Steam-cutter (Herreshoff). |
| 19 | Engine-room skylight. |
| 20 | Dinghy. |
| 21 | After compass. |
| 22 | Mainmast. |
| 23 | Main boom. |
| 24 | Bridge from top of poop to top of deck-house. |
| 25 | Poop-deck. |
| 26 | Cabin skylight. |
| 27 | Iron bitts. |
| 28 | Screw steering-gear. |
| | MAIN DECK. |
| 29 | Paint locker. |
| 30 | Chain cables. |
| 31 | Stopper for chain cables. |
| 32 | Compressor for steel-wire hawser. |
| 33 | Steam windlass. |
| 34 | Forecastle pump. |
| 35 | Lamp room. |
| 36 | Bath-room for steerage officers. |
| 37 | Water-closets. |
| 38 | Iron bitts. |
| 39 | Fore hatch. |
| 40 | Hoisting engine. |
| 41 | Dredging boom. |
| 42 | Dredge-rope rove for use. |
| 43 | Tanner sounding-machine. |
| 44 | Foremast. |
| 45 | Ship's bell. |
| 46 | Pilot-house. |
| 47 | Steam or hand steering gear. |
| 48 | Binnacle. |
| 49 | Signal-locker. |
| 50 | Deck-lights. |
| 51 | Chart-room. |
| 52 | Steam-heater. |
| 53 | Chart-table. |
| | MAIN DECK—continued. |
| 54 | Washstand. |
| 55 | Chronometer chest and lounge. |
| 56 | Berth. |
| 57 | Bunker-plate and coal-chute. |
| 58 | Upper laboratory. |
| 59 | Hatch to lower laboratory. |
| 60 | Work-table for naturalists. |
| 61 | Dispensary case. |
| 62 | Bookcase. |
| 63 | Sink. |
| 64 | Steam-heater. |
| 65 | Naturalists' state-rooms. |
| 66 | Berth. |
| 67 | Washstand. |
| 68 | Bureau. |
| 69 | Steam-drum. |
| 70 | Ash-chute. |
| 71 | Ventilators for fire-room. |
| 72 | Iron grating. |
| 73 | Galley. |
| 74 | Dresser. |
| 75 | Baird's distiller. |
| 76 | Upper engine-room. |
| 77 | Iron bitts. |
| 78 | Wardroom companion-way. |
| 79 | Wardroom skylight. |
| 80 | Commanding officer's cabin. |
| 81 | Cabin pantry. |
| 82 | Commanding officer's office. |
| 83 | State-room. |
| 84 | Berth. |
| 85 | Bureau. |
| 86 | Washstand. |
| 87 | Lounge. |
| 88 | Sideboard. |
| 89 | Table. |
| 90 | Steam-heater. |
| 91 | Bath-room. |
| 92 | Rudder-head. |
| 93 | Water-tank. |
| 94 | Silver-closet. |
| 95 | Linen-closet. |
| | BERTH DECK. |
| 96 | Yeoman's store-room. |
| 97 | Fore passage. |
| 98 | Dredging store-room. |
| 99 | Brig. |
| 100 | Chain-pipes leading to chain-lockers. |
| 101 | Collision bulkhead. |
| 102 | Hatch to ice-box. |
| 103 | Air-port. |
| 104 | Bag-rack. |
| 105 | Hatch to forehold. |
| 106 | Steam-heater. |
| 107 | Reeling-engine. |
| 108 | Governor pulley. |

*Index to the detailed plans of the steamer Albatross*—Continued.

| No. | Articles. | No. | Articles. |
|---|---|---|---|
| | BERTH DECK—continued. | | BERTH DECK—continued. |
| 109 | Steerage. | 145 | Ventilating-pipe. |
| 110 | Steerage-rooms. | 146 | Quadrant of rudder. |
| 111 | Berth. | | |
| 112 | Bureau. | | HOLDS. |
| 113 | Washstand. | 147 | Magazine. |
| 114 | Table. | 148 | Magazine-passage. |
| 115 | Open pantry. | 149 | Fore-peak. |
| 116 | Water tight iron bulkhead. | 150 | Ventilating-pipe with branches. |
| 117 | Lower laboratory. | 151 | Keelson. |
| 118 | Lockers for specimen bottles. | 152 | Keel. |
| 119 | Steam-heater. | 153 | Chain-lockers. |
| 120 | Sink. | 154 | Collision bulkhead. |
| 121 | Table. | 155 | Ice-box. |
| 122 | Photographer's dark-room. | 156 | Cold-room. |
| 123 | Coal-chutes. | 157 | Upper hold. |
| 124 | Air-ports. | 158 | Lower hold. |
| 125 | Coal-bunkers. | 159 | Steel wire hawser-reel. |
| 126 | Boilers. | 160 | Store-rooms. |
| 127 | Exhaust-fan for ventilating the vessel. | 161 | Fresh-water tanks. |
| 128 | Iron grating. | 162 | Water-tight iron bulkheads. |
| 129 | Main engines. | 163 | Laboratory store-room. |
| 130 | Dynamo-machine (Edison). | 164 | Ballast-room and sinkers. |
| 131 | Wardroom companion-ladder. | 165 | Water-tight iron bulkhead. |
| 132 | Wardroom pantry. | 167 | Boiler leg. |
| 133 | State-room. | 168 | Fire-room. |
| 134 | Bureau. | 169 | Lower engine-room. |
| 135 | Washstand. | 170 | Water-tight iron bulkhead. |
| 136 | Berth. | 171 | Wardroom store-room and shaft-alleys. |
| 137 | Wardroom. | 172 | Water-tight iron bulkhead. |
| 138 | Table. | 173 | Paymaster's store-room. |
| 139 | Steam-heater. | 174 | Equipment store-room. |
| 140 | Lounge. | 175 | Propeller-shaft. |
| 141 | Iron water-tight deck. | 176 | A-frames for propeller-shaft. |
| 142 | Bath-room. | 177 | Propeller. |
| 143 | Cabin store-room. | 178 | Rudder. |
| 144 | Quadrant-room. | 179 | Rudder-chains. |

## HULL.

The Albatross has a "bar" keel of the best hammered iron, 8 by $2\frac{1}{4}$ inches, scarfs 25 inches in length. There is one bilge keel on each side $10\frac{1}{2}$ feet from the center line, parallel thereto, of two angle-irons 4 by 6 by $\frac{5}{8}$ inches, with a $\frac{7}{8}$ inch iron plate 16 inches deep riveted between, 80 feet in length, tapering in depth to nothing at each end.

The stern-post is of the best hammered iron, $7\frac{1}{2}$ by $2\frac{1}{2}$ inches; and the stern is of the same material, $7\frac{1}{2}$ by $2\frac{1}{4}$ inches.

The frames are of angle-iron; those under the engines and boilers 4 by 3 by $\frac{7}{16}$ inches; forward and aft of these they are $3\frac{1}{2}$ by 3 by $\frac{7}{16}$ inches. Frames and floor spaces, 21-inch centers.

The floors are in one piece 18 inches deep and $\frac{8}{16}$ inch thick for three-fifths the vessel's length amidships, $\frac{7}{16}$ inch thick forward and aft. They are on every frame extending 20 inches above the top of the floor amidships, molding to the size of the frames.

One limber-hole is cut on each side of the center keelson. Enlarged floors with necessary angle-irons and strengthening plates are provided for the foundations of the engines and boilers.

### REVERSE BARS.

The reverse bars are of angle-iron, 3 by 3 by $\frac{5}{16}$ inches, one on every frame extending to the stringer plate and 12 inches above the upper turn of the bilge alternately. There are double reverse bars on all frames under the engines and boilers, and also on the line of all keelsons, hold stringers, and bulkheads. Joints are covered with angle-iron butt-straps, not less than 18 inches in length, with three rivets in each end.

### KEELSONS.

On top of the reverse bars there is a center keelson, 12 by $4\frac{1}{2}$ inches, beam iron, $\frac{5}{8}$ inch thick for three-fifths the length amidships, and $\frac{4}{8}$ inch thick forward and aft. On each side, 8 feet 8 inches from the center line, there is a keelson of two channel bars, $7\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{5}{16}$ inches, riveted back to back; and at the bilge on each side a keelson of two angle-irons, 6 by $3\frac{1}{2}$ by $\frac{7}{16}$ inches, riveted back to back. The bilge keelsons conform to the shape of the floors, and the side keelsons run parallel to the center line. There is also a cross keelson for the shaft stuffing-boxes.

At a distance of 4 feet 7 inches from the center line on each side there runs a keelson of beam iron, 8 by $4\frac{1}{2}$ by $\frac{5}{8}$ inches, riveted to the reverse bars.

### INTERCOSTAL KEELSONS.

Of these there is one of $\frac{6}{16}$ inch plate run on the center line, and one of $\frac{5}{16}$ inch plate under each side keelson, extending from keel to top of floors, well fitted between floors, and connected with them by an angle-iron $2\frac{1}{2}$ by $2\frac{1}{2}$ by $6\frac{6}{16}$ inches.

### DECK BEAMS.

Additional intercostal keelsons are placed under the engines.

For the main deck they are of T bulb-iron, on alternate frames, 7 by $3\frac{3}{4}$ by $\frac{7}{16}$ inches for three-fifths the vessel's length amidships; forward and aft they are 6 by $3\frac{3}{4}$ by $\frac{3}{8}$ inches, except at the capstan and riding-bitts forward, and at hatches, where they are 8 by $\frac{7}{16}$ inches.

### STRINGERS.

The main-deck stringers on each side are 38 inches wide by $\frac{4}{8}$ inch in thickness at midlength, reduced to 26 inches width at the end. Stringers are connected with sheer-strake by angle irons, $4\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{7}{16}$ inches, securely riveted to both the deck beams and sheer-strake. At the foremast and mainmast there is riveted to the deck beams a stringer plate 42 inches wide and $\frac{3}{8}$ inch thick, long enough to cover two beams forward and aft of the mast, securely riveted to the deck beams; through this plate a hole for the mast is cut. Similar tie-plates, covering three or four beams, are riveted in wake of bitts, windlass, capstan, hoisting engine, and reeling engine.

TIES OF MAIN DECK

are run fore and aft from end to end each side of center line, at such distance from it as to clear all hatches. They are of plate iron, 15 by ½ inches, securely riveted to deck beams and to stringer plates or breast hooks at the end; butts closely fitted and butt-straps double riveted. The width of these plates is gradually reduced to 9 inches forward and aft.

HOLD STRINGERS

are 24 inches wide by ½ inch thick at midlength, gradually reduced to 18 inches in width at the ends, and are run fore and aft on frames at a height of 10 feet above top of floors, connected to deck beams and reverse bars by angle-irons. Alongside of the engines and boilers, where there are no hold-beams, these angle-irons are doubled back to back and riveted through.

BEAMS OF BERTH DECK.

Forward and aft of engines and boilers, and between them, there are hold-beams of channel-iron, 6 by 2⅛ by ⅜ inches, spaced to every alternate frame, connected and riveted to hold stringers and frames, and kneed to frames the same as the main-deck beams.

IRON DECK-HOUSE.

The sides of the midship deck-house from the after end of the house to the bulkhead forward of the funnel, including these two bulkheads, are of plate iron, No. 5 wire gauge; stanchions, of 3 by 3 inches, angle-iron, spaced 24 inches from center to center. The beams are of angle-iron, 3 by 3 by $\frac{6}{16}$ inches, riveted to stanchion and to stringer and hatch-plate below.

PLATING.

The plating is run in fair lines, in and out strakes; all horizontal seams are lapped and all vertical seams, including bulwarks, are butted; spaces between outer strakes and frames are filled with liners of proper width and thickness.

The garboard-strake is $\frac{10}{16}$ inch thick for three-fifths its length amidships, gradually reduced to $\frac{8}{16}$ inch at the ends, and is 32 inches wide.

Sheer-strakes are fayed next to frames, $\frac{10}{16}$ inch thick for one-half the length amidships, gradually reduced to $\frac{8}{16}$ inch at the ends, and 38 inches wide. The upper edge extends 3½ inches above top of plank-sheer to connect bulwark plates.

Bulwark plates from sheer-strake to rail are $\frac{5}{16}$ inch thick, well riveted to sheer-strake and frames. The whole length of the upper edge of the bulwark plates, on the outside, is run an angle-iron, 3½ by 3½ by ⅜ inches, well riveted to bulwark plates, with proper lap-strips at the butts. To this angle-iron the rail is fastened.

The side-strake next below the sheer-strake is ⅝ inch thick at midship length, gradually reduced to $\frac{7}{16}$ inch forward and aft. The remaining side plating is $\frac{8}{16}$ inch thick, except the strakes around the shaft-pipe, which are of $\frac{7}{16}$ inch and are doubled, and the bilge-strake, which is $\frac{9}{16}$ inch thick for two-thirds the length amidships, gradually reduced forward and aft to $\frac{7}{16}$ inch.

The bottom between bilge and garboard strakes is $\frac{1}{2}$ inch thick for three-fifths the length amidships, then gradually reduced to $\frac{7}{16}$ inch forward and aft.

All butts of plating, keelsons, and stringers are double chain riveted, and the longitudinal seams lapped and single riveted.

All plates are long enough to cover at least six frame spaces, except short plates at the ends; and there are at least two strakes between butts falling between same frames. All edges and butts are planed.

Butts of garboard-strakes are at least two frame spaces apart, as also are those of sheer-strakes and deck stringers. All butts of plating are properly shifted.

### RAIL.

The rail is of white oak, $10\frac{1}{2}$ by $3\frac{1}{2}$ inches, let down to a fair bearing on the bulwark angle-iron, hook-scarfed and edge-bolted through scarfs.

## MAIN DECK (PLATE II).

### CABIN (PLATE III).

Of the structures which rise above the main rail the poop cabin extends 30 feet forward from the stern-post, is the whole width of the vessel, and 7 feet 3 inches high from deck to deck. It contains two state-rooms, an office, pantry, and bath-room, besides lockers, &c., and is supplied with light and air from eleven air-ports (five on each side and one in the stern), two windows, and three doors opening forward, and one skylight 6 feet by 5 feet overhead.

### DECK-HOUSE.

Forward of the cabin there is a clear space of 16 feet containing the wardroom skylight, and from which the gangway ladders lead over the side. Next comes the deck-house, 83 feet in length, 13 feet 6 inches in width, and 7 feet 3 inches in height. It is built of iron from the funnel aft, sheathed inside and out with wood, and fitted with iron storm-doors. From the funnel forward it is of wood, all fastenings, nails, screws, &c., being of galvanized iron. Beginning aft it is divided into the following apartments:

#### 1. ENTRANCE TO WARDROOM.

Six feet in length and the whole width of the house. One window on each side furnishes light and air, and two doors opening aft give access to the stairway leading to the wardroom below.

2. UPPER ENGINE-ROOM.

This is 10 feet 6 inches in length and the full width of the house. It has one door and one window on each side, a skylight 5 by 5 feet overhead, and a stairway leading to the engine-room below. The inside wooden doors of this room, as well as those of the kitchen and drum-room next forward, are fitted in halves, upper and lower, so that in bad weather the lower halves may be closed to keep out the water, while the upper are open for ventilation.

3. KITCHEN.

In length 8 feet, the whole width of the house, with one door and one window on each side, and a skylight 4 by 5 feet overhead. It is furnished with a table, fuel-boxes, lockers, dish-racks, and a lead-lined sink fitted with a pump, drawing water from the tanks in the hold.

4. DRUM-ROOM.

This is also the entrance to the fire-room, is 13 feet 6 inches in length, and the width of the house. It is fitted with doors and windows like those of the engine-room, has a skylight 4½ by 5 feet overhead, and communicates by a stair-way with the fire-room below. As its name implies, this room contains the steam-drum, which is so designed that the funnel passes up through it, thus utilizing the heat of the escaping products of combustion to superheat the steam.

5. STATE-ROOMS.

Forward of the drum-room the wooden part of the deck-house commences with four state-rooms, two on each side, for the members of the scientific corps. Each room is 6 feet 6 inches in length, half the width of the house, and has a door and window with blind shutters, a berth 30 inches in width, a writing-desk, washstand, drawers, lockers, &c. Additional ventilation is secured by lattice-work openings, outboard, and also between the rooms.

6. UPPER LABORATORY (PLATE IV).

This is 14 feet in length and the whole width of the house. It is supplied with light and air by two windows and a door on each side and a skylight 6 by 3 feet overhead. In the center is a very conveniently arranged work-table, square in shape, around which four persons can seat themselves, each having at his right hand a tier of drawers which form the legs of the table. There are also two hinged side-tables, a sink with alcohol and water tanks attached, wall cases for books and apparatus, and in one corner a medical dispensary.

7. CHART-ROOM (PLATE V).

Immediately forward of the laboratory is the chart-room, 8 feet 6 inches in length, the full width of the house. It has one door and window on each side and a skylight 3 by 3 feet above, drawers for charts, &c., a berth, washstand, lockers, book-shelves, and a transom sofa, which is also used as a chronometer chest. A door in the forward bulkhead gives access to the pilot-house.

### 8. PILOT-HOUSE (PLATE VI).

This is the next and last division of the deck-house. It is 8 feet in length, the full width of the house, and has one door on each side. The front is elliptical, with glass windows, balanced by weights, and protected in bad weather by strong wooden shutters hung in the same manner as the windows and fitted with 8-inch bull's-eyes in the center.

The pilot-house is raised about 3 feet above the main-deck and projects the same distance above the top of the house, with which it communicates by two windows. Suitable bell-pulls and speaking-tubes furnish the necessary means of communication with the engine-room, and instead of the ordinary ship's wheel a Higginson's steam quartermaster is used.

### TOP-GALLANT FORECASTLE.

The top-gallant forecastle is 44 feet in length and 6 feet 3 inches in height between decks. On it are stowed the anchors, which are handled by a single fish-davit amidships and a capstan which can be worked by hand or by the steam-windlass (Plate XIV) directly underneath. On the port side aft is the Sigsbee deep-sea sounding machine, and just abaft the capstan is a 3-inch breech-loading rifle mounted on a boat carriage.

Underneath the forecastle are water-closets for officers and men, bath-room for men, lamp-room, paint-locker, steam-windlass, and carpenter's bench. Two scuttles give access, one to the store-rooms, magazine, &c., forward of the collision bulkhead, and the other to the berth deck.

### BERTH DECK (PLATE VII).

This includes the space 40 feet aft from the collision bulkhead, and is 7 feet 10 inches between decks. It is supplied with light and air by the fore hatch, fore scuttle, and by eight 8-inch air-ports, four on each side. Racks for stowing bags and hammocks are fitted along the sides; the space abaft the fore hatch is occupied by the reeling-engine, and near the forward bulkhead are two scuttles opening into the ice-boxes.

### ICE-BOXES.

These occupy the space 7 feet aft from the collision bulkhead the whole width of the ship. A strong fore and aft bulkhead amidships divides this space into two compartments; the sides and ends are fitted double with an intervening air-space of four inches which is filled with proper non-conducting material. The inside is lined throughout with galvanized iron, and, at the after outboard corners, lead pipes with suitable traps drain the water into the hold. The capacity of the ice-boxes is about 3 tons each, 6 tons in all.

### COLD-ROOM.

The after part of the space in the ice-boxes for two feet is partitioned off by an athwartship bulkhead to form a cold-room or refrigerator, to which access is gained by doors opening into the fore hold. Six-inch openings at the top and bottom of the cold-room communicate with the ice-lockers, and a circulation of air is induced as the warmer air of the former rising passes above into the latter, becomes cooled by the ice, falls and re-enters the cold-room by the lower opening, to become warmer again and rise as before.

Rack-shelves to hold whatever is desired are fitted against the bulkhead.

### STORE-ROOMS, MAGAZINE, BRIG, ETC.

Forward of the berth deck, and separated from it by the collision bulkhead, is a fore and aft passage-way to which access is gained by a scuttle and stairs underneath the top-gallant forecastle.

This passage opens forward into the yeoman's store-room, to the right into the brig, lighted and ventilated by an 8-inch air-port, and to the left into the dredging store-room, similarly furnished with light and air.

Through this passage, also, the chain pipes pass down and aft, taking the chain from the windlass to the lockers below, and from the forward end of the passage a scuttle and stairs lead down to the magazine passage and magazine, and to the fore peak below them.

### FORE HOLD.

Below the berth deck the space from the cold-room aft is taken up by the fore hold, steerage store-room, engineer's store-room, bread-room, sail-room, and water-tanks. Access is gained by a hatch directly under the fore hatch.

### STEERAGE (PLATE VIII).

Opening from the after end of the berth deck is the steerage, containing four double-berth state-rooms, 6 feet 6 inches in length, two on each side, and a mess-room 13 feet in length between. It is lighted and ventilated by an 8-inch air-port in each room, a 12-inch ventilator cut through the deck just abaft the foremast, and the door opening from the berth deck. Each room has an upper and lower berth 30 inches wide, a bureau, washstand, toilet racks, drawers, shelves, &c. On the forward bulkhead of the mess-room is an open pantry.

### LOWER LABORATORY (PLATES IX AND X).

Abaft the steerage, but separated from it by a water-tight iron bulkhead, is the lower laboratory immediately below the upper laboratory, through which only can it be entered. This room extends quite across the ship, is 20 feet fore and aft, 7 feet 10 inches between decks, and is furnished with light and air by six 8-inch air-ports, two 12-inch deck-lights, and the hatch leading above.

Ample and convenient storage cases and lockers are provided for alcohol tanks, jars, and specimens in bottles of all sizes; long work-tables are fitted along each side; in one after corner is a lead-lined sink with running water; in the other a photographic dark-room; and along the bulkhead between the two is the chemical laboratory. Between the beams overhead are slings and hooks for stowing dip-nets, scoop-nets, harpoons, spears, lances, and other fishing appliances.

A hatch and stairs lead to the store-room below, a closed iron box capable of being isolated from the rest of the ship and filled with steam at short notice in case of fire. Here are stowed alcohol in tanks, nets, sieves, &c., for which suitables lockers have been provided.

Below this store-room is a small space next the skin of the ship where the sinkers used in sounding are stored.

### WARDROOM (PLATE XI).

The whole space from the laboratories aft to the wardroom is occupied by the engines and boilers, bunkers, &c., and will be described in connection with them.

The wardroom is 38 feet in length, the full width of the ship, and 7 feet 10 inches in height from deck to deck. It is lighted and ventilated by seven 8-inch air-ports on each side, a skylight 6 by 5 feet overhead, and the stairway leading to the deck above.

The space on either side of the stairway is occupied by the pantry on one side, and the chief engineer's room on the other; the latter communicating by a door with the engine-room immediately forward. Abaft these rooms a space 13 feet in length and the whole width of the ship is reserved for an athwartship extension-table, seating, at most, twelve persons. Along the sides of this space are fitted cushioned sofa transoms.

There are four rooms on each side, the starboard after one being furnised as a bath-room, the others containing a berth, bureau, washstand, drawers, lockers, &c. Two scuttles in the wardroom floor give access to store-rooms below; the paymaster's store-room forward, an iron water-tight compartment, and the equipment and navigator's store-room.

A scuttle in the pantry floor leads to the wardroom store-room, also a water-tight compartment. A door opens into a locker under the stairs.

The vessel is lighted throughout by electricity; and artificial ventilation is produced by means of an exhaust fan and conduit pipes to every compartment below the main deck.

## BOATS.

The Albatross has five boats, as follows:

### HERRESHOFF STEAM CUTTER.

The Herreshoff steam cutter is 26 feet 6 inches in length, 7 feet beam, and 3 feet 10 inches in depth, with double coil boiler and compound engine, cylinders 6 inches and 3½ inches in diameter and 7-inch stroke, developing 16 horse-power with 100 pounds of steam. It has a keel condenser, and carries an average of 26 inches vacuum. The bunkers hold 1,100 pounds of coal, and the fresh-water tank, which is placed directly underneath the boiler, has a capacity of 42 gallons, sufficient for three days' steaming.

The hull and engine are of the best material and workmanship. Water-tight compartments at bow and stern have sufficient buoyancy to prevent sinking in case the boat is filled with water. Twelve persons can be seated comfortably in the stern sheets.

In addition to steam power, the boat is provided with sliding gunter masts and sails, schooner rigged, and makes good speed under sail alone. It is cutter build, with square stern, weighs 5,500 pounds, and has a speed of 8 knots.

### STEAM GIG.

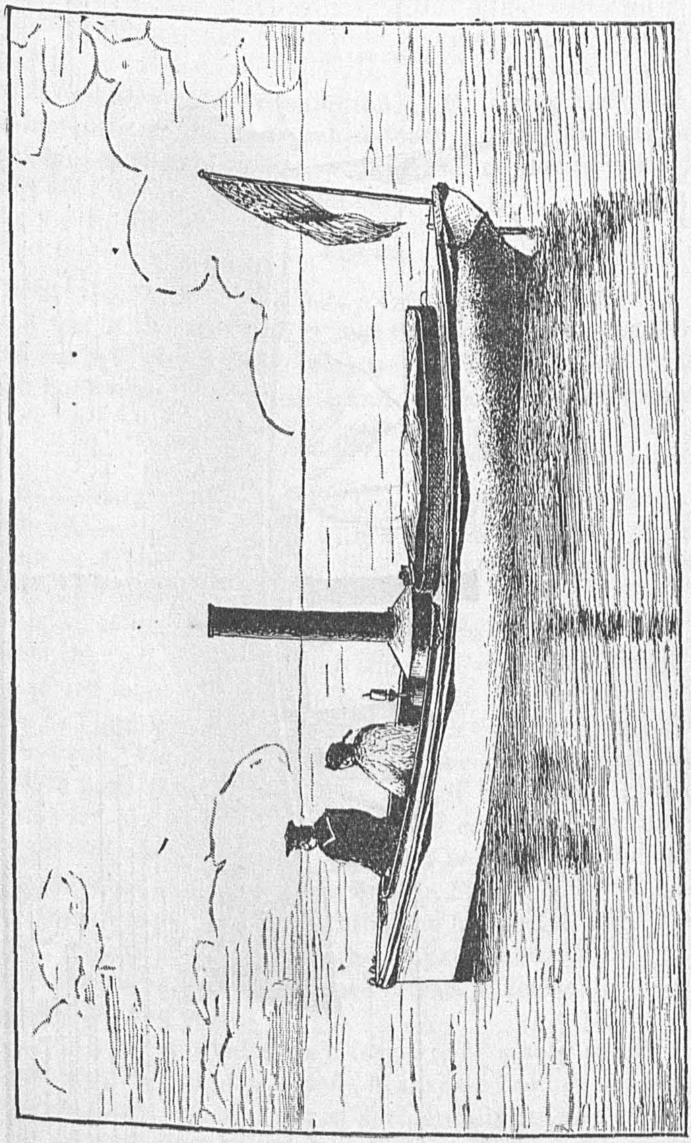
Built also by the Herreshoff Manufacturing Company. Twenty-five feet in length, 5 feet 2 inches beam, 3 feet 3½ inches depth. A single coil boiler, compound engine, 4¼ inches and 2½ inches diameter of cylinders, and 5-inch stroke, developing 7½ horse-power with 100 pounds of steam.

It has the general form of a whale-boat, is double planked, spruce inside running diagonally, and mahogany outside running fore and aft. Both layers are bound together by brass screws at short intervals, making the structure unusually strong and light. There are water-tight compartments at bow and stern of sufficient capacity to float boat and crew in case it is filled with water. The total weight is 2,650 pounds.

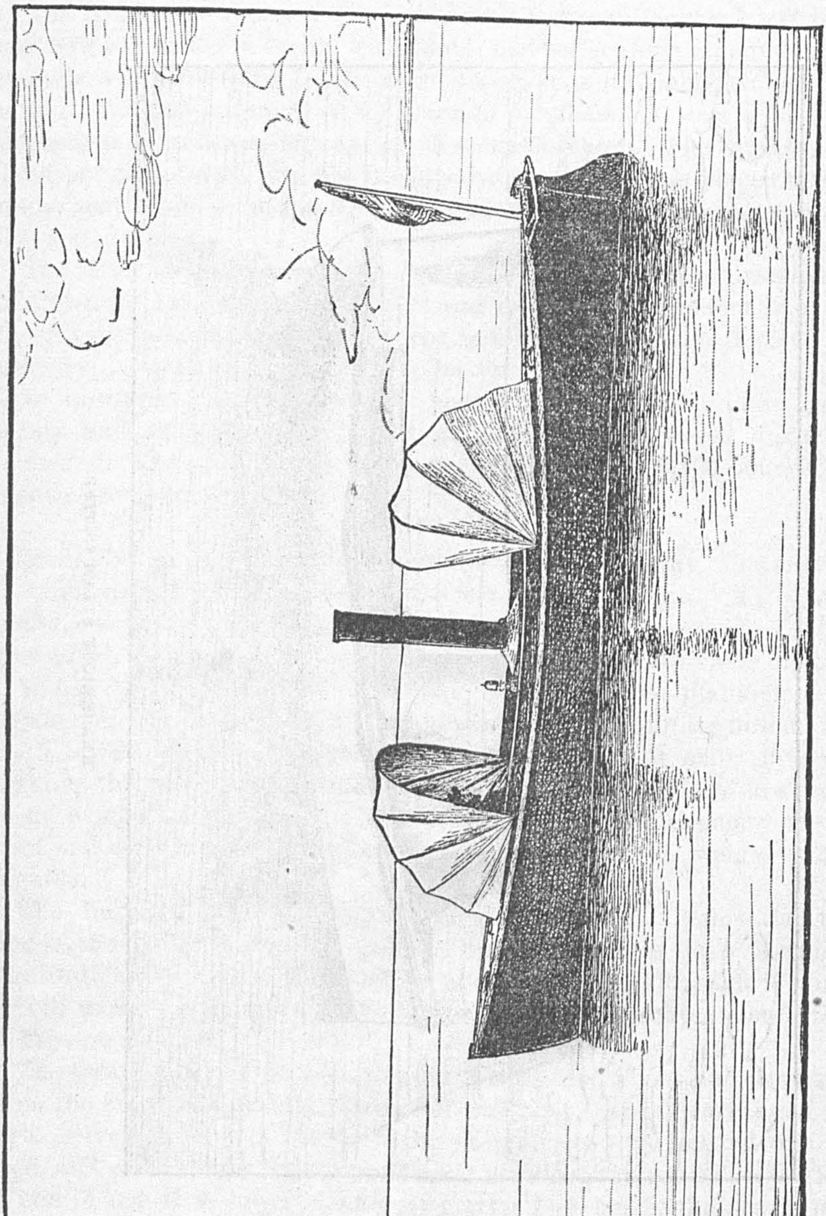
The bunkers hold 450 pounds of coal, and the fresh-water tank under the boiler carries 15 gallons, enough for two days' steaming. The ordinary speed of the boat is about 7 knots, although it can be driven to 8 for a short time. Seven persons can be seated comfortably in the stern sheets.

The location of the propeller under the bottom, about half the length from the stern, is a peculiar feature of this boat. It is so arranged that by a universal joint in the shaft the propeller can be hoisted and lowered, and when in the former position it does not project below the keel. When in use it is lowered, and no matter how heavy the sea, it is always submerged; thus racing is entirely avoided. The advantages of this system are not particularly apparent in smooth water, but her performance in a sea-way is remarkable. The gig is provided with a sliding gunter mast and sail, and makes good time under sail alone.

Steam can be raised in both cutter and gig in from three to five minutes.



HERRESHOFF STEAM CUTTER.



HERRESHOFF STEAM GIG.

### SEINE-BOAT.

Built by Higgins & Gifford, Gloucester, Mass. Square stern, 28 feet in length, 7 feet 3 inches beam, 2 feet 6 inches in depth, and weighs 1,250 pounds. It pulls eight oars, and is schooner rigged, with sliding gunter masts. This boat is very light, and is designed especially for mackerel seining.

### WHALE-BOAT.

Built at the navy-yard, Washington, D. C. Twenty-six feet in length, 5 feet 6 inches beam, 2 feet 3 inches depth. Pulls six oars, and weighs 780 pounds. Schooner rigged, with sliding gunter masts. This is an excellent boat, built with unusual care.

### DINGHY.

Built at the Washington navy-yard. Eighteen feet 2 inches in length, 5 feet 6 inches beam, 2 feet 1 inch in depth, and pulls three pairs of sculls; weight, 550 pounds; rig, split lug-sail. The dinghy was also built with unusual care, and has done excellent service.

### BOAT-DETACHING APPARATUS (PLATE XII).

The whale-boat and dinghy are kept hanging at the davits ready for emergencies, and are provided with a unique detaching apparatus, the invention of Midshipman (now Lieutenant) William Maxwell Wood, U. S. N.

The object of a detaching apparatus is to disengage both ends of a boat from the tackles at the same time, the operation being under the control of one man. To accomplish this Mr. Wood has provided a pair of links, L, Plate XII, Figs. 3 and 4, which oscillate freely about a center of motion. The form of this link is such as to permit the spherical toggle T to pass between its sides; now, if the link is pulled down by the chains *rr'*, and the ends of the chains connected by the slip hook *h*, the toggle will slide up in the link and be locked in the narrow space between its sides, as shown in full lines in Figs. 1, 3, and 4. If, however, the slip hook *h* is tripped by pulling the lanyard *a*, Figs. 1 and 2, both chains *rr'* will be slacked, and the links L released to fly up into the positions shown by the dotted lines in Fig. 1, releasing the toggles and thus detaching the boat.

The locks *g* are provided as a measure of safety to prevent the toggles from slipping out of the links in case one end of the boat is hoisted faster than the other, or a fall is accidentally let go; in fact they prevent either end from being detached until the links are released by pulling the lanyard *a*.

This simple apparatus has been in constant use, at sea and in port, under all conditions of wind and weather, and has answered its purpose admirably without a single failure or accident.

### THE RUDDER AND STEERING GEAR.

The Albatross was designed to perform much of her work stern to wind and sea, making it necessary to give unusual attention to the rudder and its appointments. The several parts are much heavier and stronger than usual in vessels of her size, and the appliances for controlling its movements are more powerful than will be found in steamers of twice her tonnage.

### RUDDER ATTACHMENTS.

There is a yoke, or quadrant, on the rudder-stock a little below the spar-deck beams, carrying the chains to which the steel wire tiller-ropes are connected; an iron tiller on the poop deck, and a yoke for a powerful screw steering-gear on the upper extremity of the stock, also on the poop deck. Projecting from the rudder is a short tiller to which are attached the rudder chains ordinarily carried by steamers.

### HIGGINSON & CO.'S STEAM QUARTERMASTER.

This admirable steering gear is located in the pilot-house (Plate VI), and is operated either by hand or steam, the change from one to the other being effected in a few seconds without interfering with the control of the helm. The same wheel is used in either case, and a spoke has the same effect on the rudder in both cases. The fact that very little exertion is required when steam is used is the only indication the helmsman has that he is not steering by hand.

A chain passes over the chain-wheel, which is fitted to take the links, to prevent slipping, and the terminals of the chain are attached to the steel wire tiller-ropes which run aft under the spar-deck beams and connect with the chains on the yoke.

This apparatus is very compact, and has performed its work in a thoroughly satisfactory manner, without accident or cost for repairs. It was furnished by the Pusey and Jones Company, Wilmington, Del.

### AUXILIARY STEERING-GEAR (PLATE XIII).

This powerful screw gear is used when it is necessary to put the vessel stern to a heavy sea, as in sounding and dredging, and is designed to hold the rudder rigidly, thus relieving the ordinary steering-gear from unusual strains. Fig. 1 is a longitudinal elevation, and Fig. 2 a plan view of the apparatus. The yoke *c* is keyed to the upper end of the rudder-stock *f*, and the arms *d*, which have a screw-thread at one extremity working on the right and left hand screw-shaft *i*, and a hole in the opposite extremity for the reception of the pins *a*, are the means of connection between the yoke *c*, the screw-shaft *i*, and the steering-wheel *l*.

The arms *d* are held in a horizontal position by the guide-rod *e*, which is supported by the adjustable bearings *k*, which also carry the screw-shaft.

To disconnect the gear, remove the pins *a* from the arms *d* and the slots *b*, when the rudder will move freely.

### SPARE TILLER.

Fig. 1 shows the spare tiller *g* keyed to the rudder-stock *f*. The eyebolts *h* for the relieving tackles slide along the whole length of the tiller, for convenience in hooking in case of accident to the steering-gear.

### RUDDER-CHAINS.

The rudder-chains are shackled to the short tiller projecting from the rudder, seized to an eyebolt in the stern, and carried along the quarters in the usual manner.

### THE ALBATROSS DREDGING.

Plate I represents the Albatross in the operation of dredging at sea. The vessel is backing with her stern to the wind, as indicated by the forward trend of the dredge-rope, flags, &c. In prosecuting this work it is necessary to maneuver in such a manner that the drift will be from the dredge-rope, thus preventing it from drawing under the vessel's bottom. If steel wire rope is used for this purpose it will also be necessary to keep it under tension, for if allowed to slacken, even for a moment, it will kink, thus reducing its tensile strength about 50 per cent. Before putting the trawl or dredge over, then, we must decide in what direction it can be dragged to the best advantage. Working in a uniform depth of water this would naturally be toward the position in which the next haul was to be made; but when operating on a steep slope, such as will be encountered off our coast, an uphill drag is the only one offering a fair probability of success. If the wind is blowing in the direction of the down slope, we would turn the vessel's stern to it and back the engine, but if the breeze should be from the opposite direction this could not be done. We would then go ahead, keeping the wind more or less on the starboard side, from which the dredge is lowered. The range of direction is, of course, much greater under the latter conditions, as the vessel is under control of the helm.

Ocean currents serve to complicate in no small degree the work of deep-sea exploration. A surface set is quickly detected and guarded against or utilized in prosecuting the work; but when the rope is suddenly swept under the bottom by a submarine current, with perhaps thousands of fathoms of line out, it requires a great deal of tact and patience to clear it from the ship and land the trawl on the bottom without capsizing it or kinking the rope.

The Albatross is represented at work under the most favorable conditions, the trawl lowered from the starboard side, and the starboard engine backing slowly. This has the tendency to keep the wind a little on the starboard quarter, thus drifting the vessel away from the rope, which is seen to trend somewhat off the bow.

The greatest advantage to be derived from backing while dredging, is that in case the apparatus fouls on the bottom a stern-board can be checked and the strain on the dredge-rope relieved more quickly than when steaming ahead.

## C.—STEAM MACHINERY AND MECHANICAL APPLIANCES.

By Passed Assistant Engineer G. W. BAIRD, U. S. N.

The designs and specifications of the motive engines, as well as the hull, were drawn by the distinguished engineer, Mr. C. W. Copeland, of New York, and they were built by the Pusey and Jones Company, of Wilmington, Del. There is a two-cylinder compound engine for each of the two propellers; the engines are independent, and are provided with steam reversing gears; they are upright but not vertical, the cylinders inclining towards each other (Plate XV) to give more room on the working-platform. There is one condenser, common to both engines, which is mounted on a bed-plate, and which forms the framing and cross-head guides for the engines; the single bed-plate supports the pillow-blocks of both engines. The condenser is of the type known as "surface condenser," and is arranged in three nests of horizontal tubes, the water passing successively through each nest, and the steam is condensed on the outside of the tubes.

There are two plunger air-pumps, placed horizontally, forward of the main engines, one plunger being worked from a concentric on the forward end of each crank-shaft. Both pumps are in one casting. The feed-pumps are worked from rods extending from the air-pump plungers.

The valves of the high-pressure cylinders are locomotive slides, over which gridiron cut-off valves are placed, while the low-pressure valves are double ported and are without cut-offs. All these valves are actuated by eccentrics and Stephenson links, in the usual manner.

The engines are provided with a system of valves by which they may be converted from compound to single expansion or simple engines.

There are two outboard deliveries, one for the circulating water and one for the air-pump or fresh water.

The circulating pump is a Davidson light-service pump, No. 26. (Plate XVII.)

There is a flexible coupling connecting each crank-shaft to its line-shaft, and the thrust-bearings are on the line-shafts.

The screw-propellers are right and left, with four blades each, the blades curving radially and axially, according to the style of the designer.

The shaft-brackets are of wrought iron; one is placed near the hub of the screw and the other half way between this and the hull. The journals of the bracket are lined with bronze and lignum-vitæ, and the shaft in these journals is covered by a bronze jacket in the usual way.

The stern pipes are of cast iron, the after floors bored to receive them, and the frames bent round them. The stern bearings are also of cast iron, with flanges fitting the hull; they are 3 feet 4 inches in length, lined with lignum-vitæ staves, and are recessed to receive the stern pipes; the usual stuffing-boxes are provided.

The sea-valves are of bronze with bronze stems, seats, and glands, with cast-iron chambers, and have outside threads.

The principal dimensions of the engines are as follow:

| | | |
|---|---|---|
| Number of cylinders to each engine | | 2 |
| Diameter of the high-pressure cylinders | inches.. | 18 |
| Diameter of the high-pressure piston-rods | do.... | 3 |
| Net area of the high-pressure cylinders | do.... | 250.93 |
| Clearance of the high-pressure piston | do.... | .5 |
| Length of the steam-port of the high-pressure cylinder | do.... | 13.5 |
| Breadth of the steam-port of the high-pressure cylinder | do.... | 1.75 |
| Area of the steam-port of the high-pressure cylinder | do.... | 23.625 |
| Length of the exhaust-port of the high-pressure cylinder | do.... | 13.5 |
| Breadth of the exhaust-port of the high-pressure cylinder | do.... | 3.5 |
| Area of the exhaust-port of the high-pressure cylinder | do.... | 47.25 |
| Number of ports in the cut-off valve | | 3 |
| Length of the ports in the cut-off valve | inches.. | 13.5 |
| Breadth of the ports in the cut-off valve | do.... | .875 |
| Aggregate area of the cut-off valve ports | square inches.. | 35.4375 |
| Diameter of the low-pressure cylinders | inches.. | 34 |
| Diameter of the low-pressure piston-rod | do.... | 3.5 |
| Net area of each low-pressure cylinder | do.... | 903.11 |
| Stroke of all the pistons | do.... | 30 |
| Clearance of the low-pressure pistons | do.... | .5 |
| Length of the steam-ports of the low-pressure cylinders | do.... | 20 |
| Breadth of the two steam-ports of the low-pressure cylinders | do.... | 3 |
| Area of the double steam-port of the low-pressure cylinders | do.... | 60 |
| Ratio of the volume of displacement of low-pressure piston to that of the high-pressure piston, per stroke | | 3.599 |
| Length of pistons, on line of axis, at the circumference | inches.. | 6 |
| Thickness of metal in all the cylinders | do.... | 1 |
| Length of packing-rings on the high-pressure pistons | do.... | 4.5 |
| Length of packing-rings on the low-pressure pistons | do.... | 3.75 |
| Diameter of each (single-acting) air-pump plunger | do.... | 16 |
| Stroke of air-pump plungers | do.... | 13.5 |
| Displacement of each air-pump plunger per stroke | cubic inches.. | 2,814.84 |
| Diameter of each feed-pump plunger | inches.. | 4.5 |
| Stroke of each feed-pump plunger | do.... | 13.5 |
| Displacement of each feed-pump plunger per stroke | cubic inches.. | 214.7 |
| Diameter of the steam cylinder of the circulating-pump | inches.. | 14 |
| Diameter of the steam piston-rod of the circulating-pump | do.... | 2 |
| Net area of the steam piston of the circulating-pump | cubic inches.. | 152.3 |
| Diameter of the water piston of the circulating-pump | inches.. | 16 |
| Diameter of the water piston-rod of the circulating-pump | do.... | 2 |
| Net area of the water piston of the circulating-pump | square inches.. | 199.49 |
| Stroke of the pistons of the circulating-pump | inches.. | 14 |
| Ratio of the area of steam piston to that of the water piston | | 1:1.308 |
| Number of brass tubes in the condenser | | 2,394 |
| Outside diameter of the condenser-tubes | inch.. | .625 |
| Exposed length of the condenser-tubes | inches.. | 66 |
| Condensing surface of the tubes | square feet.. | 2,142 |
| Number of crank-shaft journals to each engine | | 3 |
| Diameter of the forward journal | inches.. | 7 |
| Diameter of the middle journal | do.... | 8.5 |
| Diameter of the after journal | do.... | 8.5 |
| Length of the forward journal | do.... | 8.5 |
| Length of the middle journal | do.... | 16 |
| Length of the after journal | do.... | 13.5 |

| | Ft. | In. |
|---|---|---|
| Diameter of the high-pressure crank-pins | | 5¾ |
| Length of the high-pressure crank-pins | | 7½ |
| Diameter of the low-pressure crank-pins | | 7¼ |
| Length of the low-pressure crank-pins | | 9 |
| Diameter of the high-pressure cross-head pins | | 3 |
| Length of the high-pressure cross-head pins | | 4½ |
| Diameter of the low-pressure cross-head pins | | 3½ |
| Length of the low-pressure cross-head pins | | 5 |
| Diameter of the line-shafts (wrought iron) | | 8 |
| Length in the vessel occupied by the engines | 9 | 4 |
| Breadth in the vessel occupied by the engines | 15 | 6 |
| Height of the engines above center line of shafts | 12 | 6 |

The following is a list of the weights of the main engines:

| | Pounds. |
|---|---|
| **CAST IRON.** | |
| 2 condenser covers | 2,738 |
| 1 condenser | 12,010 |
| 4 cylinders | 14,820 |
| 1 bed-plate | 15,412 |
| 2 "pinch-wheels" (couplings) | 3,210 |
| 2 "crank-wheels" (couplings) | 3,270 |
| 4 slide-valves | 1,568 |
| 1 double air-pump and bed | 2,750 |
| 4 steam-chests | 2,520 |
| 4 steam-chest covers | 2,084 |
| 10 eccentrics | 1,188 |
| 4 pistons | 1,586 |
| 4 line-shaft couplings | 2,130 |
| 12 thrust-collars | 2,260 |
| 4 cylinder-heads | 2,509 |
| 2 stern-bearings | 4,897 |
| 2 thrust-bearings | 2,655 |
| 2 throttle-valve chambers | 448 |
| 2 screw-propellers | 8,076 |
| 2 stern-pipes | 1,376 |
| **BRONZE CASTINGS.** | |
| 4 tube sheets (condenser) | 4,098 |
| 2 stern-bushings | 257 |
| 2 shaft-bushings | 663 |
| 2 air-pump plungers | 1,030 |
| 6 link-blocks | 101 |
| **PHOSPHOR-BRONZE CASTINGS.** | |
| 6 lower boxes for crank-shaft | 836 |
| **IRON FORGINGS.** | |
| 2 shafts | 19,043 |
| 4 hangers | 5,480 |
| 4 connecting-rods | 2,266 |
| 4 straps, gibs, and keys | 654 |
| 4 double-cranks | 7,680 |
| 4 crank-pins | 990 |
| 4 coupling-pins | 764 |
| 6 valve-stems | 590 |
| 5 links | 786 |

| | Pounds. |
|---|---|
| Air-pump connections | 1,071 |
| Levers and arms | 731 |
| Guides | 843 |
| 12 eccentric rods | 1,202 |
| 4 "cylinder braces" (struts) | 1,104 |
| Link connections | 295 |
| STEEL FORGINGS. | |
| 4 piston-rods | 1,877 |
| BRASS TUBES. | |
| 2,400 drawn-brass condenser-tubes | 4,972 |
| COPPER PIPE. | |
| Steam, feed, and blow pipes | 3,458 |
| REVERSING GEAR. | |
| 2 steam cylinders, valves, guides, rods, arms, &c | 2,276 |
| CIRCULATING-PUMP. | |
| 1 Davidson light-service pump, No. 26 | 2,600 |
| ADDITIONAL WEIGHTS. | |
| Floor-plates, flanges, cast-iron exhaust-pipes, bolts, nuts, &c., used in fitting up | 48,017 |
| No. 5 Davidson pump | 1,100 |
| No. 5 Davidson light-service pump | 900 |
| Total weight of motive engines | 203,192 |

## BOILERS.

There are two return-flue boilers (see Plate XVI) having a half steam drum and half chimney each; they are placed fore and aft in the hold of the vessel, side by side, with the fire-room athwartships and at the after end of the boilers. The axis of the chimney cuts the center plane of the ship, and is between the boilers. The two half chimneys are divided by a ⅜ inch wrought-iron plate, riveted to both, so that the draught of one boiler is not affected by the other. Each boiler has its stop-valves, feed and blow valves, checks, whistle-valves, steam and water gauges, and damper complete. The boilers are covered with hair felting to retard radiation. The crown-sheets and flue sheets are of steel; all other portions of the boilers are of wrought iron. The flues are seamless, drawn, the flue sheets being flanged to receive them. The boilers are set in cast-iron chairs, and are provided with cast-iron ash-pans.

The principal dimensions of the boilers are as follow:

| | | |
|---|---|---|
| Number of boilers | | 2 |
| Diameter of waist | feet | 8¼ |
| Length of boilers | do | 21¼ |
| Number of furnaces to each boiler | | 2 |
| Width of furnaces | inches | 43½ |
| Length of grate bars | feet | 6½ |
| Aggregate area of grate surface in both boilers | do | 95½ |
| Number of 15-inch flues in each boiler | | 2 |
| Number of 12-inch flues in each boiler | | 2 |
| Number of 11-inch flues in each boiler | | 6 |
| Number of 9-inch flues in each boiler | | 16 |

| | |
|---|---|
| Length of the 15, 12, and 11-inch flues ........ feet.. | 10 |
| Length of the 9-inch flues ........ do.. | 16¼ |
| Diameter of the complete chimney ........ inches.. | 52 |
| Height of the chimney above the grates ........ feet.. | 46 |
| Aggregate area, for draught, over the bridge-wall in both boilers, in square feet ........ | 18.16 |
| Aggregate area through the lower flues of both boilers ........ square feet.. | 13.962 |
| Aggregate area through the back connections for draught in both boilers ........ square feet.. | 26.791 |
| Aggregate area through the upper flues of both boilers ........ do.... | 14.157 |
| Cross-area of smoke-pipe ........ do.... | 14.700 |
| Aggregate heating surface in the furnaces of both boilers ........ do.... | 224 |
| Aggregate heating surface in the lower flues of both boilers ........ do.... | 440.836 |
| Aggregate heating surface in the upper flues of both boilers ........ do.... | 1,281.614 |
| Aggregate heating surface in the combustion chambers of both boilers ........ square feet.. | 116 |
| Aggregate heating surface in the back connections of both boilers, square feet ........ | 304 |
| Aggregate heating surface in the front connections of both boilers, square feet ........ | 112 |
| Total water-heating surface in both boilers ........ square feet.. | 2,478.5 |
| Total superheating surface in both boilers ........ do.... | 204 |
| Ratio of grate to cross-area over bridge-walls ........ | 5.429:1 |
| Ratio of grate to cross-area through lower flues ........ | 6.828:1 |
| Ratio of grate to cross-area through back connection ........ | 3.558:1 |
| Ratio of grate to cross-area through upper flues ........ | 6.743:1 |
| Ratio of grate to cross-area through chimney ........ | 6.485:1 |
| Ratio of water-heating surface to grate-surface ........ | 26:1 |
| Height of the center of the steam-pipe opening above the normal level of the water in the boilers ........ feet.. | 11.5 |

The weights in the boilers are distributed as follow:

| | Pounds. |
|---|---|
| Wrought-iron and steel in the shells of both boilers ........ | 62,971 |
| The flues in both boilers ........ | 18,425 |
| Braces in both boilers ........ | 10,420 |
| Rivets, socket-bolts, manhole plates, &c ........ | 14,618 |
| Safety-valves, stops, checks, ash-pans, and floor-plates ........ | 14,394 |
| Smoke-pipe, cape, and casing ........ | 3,599 |
| Weight of water in both boilers ........ | 69,197 |

There are two screw-propellers, one right and one left, of cast iron, the blades curving backward, the edges curved, the forward or leading corner being curved to a radius of 17 inches, and the trailing corners curved to a radius of 16 inches. The length of the blades, on the line of the axis of the screws, is from 23 to 26 inches. The principal dimensions are as follow:

| | |
|---|---|
| Diameter ........ feet.. | 9 |
| Greatest diameter of the hub ........ inches.. | 17½ |
| Pitch (uniform) ........ feet.. | 14⅝ |
| Number of blades, each ........ | 4 |
| Fraction of the pitch used, from ........ | 0.2696 to 0.5898 |
| Helicoidal area of each screw ........ square feet.. | 42.02 |
| Thickness of blades at fillet of hub ........ inches.. | 4¼ |
| Thickness of blades at periphery ........ do.... | ¾ |
| Weight of each screw ........ pounds.. | 4,038 |

## THE POWER, ITS DISTRIBUTION AND THE SPEED OF THE SHIP.

The nature of the service of the ship is such that uninterrupted voyages of considerable length seldom occur, and as errors in experiments are principally in the beginning and ending, it follows that short tests must be less reliable than long ones. For this reason I determined to select one of our longest uninterrupted voyages, when the vessel's bottom was clean and when she was near her average draught of water for steaming. This opportunity occurred about seven months after the ship had been put in commission, the voyage being from the New York navy-yard to the Washington navy-yard. The coal used was anthracite, containing more than the average percentage of ash and clinker. The fires were not urged, there being no desire to make a quick voyage, so that the performance must be considered as the average and not the maximum. The wind was light but ahead; the sea was smooth.

| | |
|---|---|
| Duration of voyage ... hours.. | 42⅙ |
| Total distance, in geographical miles of 6,086 feet | 423 |
| Mean number of geographical miles per hour | 10.03 |
| Total number of revolutions of the starboard engine | 200,197 |
| Total number of revolutions of the port engine | 200,411 |
| Mean number of revolutions per minute of the starboard engine | 79.05 |
| Mean number of revolutions per minute of the port engine | 79.06 |
| Slip of the starboard screw in per cent of its speed | 14.74 |
| Slip of the port screw in per cent of its speed | 14.75 |
| Mean steam-pressure in the boilers in pounds per square inch above the atmosphere | 60.05 |
| Mean pressure per square inch above zero in the starboard receiver | 25.53 |
| Mean pressure per square inch above zero in the port receiver | 23.78 |
| Mean vacuum in the condenser, in inches of mercury | 24.46 |
| Mean height of the barometer, in inches of mercury | 30.09 |
| Mean position of the throttle-valves, in eighths | 7.20 |
| Mean point of cutting off in the starboard high-pressure cylinder, in inches | 26.333 |
| Mean point of cutting off in the starboard low-pressure cylinder, in inches | 14.032 |
| Mean point of cutting off in the port high-pressure cylinder, in inches | 19.78 |
| Mean point of cutting off in the port low-pressure cylinder, in inches | 17.831 |
| Total number of pounds of coal (anthracite) | 42,865 |
| Total number of pounds of ashes, clinkers, &c | 8,353 |
| Total number of pounds of combustible | 34,512 |
| Mean number of pounds of coal per hour | 1,016.97 |
| Mean number of pounds of combustible per hour | 818.79 |
| Percentage of refuse in coal | 19.40 |
| Mean number of pounds of coal per hour per square foot of grate surface | 10.667 |
| Mean number of pounds of coal per hour per square foot of heating surface | 0.4103 |
| Mean number of pounds of combustible per hour per square foot of grate surface | 8.598 |
| Mean number of pounds of combustible per hour per square foot of heating surface | 0.3308 |
| Mean number of strokes per minute of the circulating-pump | 80 |
| Mean temperature of the external atmosphere | 73.73 |
| Mean temperature of the injection-water | 65.73 |
| Mean temperature of the discharge-water | 93.78 |
| Mean temperature of feed-water | 76.39 |
| Mean temperature of the engine-room | 119.10 |

HORSES-POWER.

| | |
|---|---|
| Indicated horses-power developed in the starboard high-pressure cylinder | 93.460 |
| Indicated horses-power developed in the starboard low-pressure cylinder | 122.240 |
| Indicated horses-power developed in the port high-pressure cylinder | 110.224 |
| Indicated horses-power developed in the port low-pressure cylinder | 131.602 |
| Aggregate indicated horses-power developed in the starboard engine | 215.700 |
| Aggregate indicated horses-power developed in the port engine | 241.206 |
| Horses-power required to work the starboard engine | 22.116 |
| Horses-power required to work the port engine | 22.118 |
| Net horses-power applied to the starboard shaft | 193.584 |
| Net horses-power applied to the port shaft | 219.708 |
| Horses-power absorbed in friction of the load on the starboard engine | 14.519 |
| Horses-power absorbed in friction of the load on the port engine | 16.478 |
| Horses-power expended in the slip of the starboard screw | 23.278 |
| Horses-power expended in the slip of the port screw | 26.838 |
| Horses-power expended in friction of the starboard screw-blades and shaft on the water | 21.278 |
| Horses-power expended in friction of the port screw-blades and shaft on the water | 21.279 |
| *Net horses-power applied to the propulsion of the hull* | 289.642 |

DISTRIBUTION OF THE POWER.

| | |
|---|---|
| Percentage of the net power applied to the shafts absorbed in friction of the load | 7.500 |
| Percentage of the net power applied to the shafts absorbed in the friction of the screw-blades, hubs, and shafts on the water | 10.297 |
| Percentage of the net power applied to the shafts absorbed in the slip of the screws | 12.122 |
| *Percentage of the net power applied to the shafts utilized in the propulsion of the hull* | 70.081 |

ECONOMIC RESULTS.

| | |
|---|---|
| Pounds of coal consumed per indicated horse-power per hour | 2.222 |
| Pounds of coal consumed per net horse-power per hour | 3.246 |
| Pounds of combustible consumed per indicated horse-power per hour | 1.789 |
| Pounds of combustible consumed per net horse-power per hour | 2.613 |
| Pounds of coal per mile | 101.336 |
| Pounds of combustible per mile | 81.588 |

THRUST OF THE SCREWS.

The net power applied to the propulsion of the hull by the two propellers, being 289.642 horses, is equal to $(289.642 \times 33{,}000 =)$ 9,558,186 foot-pounds of work per minute, and, the speed being 10.03 knots per hour, is equal to $\left(\frac{10.03 \times 6086}{60} =\right)$ 1017.376 feet per minute; therefore, the resistance of the hull (and the equivalent thrust of the screws) at that speed was $\left(\frac{9{,}558{,}186}{1017.376} =\right)$ 9,395 pounds.

The thrust per indicated horse-power, at that speed, was $\left(\frac{9395}{457.526} =\right)$ 20.31 pounds, and per pound of coal per hour it was $\left(\frac{9395}{1016.97} =\right)$ 9.23 pounds.

## POWER ABSORBED BY THE FRICTION OF THE WETTED SURFACES OF THE HULL AGAINST THE WATER.

Taking the resistance of the water to a square foot of smoothly-painted surface of the hull, moving at a velocity of 10 feet per second, to be 0.45 of a pound, and (according to the method of Chief Engineer Isherwood, U. S. N.) deducing from the speed of the vessel the mean speed of its immersed surfaces due to the inclination of the water-lines, there results a speed of 16.35076 feet per second and a consequent surface resistance of ($10^2 : 0.45 :: 16.35076^2 :$) 1.203063 pounds per square foot at that velocity. The aggregate wetted surface during the above-mentioned voyage was 7350.44 square feet, and the power expended in this resistance was $\left(\frac{7350.44 \times 1.203063 \times 16.35076 \times 60}{33000} = \right)$ 262.893 horses; consequently, of the 289.642 horses-power required to propel the hull, $\left(\frac{262.893 \times 100}{289.642} = \right)$ 90.73 per cent was expended in overcoming the friction of the hull on the water, and the remaining 9.27 per cent was expended in displacing the water and overcoming the pressure of the wind against the upper part of the hull, the spars, and the rigging.

### SVEDBERG GOVERNORS.

In a heavy sea-way a ship, from excessive pitching, will sometimes throw the screw out of water sufficiently to relieve it of the resistance of the water; at such times the screw and engine, thus released, will spin around very rapidly, endangering the machinery. To prevent this it was formerly the custom to station a man at the throttle who would close that valve when the engine began to speed up (to "race"), and to open the throttle when the engine slowed down. This operation was never satisfactory, and gave birth to the invention of many marine governors, the majority of which were centrifugal in principle, and consequently depended on the speeding of the engine to close the throttle, or, in other words, to slow the engine after the racing had commenced. The object of the Svedberg governor is to anticipate the racing and to close the throttle-valve before it commences.

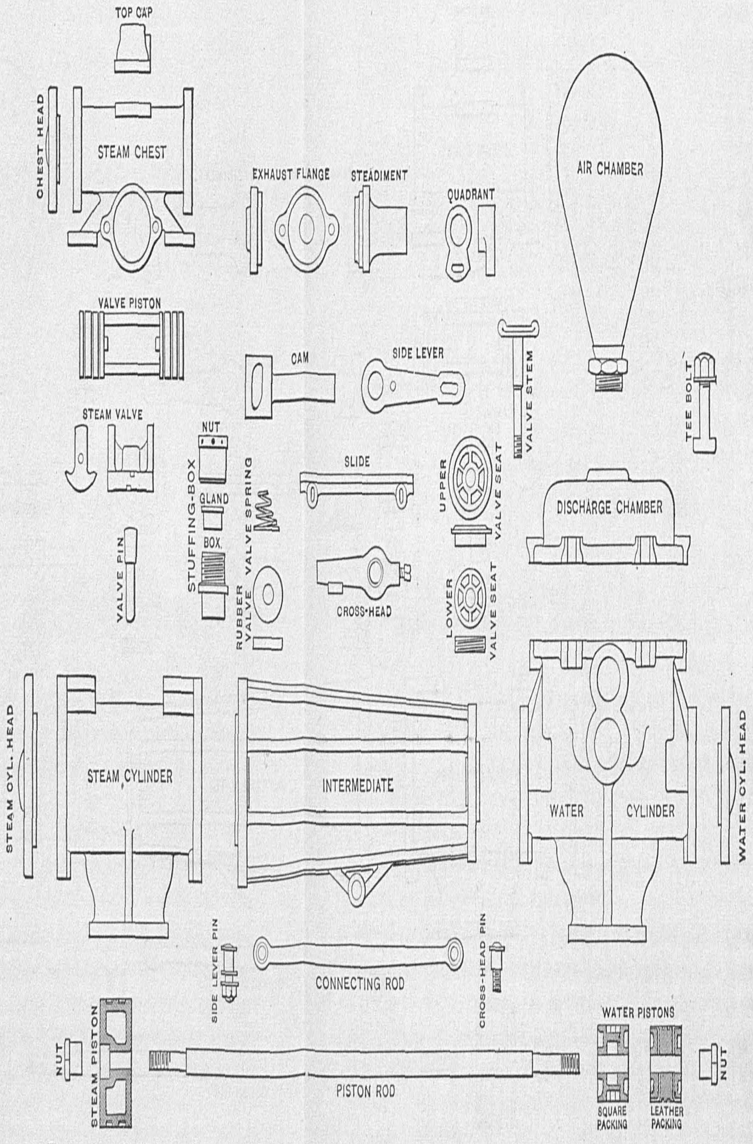
To accomplish this an air-chamber A, Plate XVIII, is placed at the stern of the ship, as low down as it can be fixed; the top of this air chamber is connected to the top of a mercury-cup by a pipe; this mercury-cup (B, Plate XVIII) is made on the principle of a Wolf jar, and besides mercury it contains a wooden float on the lower end of the rod *r*, which passes through the oblique cylinder *d* to the surface of the mercury; the cylinder, though in the same casting with the mercury-cup, has its lower rim immersed in the mercury. Any elevation of the stern of the ship, or any rise or fall of the water under the stern of the ship, will increase or diminish the pressure in the air-chamber A, which pressure is promptly communicated to the mercury-cup B, and depresses or lifts the surface of the mercury in the cup; but as the lower rim of the oblique cylinder *d* is immersed in the mercury, any rise in B will depress the mercury in *d*, and will cause the float (and rod *r*) to fall or rise accordingly; and this rise or fall is directly proportional to the pressure at the stern of the ship. The pressure exerted by the float is necessarily small, while the power required to move the throttle-valve is sometimes considerable, and for this reason a steam-engine is interposed, the float moving the valve of the little engine, while the pressure of steam in the little cylinder moves the throttle. In this engine the piston and rod are fixed, while the cylinder moves upon the piston; the valve chest and cylinder are cast in one, and the steam and exhaust pipes slide through stuffing-boxes; the cylinder is connected by the rod *e* to the throttle-valve lever. The action of the machine is as follows: The water, rolling from under the stern, causes a diminution of pressure in the air-chamber, which is transferred to the mercury-cup, lifts the float and rod *c*, and, through the levers (shown in the engraving), communicates a definite amount of motion to the valve; steam is thus admitted to the cylinder and moves it to the right until the motion of the cylinder has equaled that of the valve, when the ports are thus automatically closed, and the cylinder and throttle-valve come to rest. By changing the quantity of mercury in the cup, adjusting the length of the rods or throw of the levers, the throttle-valve can be made to come to rest at any desired position, or to work between desired limits. In practice the machine works admirably, surpassing the writer's most sanguine expectations.

STEAM PUMPS.

The Albatross is provided with three steam pumps, of the Davidson pattern, as follows:

Circulating pump, No. 26. Light service.
Boiler feed or fire pump, No. 5. Regular.
Hydrant pump, No. 5. Light service.

The circulating pump has a steam cylinder 14 inches in diameter of bore, a water cylinder 16 inches in diameter, and a stroke of piston of 14 inches. Its speed may be varied from 1 to 200 strokes per minute, its ordinary speed being about 75 strokes per minute. It is piped to pump from the sea or from the bilge, and to discharge into the condenser. Its maximum capacity is about 2,400 gallons of water per minute. The writer has indicated the pump at several speeds, and constructed a curve (Fig. 1) in which the length of the ordinates refers to the indicated horses-power and the abscissas to the interval between speeds. The power of the pump can be ascertained at any moment by counting the strokes per minute and referring to Fig. 1. The boiler




Face page 29.

FIG. 2.--Details of pumps.

feed or fire pump (Plate XXVI) is proportioned to work against great pressures; it is piped to take water from the sea or from the bilge, and to deliver to the boilers, to the hydrant pipe (which delivers water to hydrant connections on the side of the deck house, to the laboratory, the engine room, and fire room), to the ash-chute, or overboard, at pleasure. The steam cylinder is 9 inches in diameter, the water cylinder is 5¼ inches in diameter, and the stroke of piston is 12 inches. The maximum capacity of this pump is about 250 gallons per minute.

The hydrant pump has a 7-inch steam cylinder, a 5-inch water cylinder, and a stroke of piston of 10 inches. It is piped to take water from the sea or the bilge and will deliver it to the boilers, the hydrant pipe, the ash-chute, or overboard; its maximum capacity is about 200 gallons per minute.

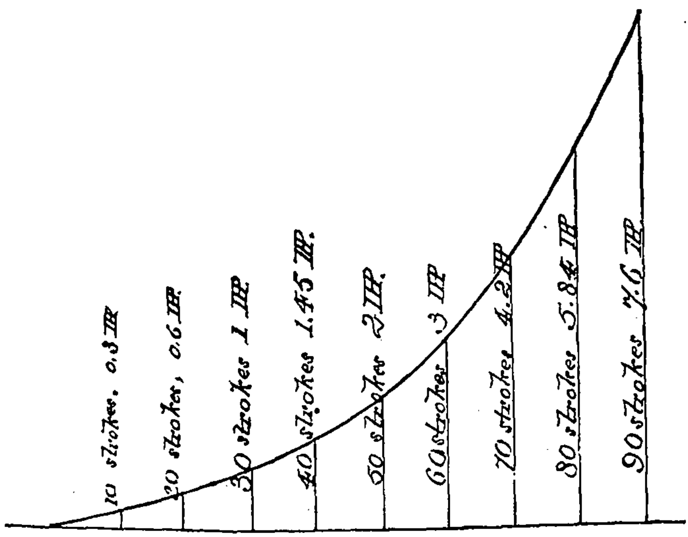



FIG. 1.

The three pumps are similar in design and in detail, differing only in size and proportion. Fig. 2 shows the details and commercial names of the parts.

The parts of the pumps are manufactured to gauges and are interchangeable; the water valves have unusually large openings; the steam valves have positive motion as well as being "steam thrown;" the water cylinders are brass lined, the valve seats and stems, glands, and piston rods are of brass. The working parts are quite accessible.

INJECTORS.

In addition to the pumps, two "Little Wonder" injectors are provided to feed the boilers. They take the water from the hot-well or from the sea and deliver only to the boilers. They are especially useful in feeding from the sea in cold weather, as they warm the water before delivering it to the boilers. We have never succeeded in working both at a time, though they work very well singly, and it rarely occurs that we are obliged to use a steam-pump to feed the boilers.

### ASH ELEVATOR AND CHUTE.

Plate XIX shows a half section of the vessel at the center line of the ash-chute, and Plate XX shows several views and sections of the hoisting engine. The object of this machinery is to hoist the ashes and dump them overboard with the least manual labor and to avoid carrying them across the deck. The vertical chute through the ship's bottom has been tried and abandoned, as the ashes soon scoured through the bottom plates of the ship, in the wake of the chute. The steam ejectors, tried in the navy, were abandoned for the reason that the ashes, blown at such a high velocity, very quickly scoured through a 2-inch thick cast-iron pipe; the writer, therefore, designed the diagonal tube (a 10-inch wrought-iron boiler flue) surmounted by a hopper, and the engine referred to. A stream of water ($1\frac{1}{4}$ inches in diameter) is projected into the hopper while ashes are being dumped, and the velocity of the descending cinders, though not great, is sufficient to project them quite clear of the ship's side. The hopper and elbow are of cast iron, and after two years' use they show scarcely any erosion. The principle of the engine is very old, it belonging to that class which is reversed by "changing the ports," *i. e.*, by having an arrangement by which the steam and exhaust ports are changed, the one for the other. For simplicity and fewness of ports the crank-shaft and hoisting drum are one and the same piece of cast iron; the cylinders are oscillating, their ports being in the trunnions, the motion of the cylinders opening and closing the ports; the steam-chest between the two cylinders is common to both, and has at its center a piston valve; steam enters through the end of the piston valve, and by moving this valve the steam goes to one side of the chest only; by moving the valve in the opposite direction the steam would go to the other side of the valve chest, which latter is divided, by a longitudinal diaphragm, into two compartments; the exhaust is through one side of the piston valve. By this arrangement it will be seen that when this piston valve is in its middle position no steam can pass into or out of the engine, which of course stops it; it is also manifest that a movement of the valve in one direction will cause the engine to run in one direction, and the opposite motion of the valve will reverse the engine. The piston valve is moved by a lever which has a long slot in it (*a*, Plate XX) through which the hoisting rope passes; on the rope there are two stops (knots), so situated that one will press and move the the lever when the bucket is up, and the other when the bucket is down. To operate the machine two men are employed; the first one fills the bucket and moves the lever, the bucket rises to its stop and is brought to rest; the second man dumps the bucket into the chute, pulls the lever (by a cord not shown), when the bucket descends to the floor and is again automatically stopped. The machine is noiseless and rapid in its action, has worked with certainty, and has required but little attention.

DISTILLING APPARATUS.

The distiller, patented by the writer, is the kind generally used on board American steamships. The object of the machine is to distil drinking-water. There are three block-tin coils placed inside an annular cast-iron cylinder, the coils terminating in manifolds which pass through stuffing-boxes in the heads of the cylinder, as represented in Plate XXI. To the top of the coils is screwed an air-injector *a*, which is supplied with steam at *b* and air at *c*, the velocity of the steam inducing the air current; the steam and air thus entering, molecule to molecule, thoroughly mixed before condensation. The current of sea-water, forced into the condenser at *d*, passing out at *e*, keeps the surfaces of the coils cool which condense the steam within. The fresh water and air rush out of the coils at *f* and into a filter of *carbo animalis purificatus*, from which it is delivered to the ship's tanks through the opening *g*. The fresh water will absorb (dissolve) only a small portion of the air (less than 2½ per cent of the volume under the pressure of the atmosphere), but the large excess of air injected into the steam serves to oxidize organic matter which is brought over by the steam, and this especial filter is to remove those oxides. The object of the annular jet of steam is to bring a larger surface of steam-jet in contact with the air, and the object of the annular condenser is to compel the circulating water to flow over the condensing surface. The filtering material requires to be renewed about once in two years. The commercial size of this machine is No. 4, and its capacity is 2,000 gallons per day; the daily consumption of water on board is about 250 gallons. A ton of coal will distil about six tons of water, so there is a saving of weight and space by employing the distiller on board ship. The quality of the distilled water is always the same, and I quote the words of an eminent medical director of the Navy in saying that "diarrhea has diminished 50 per cent on board our ships since the introduction of distilled water." The water is clear and, being well aerated, tastes quite as good as hydrant water; in fact it is difficult to detect it as the product of distillation.

*LIGHTING.*

The operation of dredging, in great depths, sometimes carries the day's work past midnight, and after the contents of the dredge are safely deposited on board, the naturalists are required to preserve the specimens, which often takes two hours longer. To facilitate this the commissioner authorized the installation of the Edison incandescent system of electric lighting. The plant consists of an 8½ by 10 inch Armington and Sims engine, an Edison Z dynamo (Plate XXII) having vertical field magnets, a resistance-box in the magnetic field-current, the necessary wiring, lamp fixtures, safety-catches, and lamps.

### THE ENGINE.

The steadiness and uniform brilliancy of the lamps depends so largely on the engine driving the dynamo that Mr. Edison has adopted the best (though quite expensive) engine he could find, which is manufactured at Providence, R. I., by Armington & Sims. The great success of this engine lies in the correct balancing and lightness of its working parts, large bearing surfaces, early exhaust closure, and in its extremely sensitive governor. It has a piston valve, which has considerable exhaust lap, which serves not only to "cushion" the piston past its centers but to save the steam thus compressed in the clearance spaces. The engine runs 300 revolutions per minute, and is belted to and drives the dynamo 1,200 revolutions per minute. The governor of the engine is fixed in the fly-wheel,

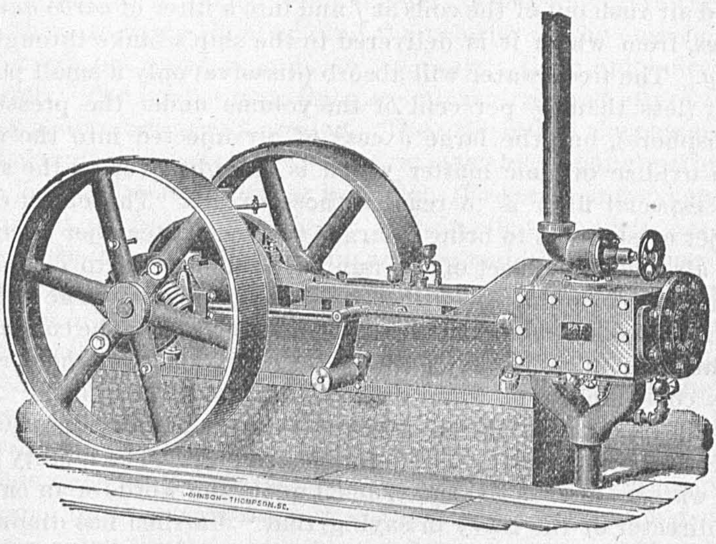



FIG. 3.

which is keyed to the shaft; there are two eccentrics, one within the other, and both movable on their axis; there are two weights, with their centers of motion opposite, and fixed in arms of the wheel; these weights are each connected to one of the eccentrics and connected by an arm or rod; spiral springs (Fig. 3), to resist the centrifugal force of the weights, are provided; the system is so constructed that any centrifugal motion of the weights will throw one eccentric ahead and the other back, thus diminishing the throw of the eccentrics and effecting a shorter cut-off, without changing the lead of the valve. When the main engines of the ship are in motion, we use a boiler pressure of 50 pounds above the atmosphere and exhaust all engines (including the dynamo engine) into the condenser, where there is from 23 to 26 inches of vacuum; lying in port, we let the boiler pressure fall to 25 pounds and exhaust the dynamo engine against pressure of the atmosphere; and notwithstanding this great difference of pressure between the two conditions, the governor of the dynamo engine so regulates the quantity of steam to the cylinder that the revolutions of the engine remain practically at 300, never varying more than 2 per cent. The engine and the dynamo are run by enlisted men in the engineers' department.

## THE DYNAMO.

The dynamo (Fig. 4) is of the size known as Z, and is wound for what is called a B circuit, *i. e.*, a circuit which will give 51 volts of electromotive force, and generate a current for 120 lamps, each requiring 0.745 amperes, offering a resistance of 69 ohms. The field magnets are

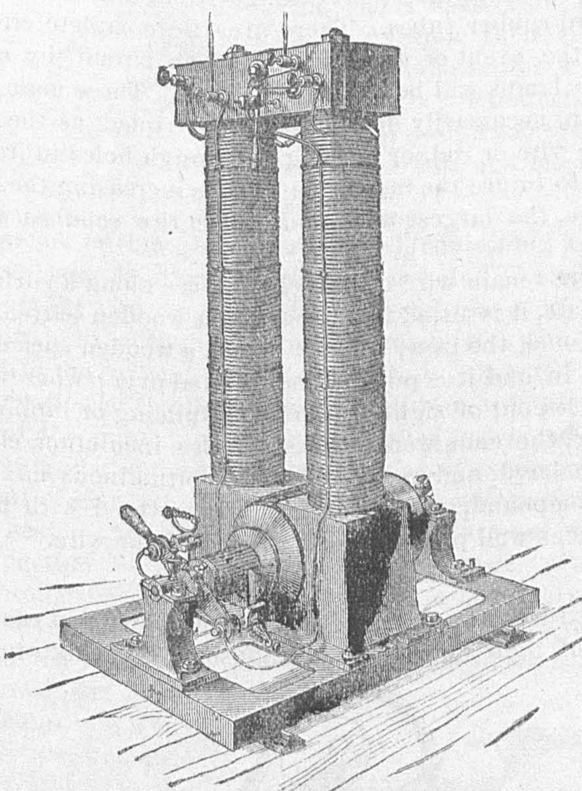


FIG. 4.

vertical, and the armature revolves on a horizontal axis, in the magnetic field. The field magnets are arranged on what is called a "derivation" or "shunt" from the commutator, placing it in the circuit as in the Siemens system. In adapting and utilizing known principles and devices and in patiently working out details, Mr. Edison has brought his system of lighting to an admirable state of perfection; wherever the eye rests it is pleased by correct proportions, sound mechanical principles, and agreeable outlines.

To preserve the uniformity of the current an adjustable resistance-box is placed in the field circuit, so that when a number of lamps are extinguished additional resistance may be thrown into the field by a switch on the resistance-box, whereby the internal and external resistance may be balanced, preserving not only the uniform brightness of the lamps, but also the economy of the machine.

### THE WIRING.

The wires are all of copper; those well protected from dampness are insulated with a woven cotton and white lead covering; where they pass damp or wet places they are further incased in rubber tubes; where they pass hot places (through the boiler room) they are run through lead tubes; and where they pass through iron bulkheads they are protected by hard-rubber tubes. There are two complete circuits round the ship; in the event of an accident to one circuit (by collision, for example) the lamps will be fed by the other. These main circuits, on board ship, are necessarily doubled or even tripled, as the short bending of a large wire or rod, or hauling it through holes in iron or wood, would be apt to injure the insulation besides increasing the labor. No. 10 is, therefore, the largest wire, and No. 20 the smallest wire used in our circuit.

Where a wire—main wire or branch—passes along a surface of iron, as a lodger plate, it is fitted in a groove in a wooden batten, and never permitted to touch the iron; when it passes a wooden surface, a groove is cut to let it in, and it is puttied and painted over; wherever possible the wires are led out of sight. Wherever splicing or tapping of wires was necessary, the ends were cleared of the insulation, cleaned with sand-paper, soldered, and recovered with a bituminous mixture called "insulation compound," and finally tightly covered with tape; these joints are thus as well protected as any part of the wire.

### LAMP FIXTURES.

The lamp fixtures are designed to suspend above and cast the unobstructed rays of light downward. Handsome brass fixtures with por-

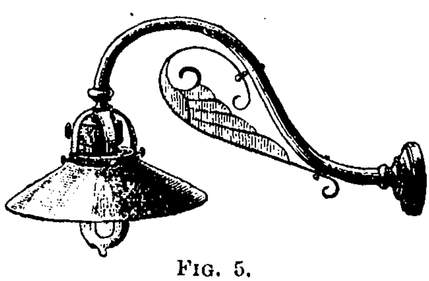


FIG. 5.

celain shades of three kinds are used on board. Fig. 5 is called a bracket, Fig. 6 a single-swing bracket, and Fig. 7 a double-swing bracket.

The wires are run through the tubes of these brackets, but in the joints of the swinging brackets the current is transmitted through insulated hinges, to which the wires are fixed by binding screws, as shown at *a* in Fig. 8, by which arrangement the wires are not twisted in swinging the bracket. The wires are brought to the binding posts in the lamp-socket, Fig. 9, between their binding screws and brass conductors; one of these brass conductors is soldered to the thin-spun brass socket into which the lamp is screwed while the other is connected, through the key, to a brass disk placed centrally in the bottom of the socket, against which one pole of the lamp presses when screwed in place. The key is mounted on a screw-thread of such pitch that one-fourth of a revolution will give it sufficient axial motion to open or close the circuit. The small number of parts used in these fixtures, their correct proportions, the adaptation of their forms to machine tool manufacture, and their beauty of design excite the admiration of both artists and mechanics.

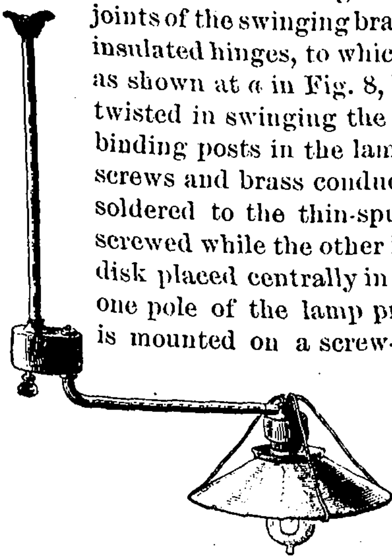


FIG. 6.

THE LAMPS.

The lamps are of thin glass, pear-shaped, containing a thread of bamboo carbon about as thick as a horse-hair. The small end of the lamp (Fig. 10) contains glass of sufficient thickness to make a tight joint on the platinum wire conductors which carry the current to the carbon. The atmosphere is exhausted by Edison's modification of the Sprengel pump, through a tube at the lower end of the lamp, and the tube is then fused and broken off. Platinum wire is used because its index of expansion is the same as that of glass, thus preventing any breakage or leakage from the heat. The bamboo-carbon, and platinum wire are soldered together by electrically-deposited copper. One wire, passing through the glass, is soldered to a small brass disk which is centered on the top of the lamp (Fig. 10), while the other wire is soldered to the spun-brass screw-thread which surrounds the cylindrical part at the top of the lamp, and when the lamp is screwed into the socket (Fig. 11) the circuit is completed or broken by the switch or key already described.

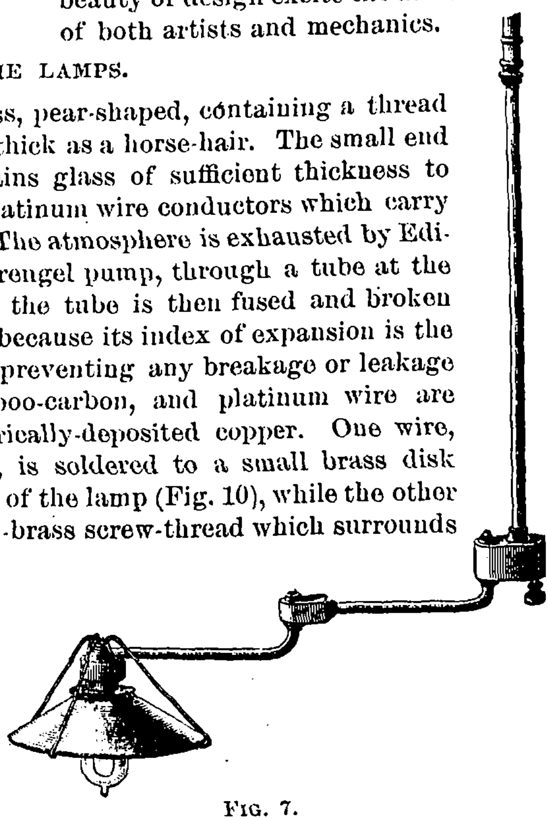


FIG. 7.

When the circuit is closed the carbon thread becomes heated to incandescence—from its high resistance—and continues to glow, in vacuum, without burning, so long as the current continues to flow. Fig. 12 shows a lamp screwed into its socket.

By varying the length, and also the sectional area of the carbon

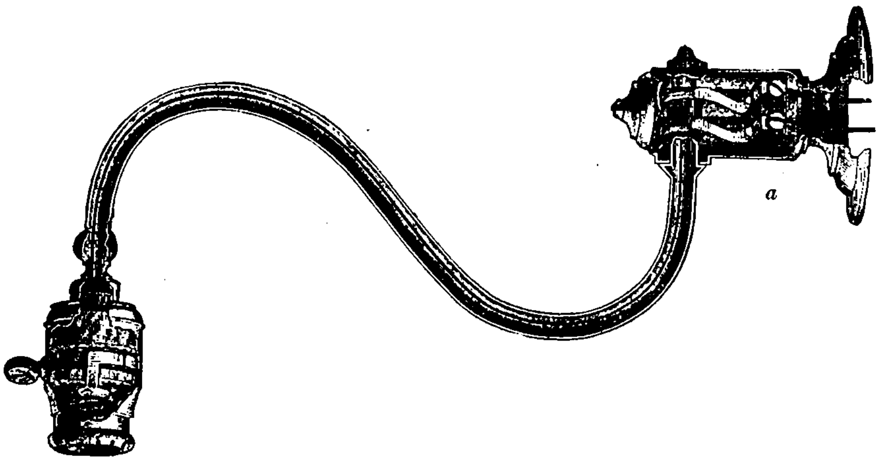



FIG. 8.

thread, keeping the electro-motive force constant, Edison has varied the candle-power of his lamps. In our circuit we have a few 16 candle-power lamps, though most of them are of 8 candle-power only. The cop-

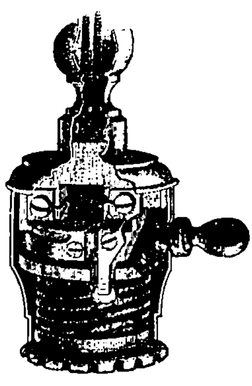


FIG. 9.

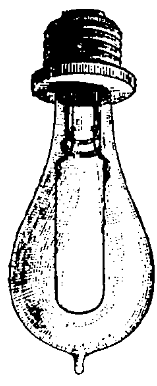


FIG. 10.

per wires, being of high conductivity, and of ample size, carry the current with but little warming, notwithstanding the white heat of the carbons in the circuit; by varying the size of the wires it will be found they follow the same law as to resistance and heating as the carbons.

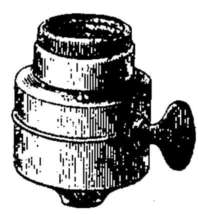


FIG. 11.

Let R = the resistance of a conductor; S = its sectional area; L = its length; $a$ = a constant depending on material of which the conductor is made; then $S R = a L$, and from this simple equation the relative sizes of the wires and carbons have been determined.

The "life-time" of these lamps is warranted to be 600 burning hours, and their cost is 85 cents apiece.

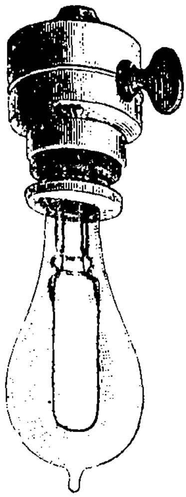


FIG. 12.

SAFETY CATCHES.

In event of a "short circuit" (an accidental connecting of the + and – wires) by a good conductor there would instantly be generated sufficient heat in the wires to melt them and to set fire to the adjacent woodwork, and possibly melt the armature also. To prevent this, Mr. Edison has devised his cut-out blocks and safety plugs shown in Figs. 13 and 14. The wires of the circuit connect to the binding screws in the blocks, while the plugs screw into the sockets of the blocks when the circuit is completed through the plugs, after the manner of the lamps; but the wire which connects the two poles of the plug is made of a fusible alloy, which melts at about 400 degrees, and the melting of this wire breaks the circuit. When this happens all the lamps fed through that plug will go out. These safety catches are placed on the main wires near the dynamo and on every branch circuit near the point where the mains are tapped.

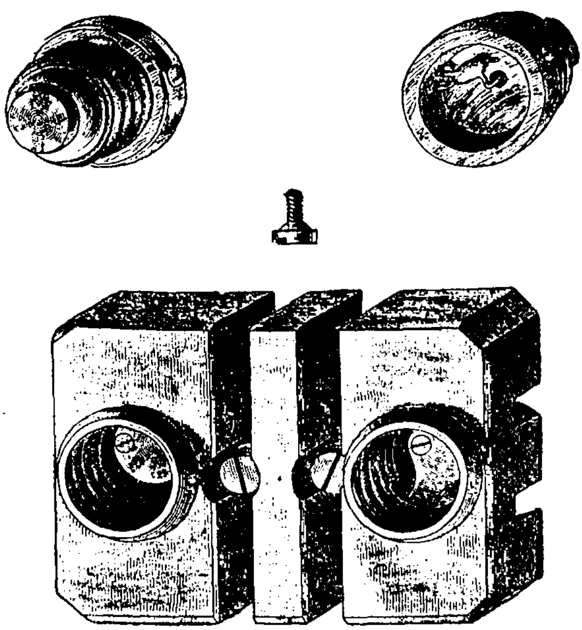


FIG. 13.

ECONOMY OF THE SYSTEM.

The writer indicated the engine with the current switched off; again with forty-five, with fifty, and finally with seventy lamps (8 candle-power B lamps) in circuit, respectively. By deducting from these experiments, respectively, the power required to run the engine and dynamo we obtain the power applied to the shaft, and from this quan-

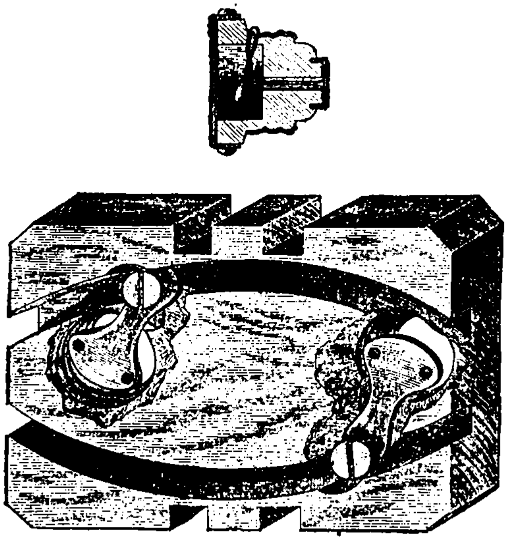


FIG. 14.

tity we deduct the friction of the load, leaving as a remainder the net power required to revolve the armature in the magnetic field with those respective lamps in circuit.

DISTRIBUTION OF THE POWER.

| | |
|---|---|
| Horses-power required to run the engine and dynamo | 3.56 |
| Indicated horses-power required to run 45 lamps | 5.79 |
| Indicated horses-power required to run 50 lamps | 5.85 |
| Indicated horses-power required to run 70 lamps | 6.92 |
| Net horses-power applied to the revolution of the armature in the magnetic field, using 45 lamps | 1.80 |
| Net horses-power applied to the revolution of the armature in the magnetic field, using 50 lamps | 1.85 |
| Net horses-power applied to the revolution of the armature in the magnetic field, using 70 lamps | 2.84 |
| Mean number of lamps, per indicated horse-power, using 45 lamps | 7.77 |
| Mean number of lamps, per indicated horse-power, using 50 lamps | 8.50 |
| Mean number of lamps, per indicated horse-power, using 70 lamps | 10.11 |
| Mean number of lamps, per net horse-power, using 45 lamps | 25.00 |
| Mean number of lamps, per net horse-power, using 50 lamps | 27.02 |
| Mean number of lamps, per net horse-power, using 70 lamps | 24.63 |
| Mean of the last three quantities | 25.55 |

So far the greatest number of lamps in operation at any one time has been (to the best of the writer's knowledge) 70, and he believes the average number to be about 47. The number of lamps, per indicated horse-power, increases with the number of lamps used, for the reason that the fraction of the power utilized becomes larger at the higher power. The cost, in coal, of a horse-power developed by the dynamo-engine has been arrived at by calculating the quantity of steam passed through the steam-cylinder and reducing this to pounds of water evaporated by a pound of coal. Had steam been used for the light alone this calculation would have been unnecessary, but as it was used from the same boiler to warm, ventilate, and light the ship at the same time, the writer adopted this method of separating the respective quantities. From these indicator diagrams I have calculated that a horse-power costs 30.7 pounds of water or 3.41 pounds of coal per hour. The mean cost of coal during the two* years the ship has been in commission has been $6.07 per ton, or 0.271 cent per pound. The total cost of the oil used on the dynamo and its engine has been $106.74.

During the year 1833 the dynamo was in operation 1,592 hours and 45 minutes, and during 1884 1,481 hours and 30 minutes, making a total of 3,074 hours and 15 minutes.

The cost of running the plant for the two years has been—

| | |
|---|---|
| Total cost of coal: | |
| For 1883 | $79.60 |
| For 1884 | 95.51 |
| Total cost of oil: | |
| For 1883 | 48.57 |
| For 1884 | 58.17 |
| 2 K brushes | 5.00 |
| 11 Z brushes | 11.00 |
| 2 cut-out blocks | .64 |
| 73 3-light cut-out plugs | 5.84 |
| 16 6-light cut-out plugs | .48 |
| 5 20-light cut-out plugs | .40 |
| 13 40-light cut-out plugs | 3.20 |
| 5 key-sockets | 4.60 |
| 2 pounds of insulation compound | .24 |
| 1 wire shade-holder | .10 |
| ½ pound insulation tape | .24 |
| 2 attachment plugs | .80 |
| 3 pounds No. 14 insulated wire | 1.20 |
| 1 pound No. 20 insulated wire | .40 |
| 1 new valve for the engine | 5.00 |
| 1 new cross-head for the engine | 25.00 |
| 1 new belt | 20.00 |
| Repairs (shortening) of belts | 5.62 |
| 241 lamps† | 241.00 |
| Total expenditure, exclusive of labor and interest | 665.97 |

* These figures include the work for 1883 and 1884.

† The lamps do not now come in the writer's department on board, but are here entered to complete the account.

As the engine and dynamo are run by a coal-heaver in addition to other duties, the writer has not entered the item of wages.

As the price of the lamps has been reduced 15 per cent, and the price of fixtures continues to diminish, we have no doubt that the running expense of the light will grow less. During 1884 we paid as high as $18 a ton for coal, at Aspinwall, and in 1883 as low as $3.93 a ton, at the Norfolk navy-yard. Between such ranges the cost of the light must vary, but as the writer has included all the coal consumed on board for that purpose during the entire period of the ship's existence, he believes the mean will be found to be very close to the correct one.

A correct average number of lamps cannot be ascertained where they are being turned on and off by so many persons, but the writer's average, taken from a number of observations, places the number at 47½. Assuming this to be correct, the cost of the light in candles-power per hour becomes $\frac{66597}{(1592.75+1481.5)\ 47\frac{1}{2}\times 8} = .05707$ cent.

This is about 38 per cent more than the cost of an equivalent amount of gas-light in Washington City, where coal costs less than $5 per ton.

## DEEP-SEA LAMPS.

Our deep-sea cable is 940 feet in length and is coiled upon a reel, from which it may paid out to any depth within that limit. The lamps are according to Edison's patent, but the wires simply extend through the bottom of the lamp, the ends being free. We solder these wires to our cable, insulate with gutta-percha, tape, and "insulation compound." The lamps are of about 42 ohms resistance and are about 16 candle-power. The lamps burn quite well under water and can be seen very plainly at moderate depths, but they disappear entirely when 70 feet below the surface. We have had the deep-sea lamp down about 750 feet. There are two other submarine lamps, having each about 40 feet of cable with attachment plugs, so that they can be attached to any lamp socket. These have been used by the naturalists, who immerse them a few feet beneath the surface of the water to attract marine animals; by this means they have secured squid in large numbers, amphipods, silver-sides, young bluefish, young lobsters, and flying-fish, and dolphins have been seen to approach these lamps.

## *WARMING AND VENTILATING.*

Experiments made by the writer on two wooden ships of the Navy show that 1 square foot of steam "radiator" surface is sufficient to warm 1 cubic foot of space on shipboard, even in the coldest weather, and he employed that rule in proportioning the steam radiators for the Albatross. The simplest forms of radiators were adopted, and we find, in practice, that they are quite as "noiseless" as the patented radiators, when properly piped for draining. In the pilot-house we adopted a plain return-bend brass coil; in the deck-house rooms we put single columns; in the cabin, ward-room, laboratories, captain's office, and chart-room, and berth-deck apartment we put common steam radiators having cast-iron rectangular bases with vertical 1-inch wrought-iron tubes, 35 inches high, screwed into the open bases. The 1-inch (inside diameter) tube, 35 inches long, gives, in round numbers, 1 square foot of surface, making the distribution of the surface quite simple. Among the advantages of steam heat on board ship are cleanliness, easy regulation, economy of space, and safety.

The water condensed from the steam in the radiators is trapped and conveyed into the "hot well" (whence it is pumped into the boilers) or into a tank which is used as a reservoir for washing water.

The ventilation is effected by a single Sturtevant exhaust fan, driven directly from a "Wise motor," shown in Fig. 15. The fan has openings

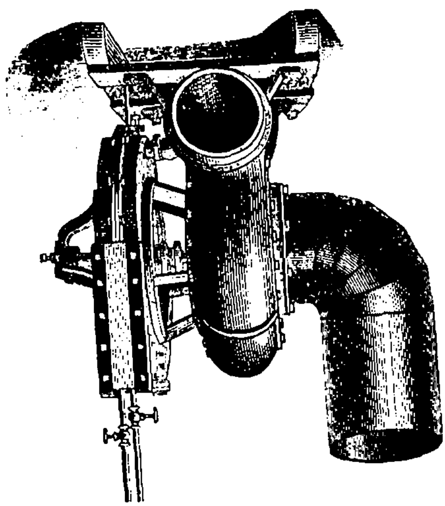


FIG. 15.

of 14 inches diameter, both for receiving and for discharging the air; there are two branch (11-inch) pipes from the suction side of the fan, one running to each side of the ship, and these 11-inch pipes branch into a 9-inch pipe leading forward and a 7-inch pipe leading aft, on each side of the ship. There is a sliding gate in each of the 9 and 7 inch conduits, near their connection with the 11-inch mains, which enables us to close either section; this would be essential in case of fire. The 9 and 7-inch conduits, which run close under the lodger plates of the berth deck, diminish in size to the extremities of the ship, where they are only 3 inches in diameter. From these pipes, or conduits, we have led 3-inch diameter pipes through the deck to the apartments to be ventilated, these small pipes terminating in polished brass registers, the area through which may be regulated at will. The conduits are made of Root's spiral galvanized wrought-iron pipe, the edges riveted and soldered, and though none of it is over No. 16 in thickness, it is amply strong for the purpose. The polished registers are made to finish with the joiner-work of the ship, and the pipes connecting them with the conduits are, wherever possible, led behind the ceiling and other joiner-work, and are quite out of sight. The fan is too well known, commercially, to warrant a detailed description here; it is sufficient to say that it is a Sturtevant No. 6 centrifugal exhaust fan, and that the ventilation of the ship is effected by drawing out the foul air, permitting the fresh air to find its own way in, to supply the void, and is known as the aspiration system. The motor, though one of the earliest forms of steam-engine, bears a recent United States Patent Office date, and is remarkable alone for its simplicity. It consists essentially of a short hollow cylinder, its axis horizontal, containing a wheel in the circumference of which there is placed a number of pockets or "buckets." The "buckets" just clear the surface of the cylinder, and revolve freely within it; there are eight steam jets, arranged in such a manner that the steam from them will impinge directly into the buckets and cause the wheel to revolve upon its axis. The shaft of the motor extends through and is also the shaft of the fan. The fan, according to the figures of the builder, requires 2.86 horses-power to drive it 1,018 revolutions per minute, at which velocity it should deliver 3,669 cubic feet of air per minute. The quantity of air and the consequent size of fan was determined from the experiments of the writer, on board the Unifed States ship Vandalia in 1879.*

Let $Q$=the number of cubic feet of air to be supplied; $n$=the number of men; $a$=the cubic feet of carbonic acid exhaled per man per hour (.0686); $b$=fraction of carbonic acid normal to the external atmosphere (.0004); $c$=fraction of carbonic acid found in the apartment. Then

$$na+Qb=(Q+na)\,c$$

from which we find

$$Q=\frac{na-nac}{c-b} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

From the experiments referred to we found the value of $c$ to equal .0006983. By substituting numericals for letters and deducing we found 2,298 cubic feet per hour per man to be necessary.† The No. 6 fan, therefore, would be ample to ventilate for the 65 people who were to compose the crew, and leave us a reserve of nearly one-third its capacity for the hold of the ship, which we also provided with registers.

It at once became a matter of interest to know what quantity of steam was being used by the motor, and to ascertain, within reasonable

* Proceedings of the Naval Institute for 1880.

† The chemical analysis of the air were made by Dr. Arthur, of the Navy; the writer is responsible for the air measurements, the method, and the correctness of the calculation.

limits, what power was produced from this. For this purpose the writer connected the exhaust-pipe from the motor with the distilling apparatus, measured the condensed water by a "crown meter" and verified it by measurement in the ship's tanks, where the water was delivered.

*Experiment to determine the power and the economy of the fan-motor.*

| | |
|---|---|
| Duration of the experiment, in hours | 12. |
| Cubic feet of water condensed from the exhaust | 96.75 |
| P=Absolute steam pressure, mean, per square inch, in pounds | 63.00 |
| T=Temperature of the water | 91° |
| Relative volume of the steam and water | 409. |
| Volume of steam, in cubic feet | 39,570.75 |
| Cubic feet of steam per second | 0.916 |
| A=Area of the steam jets, in square feet | 0.0027266 |
| V=Velocity of the steam, in feet, per second $\left(\frac{.916}{.0027266}=\right)$ | 332.2 |
| $W_1$=Weight of a cubic foot of steam at P pressure, in pounds | 0.152445 |
| $w$=Weight of steam per second | 0.13808 |
| R=Radius, to center of pressure of the "buckets" or vanes, in feet | 1.2916 |
| N=Number of revolutions per minute | 550. |
| U=Velocity of the vanes ("buckets"), in feet, per second | 74.3944 |
| W=Work done. | |

Then

$$W=\frac{w}{2g}(V^2-U^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

This assumes that the total velocity lost by the steam is utilized in power.

$$U=\frac{2\pi\, RN}{60}$$

and

$$w=VAW_1=.13808 \text{ pounds of steam per second.} \quad . \quad . \quad (3)$$

Substituting in equation (2) we have

$$\frac{.13808}{64}(332.2^2-74.3944^2)=.00216\ (110356.84-5533.87)$$

$=226.417$ pounds of work per second, or $\frac{226.417}{550}=0.41$ horse-power.

A cubic foot of water at T degrees weighs 62.07 pounds; the volume of water condensed per hour was $\left(\frac{96.75}{12}=\right)$ 8.0625 cubic feet. Consequently, the weight of water per horse-power per hour was

$$\left(\frac{8.0625\times 62.07}{0.41}=\right) \text{ 1220.6 pounds.}$$

During the entire experiment the two throttles on the motor were kept wide open.

Though the fan does not run as fast as expected, the air is changed rapidly in the ship, and there is an absence of odors peculiar to ships, of the "stuffiness" in the sleeping apartments, and of the sensation of headache and nausea on waking in the morning.

*STEAM CUTTERS.*

The Albatross is provided with two steam cutters, built by the Herreshoff Manufacturing Company, of Bristol, R. I., from their own designs. The boats have wooden hulls, the larger one being coppered; both are fastened with screws, and are built as light as is consistent with strength. They have compound engines, Herreshoff's patent coil boilers, and external surface condensers. That which distinguishes Herreshoff's system is the coil boiler fed at the top, emptying its steam and water into a separator (whence steam is fed to the engine), and a "circulating pump" which takes the excess of feed-water from the bottom of the separator and delivers it again to the top of the coil. The larger boat has its shaft parallel with the base line and has a 4-bladed screw; the smaller boat has its shaft inclined, passing through the bottom of the hull, a little to one side, and about amidships, and has a 2-bladed screw; just outside the hull there is a universal joint in the line shaft, which permits the screw being pulled close up under the bottom of the hull, with its two blades lying horizontally, in a recess left in the keel, and when thus placed the lower edge of the keel is below the edges of the screw. The object of this is to protect the screw when passing over shoals. The screw being placed under the bottom of the hull, works always in solid water, and no matter how rough the sea, the propeller is never thrown out of water, and does not "race." Fig. 16 is a cut of the double-coil boiler of the steam cutter. The feed water enters the bottom of the outer coil, passing upward and through the spiral coil, then into and down the inner coil, and finally up, through an external pipe F, and into the separator D. The gases of combustion pass through the spaces between the coils. The furnace is lined with fire-bricks to a height of about 6 inches, and the coils are supported by wrought iron straps, with stirrup bolts, resting on the fire-bricks; the casing of the boiler is of sheet iron. The lightness of the boiler, the very small amount of water it contains, its great strength, and large heating surface give it great advantages over other boilers, and its results have been admirable. The boiler of the smaller boat is similar to the one in Fig. 16, except it has not the outer coil.

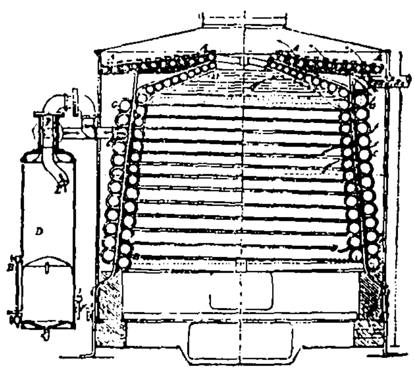



FIG. 16.

Fig. 17 is a perspective view of the engine of the cutter.

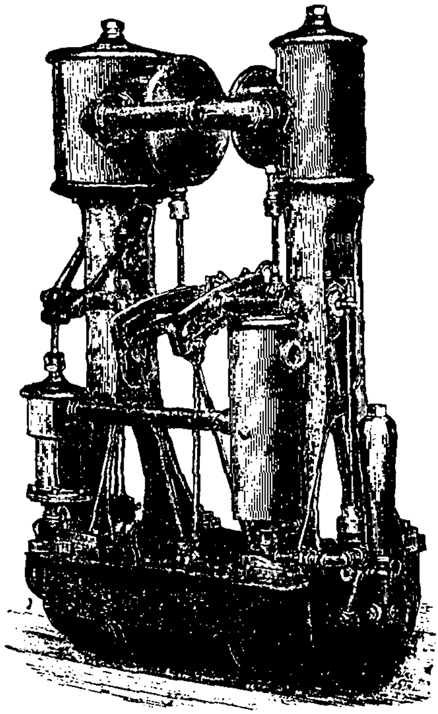


FIG. 17.

The principal dimensions of the boats and machinery are as follow:

| | Large boat. | Small boat. |
|---|---|---|
| Length from forward edge of stem to after edge of stern ............ feet.. | 26.500 | 25.083 |
| Length at the load water-line ............ do.... | 24.500 | 24.583 |
| Greatest beam ............ do.... | 6.750 | 5 |
| Beam at the load water-line ............ do.... | 6.400 | 4.833 |
| Depth from top edge of gunwale to lower edge of rabbet of keel: | | |
| Forward ............ do.... | 4.333 | 3.500 |
| Amidships ............ do.... | 3.417 | 2.667 |
| Aft ............ do.... | 3.677 | 3.667 |
| Draught of water, exclusive of keel: | | |
| Forward ............ do.... | 1.607 | 1.417 |
| Amidships ............ do.... | 1.625 | 1.417 |
| Aft ............ do.... | 1.583 | 1.417 |
| Depth of keel: | | |
| Forward ............ do.... | .25 | .208 |
| Amidships ............ do.... | .625 | .458 |
| Aft ............ do.... | 1.000 | .375 |
| Area of greatest immersed transverse section ............ square feet.. | 7.27 | 6.216 |
| Area of load water-line ............ do.... | 101.65 | 86.67 |
| Aggregate area of the wetted surfaces ............ do.... | 116.25 | 99.76 |
| Displacement at the load water-line ............ cubic feet.. | 80.29 | 46.86 |
| Weight of hull and fittings ............ pounds.. | 3,300 | 1,700 |
| Weight of boiler ............ do.... | 1,115 | 527 |
| Weight of coal and water ............ do.... | 780 | 690 |
| Weight of engine, including screw ............ do.... | 520 | 182 |
| Weight of the boat complete ............ do.... | 5,715 | 3,099 |
| Number of boilers ............ | 1 | 1 |
| Diameter of casing of boiler ............ inches.. | 36 | 26 |
| Extreme height of boiler from ash-pit to base of smoke-pipe ............ do.... | 39 | 32 |

| | Large boat. | Small boat. |
|---|---|---|
| Diameter of furnace ........ inches.. | 29 | 22 |
| Area of grate surface ........ square feet.. | 4.58 | 2.64 |
| Diameter of smoke-pipe ........ inches.. | 10 | 8 |
| Height of smoke-pipe above grate bars ........ feet.. | 8.75 | 6.75 |
| Diameter of separator ........ inches.. | 6 | 3 |
| Height of separator ........ do.... | 31 | 26 |
| Steam cylinders ........ number.. | 2 | 2 |
| Diameter of high-pressure cylinder ........ inches.. | 3½ | 2⅛ |
| Diameter of low-pressure cylinder ........ do.... | 6 | 4¼ |
| Stroke of pistons ........ do.... | 7 | 5 |
| Diameter of the piston rods ........ do.... | ⅝ | 7/16 |
| Diameter of the air pump (single-acting) ........ do.... | 2½ | 2¾ |
| Stroke of air pump ........ do.... | 2⅞ | 2⅛ |
| Diameter of circulating pump-plunger ........ do.... | 7/16 | ⅜ |
| Diameter of feed pump-plunger ........ do.... | 7/16 | ⅜ |
| Stroke of pumps ........ do.... | 7 | 5 |
| Length of condensing pipes ........ feet.. | 15 | 13 1/15 |
| Condensing surface ........ square feet.. | 9.83 | 4.95 |
| Main journals ........ number.. | 3 | 3. |
| Diameter of main journals ........ inches.. | 1½ | 1¾ and 2¼ |
| Length of main journals ........ do.... | 3 | 2⅛ |
| Crank-pin journals ........ number.. | 2 | 2 |
| Diameter of crank-pin journals: | | |
| High-pressure ........ inches.. | 1½ | 1⅛ |
| Low-pressure ........ do.... | ⅞ | 9/16 |
| Length of crank-pin journals: | | |
| High-pressure ........ do.... | 1½ | 1 |
| Low-pressure ........ do.... | 1¾ | 1¼ |
| Space occupied by the engine: | | |
| Length fore and aft ........ do.... | 24½ | 21 |
| Width ........ do.... | 21 | 18 |
| Height ........ do.... | 44 | 26 |
| Diameter of the screw propeller ........ do.... | 28 | 16½ |
| Pitch of the screw propeller (uniform) ........ do.... | 48.72 | 30 |
| Projected length of the screw on line of its axis ........ do.... | 5 | 3 |
| Blades of the screw ........ number.. | 4 | 2 |
| Friction of the pitch used ........ | 0.19 | 0.2 |
| Helicoidal area of the screw blades ........ square feet.. | 3.69 | ⅛ |
| Weight of the screw ........ pounds.. | 45 | 6 |

## *DREDGING ENGINE.*

Plates XXIII and XXIV represent the dredging engine, the principal use of which is to hoist the trawls and dredges, but it is provided with additional "gypsy heads" for hoisting boats, &c. It was built by Copeland & Bacon, of New York, according to their patents. It has three gypsy heads (the large one of steel) mounted on the same horizontal shaft, and driven by a double-cylinder half-trunk steam-engine through the intervention of toothed gearing and a modification of Mason's friction clutch. The engines have locomotive valves which are actuated by Stephenson's links and eccentrics; the cranks are cast-iron disks; each pair of eccentrics is cast in one; the cut-off is effected by the lap on the valves. The machine has a friction brake to regulate the "paying out" of the dredge rope, and also a roller guide, with treadle motion, to press the rope aside and prevent the turns from riding. The engine is placed on the main deck, forward of the foremast; it takes its steam from the main boilers and may be exhausted either into the main condenser or into the atmosphere.

Its principal dimensions are as follow:

| | |
|---|---|
| Greatest diameter of the large gypsy head ........ inches.. | 36½ |
| Least diameter of the large gypsy head ........ do.... | 22 15/16 |
| Length of the large gypsy head on line of its axis ........ do.... | 24 |
| Diameter of the inboard end of the small gypsy heads ........ do.... | 21½ |

| | | |
|---|---|---|
| Diameter of the outboard end of the small gypsy heads | inches.. | 11½ |
| Diameter of the middle of the small gypsy heads | do.... | 8½ |
| Length of the small gypsy heads on line of their axes | do.... | 12½ |
| Total length over the three gypsy heads | do.... | 113½ |
| Diameter of the main shaft | do.... | 4½ |
| Diameter of the spur wheel at the pitch line | do.... | 40 |
| Pitch of the teeth of the gearing | do.... | $2\frac{1}{16}$ |
| Width of the face of the gearing | do.... | 6 |
| Width of the face of the friction brake | do.... | 4 |
| Number of journals on the main shaft | | 2 |
| Diameter of the journals on the main shaft | inches.. | 4 |
| Length of the journals on the main shaft | do.... | 13 |
| Diameter of the pinion on the pitch line | do.... | 9 |
| Number of steam cylinders | | 2 |
| Diameter of the steam cylinders | inches.. | 10⅛ |
| Width of the piston trunks fore and aft | do.... | 9 |
| Width of the piston trunks athwartship | do.... | 2¾ |
| Area of cross-section of each trunk | square inches.. | 23½ |
| Net area of the steam pistons, each | do.... | 74.84 |
| Stroke of the pistons | inches.. | 10 |
| Number of journals on the crank shaft | | 2 |
| Diameter of the crank-shaft journals | inches.. | 3¼ |
| Length of the crank-shaft journals | do.... | 6 |
| Diameter of the crank pins | do.... | 1⅞ |
| Length of the crank pins | do.... | 2 |
| Length of the engine base fore and aft | do.... | 60 |
| Width of the engine base athwartship | do.... | 96 |
| Height of the engine | do.... | 53½ |
| Weight of the engine | pounds.. | 6,500 |

## POWER OF THE DREDGING ENGINE.

The wire rope from the dredge passes over the dredging block at the end of the dredging boom, then under a sheave in the heel of the boom, then upward and over a block suspended from the "accumulator," and then to the central (or large) gypsy head of the dredging engine.

The "accumulator" (Plate XLIV), which is a series of rubber "buffers" moving freely on their longitudinal axes by the tension on the dredge rope, becomes a good dynamometer, though its motion is small and its scale fine. By taking a large number of dynamometer readings simultaneously with indicator diagrams from the dredging engines, noting at the same time the actual velocity of the rope as it is measured by the register on the boom sheave and also the speed of the engines, and by taking the mean of these quantities we shall approach very closely to the true conditions.

The gypsy head, by which the wire rope is wound, is curved, and the rope comes in, consequently, on a varying diameter; as the mean velocity of the wire is less than that due to velocity of the center line of the wire wrapped on the smallest diameter of the head it is evident there is a slip. The tendency of the rope, winding on the head, is to coil into a helix, but the inclination of the surface causes the wire to surge toward the central part of the head, with some jar, slipping back at the same time. The loss of power due to this slip, plus the power required to overcome the stiffness of the rope in bending it on the head, will be found by taking the difference between the net power applied to the revolution of the gypsy head and the power indicated by the dynamometer.

The diameter of the smallest part of the gypsy head is $22\frac{15}{16}$ inches, and the diameter of the wire rope is three-eighth of an inch, consequently the velocity of the rope, per revolution of the head, supposing there were no slip nor "creeping", should be $\pi\left(\frac{22\frac{15}{16}+\frac{3}{8}}{12}\right)=6.104$ feet,* but from the reading of the register it is only 5. 924 feet.

The following record is from the mean of a number of observations made by the writer and assistants:

| | |
|---|---|
| Velocity of the rope indicated by the register, in feet, per minute | 148. 600 |
| Velocity of the rope due to the smallest diameter of the gypsy head | 153. 100 |
| Tension on the wire, in pounds, indicated by the dynamometer | 2, 737. 5 |
| Revolutions of the gypsy head per minute | 25. 083 |
| Revolutions of the engine per minute | 107. 500 |
| Indicated horses-power developed by the engine | 15. 563 |
| Indicated horses-power required to work the engine | 1. 453 |
| Horses-power absorbed by the friction of the load | 1. 167 |
| Net horses-power applied to the tension on the rope | 12. 943 |
| Horses-power accounted for by the dynamometer | 12. 327 |
| Horses-power absorbed by the slipping and bending of the rope on the gypsy head | . 616 |

The 15.563 horses-power indicated by the engine is divided as follows:

| | Per cent. |
|---|---|
| For pulling in the rope | 79. 207 |
| For working the engines | 9. 335 |
| For overcoming the friction of the load | 7. 500 |
| For overcoming the slip and bending of the rope | 3. 958 |
| | 100. 000 |

### *REELING ENGINE.*

The reeling engine, Plate XXV, was built by Copeland & Bacon, of New York, and is of the same character of design as the dredging engine. Its object is to stow the wire rope, and to keep a limited tension on that rope when in motion. It is essentially a wrought-iron, built-up drum, mounted on a horizontal axis, driven by a double-cylinder half-trunk steam-engine, through the intervention of toothed gearing and a friction clutch. It has a friction brake to regulate the paying out.

It is provided with a traveling guide, mounted in front of the drum, for guiding the rope smoothly and uniformly upon the drum. The guide is actuated by a double screw, with equal right and left pitches,

*This is on the assumption that the rope travels on a radius due to that of the gypsy head plus its own radius, which has been proved by the passage of the same wire over our register sheave.

similar to that employed on the distributing roller of the Adams printing press; this screw reverses the direction of the guide when it reaches the end of the thread, and the pitch of that thread is equal to the diameter of the rope. It is geared to the drum by toothed gears of equal pitch diameters, one of which has a clutch coupling for disengaging. When paying out rope the guide is disengaged not only from the toothed gears, but also from the double screw, which leaves it free to travel by the pressure of the wire rope upon its sides.

The principal dimensions and the weight of the reeling engine and wire rope are as follow:

| | | |
|---|---|---|
| Diameter of the drum | inches.. | 16 |
| Length of the drum | do.... | 36 |
| Width of the flanges | do.... | 17 |
| Ratio of the gearing | | $4\frac{3}{16}$:1 |
| Number of steam cylinders | | 2 |
| Diameter of the steam cylinders | inches.. | $7\frac{1}{2}$ |
| Stroke of the pistons | do.... | 8 |
| Length of $\frac{3}{8}$-inch diameter wire rope the reel will hold | fathoms.. | 4,500 |
| Weight of the reeling engine | pounds.. | 3,500 |
| Weight of the 4,500 fathoms of wire rope | do.... | 5,940 |
| Total weight of the engine and wire rope | do.... | 9,440 |

The engine receives steam from the main boilers and exhausts it into the main condenser or into the atmosphere as desired.

The wire rope, after leaving the dredging engine, is passed under a governor, *a* (Plate XXV), then to a leading block forward of the engine, and finally back to the reeling engine. The object of the governor is to keep a tolerably uniform tension on the rope, compensating for the surging on the dredging engine, and at the same time accommodating the plane of its sheaves' rotation to the varying direction of the wire rope as it passes. This governor is the invention of Lieutenant-Commander Tanner, the writer being responsible for its proportions. It consists of a sheave revolving in a vertical plane, within a frame which moves on a horizontal axis; the pressure on the sheave being resisted by a spiral spring shown in Plate XXV. To augment the efficiency of the governor the writer added the bell-crank and rod (*b*) to operate a Watson & McDaniel pressure-regulating valve, instead of the throttle as was originally intended. By this simple arrangement the tension on the wire between the dredging engine and the reeling engine controls the motion of the latter. The pressure regulator is automatic, independently of the motion of the engine, and is, therefore, an additional safety; it is similar to the valve shown in Fig. 18, but has a lever and weight instead of a spring as shown in that figure.

*SOUNDING ENGINE.*

The sounding engine (Plate XXVII) was built by Copeland & Bacon, of New York, according to the design and safe patent of Mr. E. C. Bacon. It is a single-cylindered, vertical, half-trunk engine with a locomotive slide valve, actuated by a rod and a pin in the end of the shaft. The cranks are cast-iron disks, one of which is scored to receive a round belt for driving the drum which carries the sounding wire.

The steam cylinder is 5¼ inches in diameter and the stroke of piston is 5 inches. The diameter of the driving wheel (or crank) measured to the center line of the round belt is 13 inches, and the diameter of the drum, measured in the same manner, is 24⅛ inches. The power of the engine is ample and its design is simple. It exhausts into the main condenser, and the cylinder cocks have been piped to discharge into the exhaust passage.

The belt is unshipped when the sounding wire is being paid out, and must be shipped each time it is hove in, which occasions a little delay, but when this is finished and the cylinder clear of water, the engine hauls in the wire at the average rate of about 100 fathoms per minute. The speed of the engine is usually regulated to the tension on the wire as recorded by the dynamometer, the attendant keeping it as nearly as possible at 80 pounds, which is about 40 per cent of the maximum strength of the wire.

*THE STEAM WINDLASS.*

This machine, shown in elevation in Plate XIV, is commercially known as the "No. 4, Providence capstan windlass," and was built by the American Ship Windlass Company. It is situated under the forecastle on the main deck. The windlass portion consists of a horizontal wrought-iron shaft, mounted in journals on cast-iron frames, and carries two gypsy heads, *a a*, two cam-clutch wheels, *d d*, a bevel gear-wheel, and a spiral gear-wheel, which are keyed to the shaft; it also carries a pair of chain-holders, *b b*, and friction-breaks, *c c*, which are not keyed to the shaft. The bevel gear communicates motion to or from the capstan, and may be uncoupled by unkeying the pinion; the spiral gear is for communicating the motion of the engine to the windlass. By revolving the cam-wheels, *d d*, a fraction of a revolution they are coupled to the chain-holders, *b b*, by which means the chain-holders may be made to revolve with the shaft at pleasure, and by this means the chain may be veered to one anchor while the other is hoisted; both may be hoisted or both veered while the engine is in motion. The capstan is on the forecastle deck and is keyed to the shaft or spindle *f*. This capstan, which is revolved through the bevel gears, is used for catting and fishing the anchors, for hauling upon hawsers, hoisting boats, &c.

The engines are placed horizontally beneath the forecastle deck. They rotate in the same plane, are placed at an angle of 90°, and act upon the same crank-pin. They have locomotive slide valves actuated by "loose" eccentrics, by which means the engines are reversible. The cylinders and their respective cross-head guides are in one casting, while the outer cylinder heads only are movable. The cylinders are sufficiently large to hoist both anchors at ordinary depths of water, with 10 or 12 pounds of steam per square inch of piston, and for this reason we placed a pressure-regulating valve (Fig. 18) in the steam-pipe; by tightenning or slacking the screw we can adjust the steam in the cylinder to any pressure inside the limit of the boiler pressure.

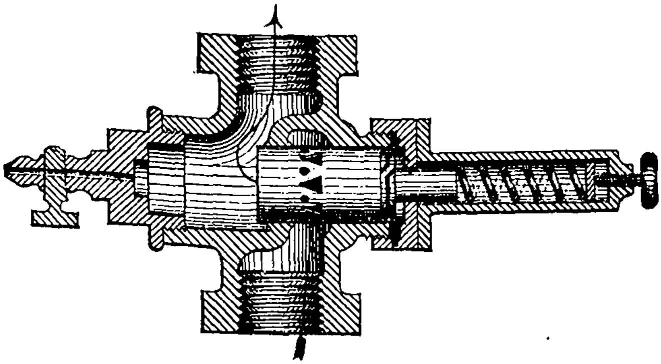


Fig. 18.

The engine takes its steam from the main boilers, and exhausts into the main condenser or into the atmosphere, as desired.

The principal dimensions of the steam windlass are as follow:

| | | |
|---|---|---|
| Diameter of the windlass shaft | inches.. | $3\frac{3}{4}$ |
| Smallest diameter of the gipsy heads | do.... | $10\frac{1}{2}$ |
| Largest (inboard) diameter of the gipsy heads | do.... | 15 |
| End (outboard) diameter of the gipsy heads | do.... | $13\frac{1}{2}$ |
| Length of the gipsy heads | do.... | $13\frac{1}{2}$ |
| Number of whelps on the chain-holders | | 5 |
| Size of the starboard chain (diameter of iron) | inches.. | $1\frac{3}{8}$ |
| Size of the port chain (diameter of iron) | do.... | $1\frac{3}{16}$ |
| Chain per revolution of the starboard chain-holder | fathoms.. | $\frac{3}{8}$ |
| Chain per revolution of the port chain-holder | do.... | $\frac{9}{17}$ |
| Diameter of the friction-brakes | inches.. | 23 |
| Width of face of the friction-brakes | do.... | $2\frac{1}{2}$ |
| Total length of the windlass shaft | do.... | 92 |
| Number of teeth in the bevel spur-wheel | do.... | 49 |
| Number of teeth in the bevel pinion | | 12 |
| Number of teeth in the spiral gear-wheel | | 52 |
| Number of convolutions of the "worm" screw thread | | 4 |
| Outer diameter of the worm screw | inches.. | 8 |
| Radial length of the worm-screw threads | do.... | $1\frac{1}{4}$ |
| Pitch of the spiral gear | do.... | $1\frac{5}{8}$ |
| Diameter of the capstan spindle | do.... | $3\frac{7}{16}$ |
| Smallest diameter over the capstan whelps | do.... | $10\frac{3}{4}$ |
| Projected height of the capstan drum | do.... | 14 |
| Number of steam cylinders | | 2 |
| Diameter of the steam cylinders | inches.. | 8 |
| Stroke of the pistons | do.... | 8 |
| Diameter of the piston rods | do.... | $1\frac{3}{8}$ |
| Diameter of the connecting rods at the neck | do.... | $1\frac{1}{2}$ |
| Diameter of the crank pin | do.... | $2\frac{3}{4}$ |
| Length of the crank-pin journal | do.... | 6 |

| | | |
|---|---|---|
| Diameter of the cross-head pins | inches | 2 |
| Length of the cross-head pin journals | do | 2 |
| Ordinary speed of the engine, in revolutions, per minute | | 300 |
| Rate of heaving in the starboard anchor, in fathoms, per minute | | 4 |
| Rate of heaving in the port anchor, in fathoms, per minute | | $3\frac{4}{10}$ |
| Length of the starboard chain | fathoms | 120 |
| Length of the port chain | do | 120 |
| Weight of the starboard chain | pounds | 14,745 |
| Weight of the port chain | do | 9,283 |
| Weight of the starboard anchor and stock | do | 2,760 |
| Weight of the port anchor and stock | do | 1,950 |
| Total weight of both anchors and chains | do | 28,737 |
| Weight of the steam capstan windlass, complete | do | 9,000 |

The engine makes from 275 to 325 revolutions per minute; at 300 revolutions the velocity of the starboard chain would be 4 fathoms per minute and the port chain three and four tenths (3.4) fathoms per minute.

### *STEAM STEERING GEAR.*

The steam steering gear, known as the "steam quartermaster," was built by the Pusey & Jones Company according to the patents and design of Mr. Andrew Higginson, of Liverpool, England. The machine may be shifted from steam to hand power by the motion of a clutch, and the same wheel is used for steering by steam as by hand. Like other improved steam steerers the valve is arranged to reverse the engine by changing the ports, and an automatic arrangement is provided to bring the valve to its middle position (and stop the engine) by gearing from the engine itself.

There are three half-trunk, oscillating, single-acting steam cylinders arranged at angles of 120 degrees from each other, all acting on the same crank pin, after the "brotherhood" system. The cylinders are $4\frac{1}{4}$ inches diameter and 5-inches stroke of piston. On the crank shaft is a toothed pinion which gears into a spur-wheel; on the shaft of the spur-wheel is keyed a second pinion-wheel which gears into a second spur-wheel, making the ratio of gearing nearly 36. The second pinion and the second spur-wheel are keyed to hollow cast-iron shafts, through which the other two shafts, respectively, work.

Motion is communicated to the tiller chains by a chain-holder (or "wild-cat") similar to those used on patent windlasses. On the extended portion of the upper shaft there is a screw thread on which a large nut works; this nut is clutched to one of the pinions; on the forward end of the same shaft is placed the steering wheel, 5 feet 4 inches in diameter.

The motion of the steering wheel communicates like motion to the clutch-nut, which, in turn, imparts motion to the slide-valve of the engines; and the motion of the engines, transmitted through the gearing described, revolves the clutch-nut upon its thread in the opposite direction, and brings the valve back to its central position. By this contrivance the engine ceases its motion directly the helmsman brings his wheel to rest. The slide-valve, is common to the three cylinders; it is circular in form, and revolves upon its center by gearing from the steering wheel; its partitions or ribs divide it into three valves (one for each cylinder), though it is one casting. The exhaust is delivered into the steam-tight box which incloses the engine, and all the oil the crank-pin and crank-shaft journals ever receive must come with the steam worked through the cylinders. It cannot be hoped to keep the engine-box and main journal-boxes tight against air-leaks, and when the steering engine is exhausted into our main condenser we find a diminution of vacuum. The mechanical performance of the machine is all that can be desired. The engine starts the moment the wheel is moved and stops with equal promptness; the power of the machine is ample and it is comparatively light and compact. The toothed gears are rather noisy when steam is used.

## D.—APPARATUS FOR DEEP-SEA RESEARCH.

Sigsbee's machine for sounding with wire is shown in Plate XXVII as in position on board the Albatross.

*Nomenclature of the machine and its appointments.*

*a.* Cast-steel bed plate.
*b.* Oak bed plate.
*c.* Cast-steel frames for reel.
*d.* Steel reel.
*e.* Register.
*ff.* Guide frames.
*g.* Cap.
*h.* Accumulator-pulley.
*i.* Accumulator-rope attached to pulley.
*j.* Friction rope.
*k.* Hinged frame.
*l.* Cylinder of hoisting engine.
*m.* Driving pulley.
*n.* Ratchet crank.
*o.* Tightening-pulley.
*p.* Rope belt.
*q.* Belt tightener.
*r.* Flexible exhaust-hose.
*s.* Flexible steam-hose.
*t.* Strut.
*u u.* Castors.
*v.* Lewis bolt.
*w.* Brace.
*x x.* Guys.
*y.* Guide pulley.
*z.* Auxiliary brake.

The machine is placed on the port side of the topgallant forecastle, near the after end, and is rigged for reeling in.

The two bed plates *a* and *b* are firmly bolted together, the outboard end resting on a broad friction plate of brass (not shown in the sketch), one end of which is secured to the forecastle rail and the other supported by the strut *t*, which, by means of right and left hand screws on its ends, not only holds the friction plate in position, but regulates the height of the inboard end, so that the bed plate rests fairly on it at all times.

The friction plate has a groove along its center line through which passes a compressor bolt (not shown in the sketch), the upper end of which is secured to the bed plate, the lower end carrying a thread and nut. The inboard end of the machine is supported by a pair of brass castors, *u u*, arranged to conform to any direction in which it may be moved, and by simply tightening the compressor it is held in any desired position. For additional security when rigged out for use, a Lewis bolt, *v*, is set in the deck, through which a lashing may be passed to an eye-bolt on the bed plate.

The reel *d* is of steel strongly bolted; the sides are of boiler plate; the barrel is forged and welded; the hub is of cast iron, and the shaft of steel. The diameter of the reel is 22.89 inches, a turn of the wire equaling exactly one fathom, and it will hold about 6,000 fathoms of No. 11 music, 0.028 inch in diameter, the wire used in deep-sea sounding.

The friction ring, with the V-groove common to all sounding reels, is bolted to the right flange. The shaft carries a ratchet wheel on the left of the reel and a worm wheel on the right, into which the register *e* is geared.

The guide frames *f f* are hollow steel tubes, their bases screwed into the cast-steel hinged frame *k*, and their tops tied together by a steel casting which carries two pulleys, over which runs the accumulator-rope *i*. A neat copper cap *g* covers the apertures in the guide frames and protects the spiral accumulator springs inclosed within them.

The accumulator-pulley *h* is of brass, with brass guards over the upper half to prevent the wire from flying out of the score.

The frame is cast steel, having cross-heads working on guides bolted to the inner sides of the frames, with small grooved rollers at either end, the upper one for the accumulator-rope *i* and the other for the friction line *j*, the whole being very light in order to reduce its inertia to the minimum.

The spiral accumulator springs referred to above are 28½ inches long and 2⅛ inches outside diameter. They are made of No. 4 (American gauge) steel wire, and have an elastic limit of about 4 feet, with a weight of 150 pounds applied to the end of the wire, which will give the latter a cushioning of about 8 feet before it can be subjected to a violent jerking strain.

Graduated scales are so placed on the guide frames that the accumulator springs act also as a dynamometer, showing at all times the strain on the wire.

The reeling engine *l* has its frame, which is of cast iron, in one piece bolted to the bed plate *a*. The cylinder is vertical (Copeland & Bacon's patent trunk) and 5½ inches in diameter.

The driving pulley *m* has a V-groove corresponding to that on the reel over which the rope belt *p* is rove. The tightening-pulley *o* actuated by the belt tightener *q* gives the belt the desired tension.

The ratchet crank *n* is used in working water out of the cylinder and also, in starting, to assist the crank over the center.

Steam is received through the flexible hose connection *s*, and the exhaust is carried through a similar one *r*, both having brass connections flush with the forecastle deck.

The guide frames are held rigidly in position by the guys *x x* and the brace *w*. The guide pulley *y* is shown in position, and the grating hinged to the side for convenience in handling sinkers, &c., is shown in the sketch.

The machine being rigged and in place, to take a sounding, reeve the stray line over the accumulator-pulley and down through the fair-leader, bend on the sounding rod with sinker attached, reeve the friction line *j*, as shown in the sketch, bringing the standing part up over the V-groove on the reel and making it fast to its hook on the bed plate between the reel and the engine; the hauling part being led out under and abaft the reel where it is attended by the officer in charge or a careful man. The belt is, of course, thrown off when sounding. Everything being in readiness, the sinker is carefully lowered to the water's edge, either by means of the crank or friction line (the former being preferable), the small lead is bent to the stray line, the thermometer and water specimen cup are clamped on, the register is set at zero, and the vessel laid properly. The officer in charge takes his station on the grating outside of the machine, where he has a view of the wire at all times. A seaman is at the friction line; another, crank in hand, stands on the left; another at the brake *z*, on the right, also with a crank, and a fourth is on the grating outside to attend the guide pulley, handle sinkers, &c. A fireman is stationed at the engine. The record keeper takes a favorable position for reading the register, and the officer in charge gives the order, "Let go!" The friction line is then given a tension that allows the sinker to descend from 70 to 110 fathoms per minute, as may be considered prudent, the record keeper timing each 100 fathoms.

The officer in charge maneuvers the vessel to keep the wire vertical. The instant the sinker strikes bottom the reel is stopped by the friction line, assisted, if necessary, by the brake. The record keeper notes the number of turns indicated by the register, the cranks are shipped and sufficient wire hove in by hand to clear the bottom, when they are unshipped and laid one side; the belt is adjusted, steam admitted to the cylinder, and the ratchet crank brought into requisition to assist in starting with a gentle motion. As soon as the engine works uniformly the speed is increased and the wire hove in at the rate of 100 to 150 fathoms per minute, each 100 fathoms being timed by the record keeper the same as when going out. The last 10 fathoms are reeled in by hand. The thermometer is read by the officer in charge and verified by the record keeper; the specimen cup of water is turned over to the medical officer, who either determines the specific gravity of the water or preserves it in specially prepared bottles to be sent to the laboratory at Washington for chemical analysis.

To secure the machine when not required for use, remove the register *e*, belt tightener *q*, ratchet crank *n*, and the steam and exhaust hose *s* and *r*, and stow them away. Unship the reel *d* and stow it in its tank, which contains sufficient sperm oil to cover the wire. Cast off the lashing *v*, loosen the compressor, and run the machine in; slacken the brace *w* and guys *x x*, and bring the head of the guide frames *f f* inboard until they are horizontal, when the after one will rest in a crutch on the engine frame. The frame *k* will then be in a vertical position, the guide pulley will be lowered between the guide frames *f f*, the accumutator pulley *h* unshipped, and the upper half of the guide frames turned back upon the lower portion, a double-hinged joint being provided for the purpose. The machine will then be turned fore and aft on the friction plate close to the forecastle rail, where it is held in position by the compressor. A painted canvas cover is drawn over all and secured under the bed plate to protect it from the weather.

The clamp is a cylindrical piece of lignum-vitæ about 6 inches in length by 4 in diameter, divided longitudinally through its center, and right and left hand screws introduced, by means of which the halves can be separated or brought together. It is used for holding the sounding wire, when, from any cause, it is necessary to slacken it between the reel and guide pulley. It is usually carried in an appropriate socket on the bed plate, ready for instant use.

Defective splices are usually discovered while reeling in, and the clamp is brought into requisition to hold the wire while a new splice is made. The machine had some defects when received from the maker, D. Ballauf, Washington, D. C., although the workmanship was performed in the best possible manner. The Sigsbee reel, weighing about 90 pounds, proved unequal to the crushing strain to which it was subjected in depths exceeding 2,000 fathoms. We then strengthened one, adding about 40 pounds in weight, which did good service in depths up to 3,000 fathoms, but finally collapsed. Two heavier reels, weighing 150 pounds each, were then constructed. Sigbee's general plan was followed, the extra material being placed where former reels had been deficient in strength. We have experienced no further trouble in that direction, and the increased weight is hardly noticed in practice.

The round leather belts furnished with the machine were useless, and were replaced by round gutta-percha belts, which answered very well so long as kept away from the cylinder of the reeling engine. This, however, was difficult at times, and when they did accidentally touch it the gutta-percha would melt almost as quickly as tallow The belt finally adopted is a simple grommet strap of 18 or 21 thread ratlin stuff which is quickly made on board ship, does its work well, and is very durable.

### BELT TIGHTENER.

The tightening pulley was formerly adjusted by hand, requiring the united strength of two or three men; even then the belt would frequently slip. To remedy this evil the belt tightener (Plate XXVIII) was designed. I made a rough sketch of it, and Passed Assistant Engineer G. W. Baird, U. S. N., reduced it to the proper proportions, and superintended its construction. Fig. 1 shows a general view of the apparatus ready to be attached to the vertical shaft carrying the tightening pulley. This is done by placing it over the end and inserting the pin, Fig. 2, in a hole in the shaft, as shown in Plate XXVIII. By the use of this simple appliance the belt was promptly brought to the desired tension and our troubles in that direction ceased.

### THE RATCHET CRANK (PLATE XXVIII).

The reeling engine having a single cylinder, it was found necessary in starting to open the throttle wide, and assist the crank over the center by hand, when it would start off at great speed, bringing undue strain on the wire. This difficulty was partially remedied by shipping the reel cranks and starting by hand, thus attaining the gentle motion desired. The only objection to this arrangement was the difficulty inexperienced men had in unshipping the cranks while the engine was in motion. A rachet crank on one end of the crank shaft seemed to me the simplest and most direct remedy, as it would always be in position for instant use; and, instead of unshipping it when the engine was working, it would remain in place, hanging vertically as shown in Plate XXVII. I made a rough sketch, and gave it to Passed Assistant Engineer Baird, who reduced it to the proper proportions, made a working drawing, and superintended the making of the crank, which has performed its work admirably. Fig. 1 is a front, and Fig. 2 a side view of the ratchet crank.

### TANNER'S SOUNDING MACHINE (PLATE XXIX).

This machine was designed for service on board the United States Fish Commission steamer Fish Hawk, where it was used in depths not exceeding 800 fathoms. It is used on board this vessel when working in 200 fathoms or less, and for navigational purposes (where it is very useful, being always in readiness for sounding).

It is mounted on the port rail forward of the fore-rigging.

NOMENCLATURE.

*a*. Spindle.
*b b*. Frame.
*c*. Arm.
*d d*. Reel.
*e*. Guide pulley.
*f*. Fair-leader.
*g g*. Cranks.
*h*. Register.
*i*. Pin.
*j*. Reel-tackle block.
*k*. Accumulator spring.
*l l*. Stray line.
*m*. Friction rope.
*n n*. Accumulator rope.
*o*. Eye for friction rope.
*p*. Socket.
*q*. Set screw.
*r*. Guide.
*s*. Lead.
*t*. Clamp.

The spindle is made of iron, turned, slightly tapering, and screwed firmly into the base of the frame *b b*. There is a brass bearing on the rail through which the spindle passes, the lower end resting in the socket *p*. The set screw *q* holds the machine in any desired position.

The frame above mentioned is of brass, cast in one piece, is bored to receive the reel shaft, and has appropriate lugs for the pawl and register. The reel *d d* is of cast brass, 22.89 inches in diameter, the initial turns of wire equaling 1 fathom, increasing as the score is filled, its capacity being about 2,000 fathoms.

The V friction groove, common to all sounding reels, is on the right flange, and is part of the same casting.

The cranks *g g*, by which the reel is turned, have conical friction surfaces, which are brought into contact with similar surfaces on the ends of the reel shaft by moving the right crank one-half a revolution ahead, the left one remaining clamped at *t*, or held firmly in the hand. The reverse motion releases the reel, allowing it to revolve freely without moving the cranks.

On the left side, between the frame and crank, is a worm wheel which operates the register. The ratchet and pawl are shown on the right, between the frame and crank.

The arm *c*, which supports the guide pulley *e*, is of iron, hinged between lugs on the frame, and held in position by the pin *i*. The small metal reel-tackle block *j*, projecting from the arm, is part of a tackle for suspending the reel when mounting or dismounting.

The guide pulley *e* is of brass, with a V groove, the upper portion being covered with a guard to prevent the wire from flying off. The pulley is hung on a frame, having a spindle extending into the metal casing above, the small arm *k* being confined to its upper end by a nut.

A spiral accumulator spring surrounds the spindle, and is compressed by the weight of the lead *s*, giving the guide pulley *e* a vertical play of about 3 inches. The fair-leader *f* swings freely in and out, but is rigid laterally, and guides the wire fairly into the score of the pulley. The aperture through which the wire passes is lined with highly tempered steel.

The standing part of the friction rope *m* hooks to the eye *o* in the frame, is carried around the reel in the V groove, and the free end is secured to the bight of the accumulator rope *n n* at *m*; one part being hooked to the small arm *k*, and the other made fast to the arm *c*, for the purpose of supporting the friction rope when it is slack and preventing its flying out of the V groove. The guide *r* leads the wire fairly on the reel. The machine revolves freely, its weight being sustained by the socket *p*. The set screw *q* holds it in position.

To take a sounding, the wire being on the reel and the latter mounted, haul the friction rope hand-taut before the lead is attached, and while the guide pulley is up in place. In this position it requires a strong man to move the reel, but the lead being bent and suspended, it compresses the accumulator spring, and drags the pulley down sufficiently to slack the friction rope and allow the reel to revolve with comparative freedom. The instant the lead strikes the bottom, however, or the weight is removed from any cause, the pulley flies up, putting a tension on the friction rope, which instantly checks the reel.

The friction rope being properly adjusted, reeve the stray line over the guide pulley and bend on the lead. Throw the pawl out of action, attend the friction rope, and lower the lead to the water; set the register at zero, and take the cast, governing the speed of descent by means of the friction rope, which is grasped by the right hand at *m*. As soon as the lead reaches bottom, bring the cranks into action by turning the right one a half turn ahead, read the register, unclamp the left crank at *t*, throw the pawl into action and heave in. When the lead is up, clamp the left crank at *t*, move the right one a half turn back, thus throwing them out of action, and the machine is ready for another cast.

If there is much sea running, it is necessary to use a light lead attached to the upper end of the stray line to prevent kinking the wire when slackened by the vessel's pitching.

To dismount the reel reeve the tackle *j* and take the weight off the reel; remove the nut on the left or after end of the reel shaft, grasp the ratchet wheel with both hands, and withdraw the shaft and right crank, leaving the left crank and worm wheel in position; swing the reel clear and lower it on deck, returning the shaft and crank to their place. If the frame is to remain on the rail, remove the register, withdraw the pin *i*, and bring the arm and guide pulley down to the frame *b b*, turn the machine inboard, and tighten the set screw to hold it in position.

To wholly dismount the machine for transportation or storage, remove the reel, cranks, and register, disconnect the arm at *i*, and unscrew the spindle from the frame. The total weight is 135 pounds.

In sounding with wire it is absolutely necessary to keep it taut, slack wire always kinks, and a kink is followed by a break. It is also liable, when slackened, to fly off the reel.

If the ordinary sounding wire (No. 11 music, Washburn and Moen) is used, it is necessary to protect it by keeping the reel in oil when not in use; but with a view to having the machine ready for service at all times, we substitute No. 21 wire, and allow it to remain on the reel without other protection than an occasional oiling. It rusts as a matter of course, but we find by experience that it lasts from six to eight months.

It is hardly necessary to observe that this heavy wire is practicable in depths of a few hundred fathoms only.

The machine is protected from the weather by a painted canvas cover.

## PIANO-FORTE WIRE FOR SOUNDING.

The piano wire used for sounding by the vessels of the United States Fish Commission is made by the Washburn & Moen Manufacturing Company, of Worcester, Mass., and is called by them No. 11 music. It is 0.028 of an inch in diameter, corresponding to No. 21 American and No. 22 Birmingham gauge. It is furnished by the manufacturers in sealed tin cans containing 50 pounds each, or about 3,850 fathoms in six coils 8½ inches in diameter, containing about 640 fathoms in two lengths.

The coils are double, wrapped with heavy paper, a liberal sprinkling of whiting being inclosed with the wire. It is practically indestructible as long as it remains in the sealed can, and if put in a dry place will keep well in the paper wrapping after it is removed from the can. We have never lost a fathom of American wire from rust in the coil. It is highly polished and resists rust remarkably well when in use. Its weight is 1.3 pounds per 100 fathoms in air and 1.13 pounds in sea water. Its tensile strength is quite uniform, the mean of several tests giving the breaking strain 207 pounds. The cost is $1.50 per pound.

We have also used English wire from Messrs. Webster & Horsfall, Birmingham, England, of the same size, No. 22 Birmingham gauge (0.028 inch diameter), corresponding to No. 21 American gauge or No. 11 music.

The tensile strength from the mean of several tests was 214 pounds, practically the same as the American wire. The cost is 75 cents per pound.

It possesses certain disadvantages, however, for use on board ship, which tend to counteract the advantages derived from its cheapness at first cost. It is received from the makers in 18-inch coils, made up of pieces from 100 to 400 fathoms in length, the coils weighing about 60 pounds each. They are wrapped in oiled paper, which is liable to be torn in handling, exposing the wire to the sea air, when it is soon ruined by rust. The losses from this cause prove at times quite serious. When this wire is used for sounding it is advisable to put the whole supply on reels of some sort and place them in oil at once, where it will remain free from rust until it is required for use.

This wire is less highly polished than the American and for this reason rusts more quickly, requiring greater care when in use.

### METHODS OF SPLICING WIRE.

The following simple and effective method was formerly used with good results, and, although no longer followed, it is worthy of mention. Clean the ends of the wire thoroughly for two feet and lay them together with about eight turns; wind the ends and two intermediate points with a few turns of very fine annealed wire; cover them with solder and smooth the surface with knife and sand paper.

### MAY'S SPLICE (PLATE XXX).

Lieut. Sidney H. May, U. S. N., had general charge of the sounding apparatus during our first year's work, and among many useful suggestions was the wire splice above mentioned, which was used with such excellent results that we finally adopted it in preference to all others.

The ends are filed to a long tapering point, and thoroughly cleaned for about a foot, then laid together with four turns and a seizing of very small annealed wire put on near each end (Fig. 2). The tapered ends, which have become annealed during the filing process, are wrapped closely around the standing parts, and the whole splice is covered with solder by running it back and forth through a groove in a piece of board, in which a small quantity of solder is kept in a fluid state by the application of a soldering iron. It is smoothed down with knife, file, and sand paper. Fig. 3 shows the splice partially covered with solder, and Fig. 4 the completed splice; the total length of which is from 6 to 7 inches.

The ends are quickly tapered by grasping the wire with nippers or a small hand-vise, and laying it on a plane hard-wood surface for filing.

### SPIRIT LAMP FOR SOLDERING SPLICES OF SOUNDING WIRE (PLATE XXXI).

The soldering iron has been partially superseded by the spirit lamp for soldering sounding wire. A quantity of solder is placed in the cup over the flame, where it is soon melted. The wire having been prepared as directed, is drawn back and forth through the fused metal until a sufficient quantity adheres, when the splice is smoothed in the usual manner.

## METHOD OF SPLICING WIRE TO STRAY LINE (PLATE XXX).

In sounding with wire it is necessary to have a flexible cord between the sinker and wire to take up any slack that may occur when the former strikes the bottom. This cord is known as stray line, Fig. 5; cod line is used for the purpose, and is attached to the wire in the following manner: The wire is stuck twice against the lay 5 inches from the end of the stray line, then passed with the lay from 4 to 6 inches, the end stuck twice against the lay, and served over with sail twine. The wire is then passed with the lay to the end of the line, the strands trimmed down and served over with twine, and a seizing is also put on over the wire first stuck against the lay. This makes a neat and secure splice, which passes readily over the accumulator pulley without danger of catching on the guards or fair-leader.

## THE MEASURING REEL (PLATE XXXII).

The service reel being 22.89 inches in diameter, the initial layer of wire, 0.028 inch in diameter, equals one fathom to the turn, the next layer a trifle more and so on, until with a full reel the error would be about 10 inches to the turn; and as the register indicates the turns only, a correction must be applied to its reading. In order to determine the amount of error, the wire is measured as it is wound on the service reel by means of the measuring reel, which is made of cast iron, is 22.89 inches in diameter, and mounted in a cast-steel frame bolted to a heavy oak bed plate. On the reel shaft between the reel and frame is a worm wheel which actuates the register.

## THE BLADE (PLATE XXXII).

The blade is used in connection with the measuring reel for transferring wire from the coil to the service reel. Fig. 1 is a longitudinal sectional elevation showing the method of construction. It is made of oak with the following exceptions: an iron screw and washer at the top of the spindle, which supports the reel; a galvanized iron washer, which is placed on the reel over the coil of wire to prevent slack turns from flying off; and a galvanized iron rim around the base of the reel to confine slack turns that might fall between it and the bed. Fig. 2 shows the reel ready for service.

## TRANSFERRING AND MEASURING WIRE.

The service reel is mounted on the Sigsbee sounding machine, which is set at any desired angle with the deck; the hand cranks and register are shipped, and the reel carefully cleaned and oiled.

The measuring reel is placed directly in the rear of the sounding machine, and the blade in the rear of the reel and in line with both. The sealed tin can in which the wire is received is opened, a coil taken out, removed from the paper, and placed on the blade; the wire stops are cut, the free end of the wire led out, and three turns taken around the measuring reel in such a manner that the register will count ahead during the transfer. The end is then taken to the service reel, and clinched through the hole provided for this purpose. The two men at the blade reel back the slack wire, the record keeper sets both registers at zero, and takes his station for reading the one on the measuring reel, the officer in charge watching that on the service reel. The cranks are manned and the transfer begins, the reel being turned at any desired speed. One of the men at the blade puts a slight tension on the wire by applying an old piece of canvas in his hand to the iron rim at the base of the reel.

The record keeper calls out "mark!" at every 50 fathoms registered by the measuring reel, the officer in charge reads the register on the service reel at the same instant, and this being recorded the difference between the two readings shows the error at that point. This process being carried on until the reel is filled, furnishes data from which a correction table is made, by which soundings can be corrected readily by inspection.

A correction table once made for a certain reel is always available for that reel, or any others of the same dimensions, provided the amount of wire on it is less than that for which the table was constructed.

*Correction table.—Reel No. 1.*

| 0 | 500 | 1,000 | 1,500 | 2,000 | 2,500 | 3,000 | 3,500 | 4,000 | 4,500 | 5,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 53 |
| | | | | | | | | | 49 | 102 |
| | | | | | | | | 43 | 92 | 145 |
| | | | | | | | 38 | 81 | 130 | 183 |
| | | | | | | 32 | 70 | 113 | 162 | 215 |
| | | | | | 27 | 59 | 97 | 140 | 189 | 242 |
| | | | | 22 | 49 | 81 | 119 | 162 | 211 | 264 |
| | | | 16 | 38 | 65 | 97 | 135 | 178 | 227 | 280 |
| | | 11 | 27 | 49 | 76 | 108 | 146 | 189 | 238 | 291 |
| 0 | 7 | 18 | 34 | 56 | 83 | 115 | 153 | 196 | 245 | 298 |

ILLUSTRATIVE EXAMPLES.

| | | |
|---|---|---|
| Number of turns on the reel | | 4,500 |
| Turns registered in sounding | | 2,500 |
| Turns remaining on reel | | 2,000 |
| Corrections | fathoms.. | 189 |
| Turns | do .... | 2,500 |
| Depth | | 2,689 |

The table given above illustrating our method of correcting soundings gives the error for every 500 fathoms; but that in actual use on board gives it for every 50 fathoms and at any intermediate point it can be ascertained by a simple interpolation. This table is the work of Lieut. Seaton Schroeder, U. S. N.

SIGSBEE'S DETACHER (PLATE XXXIII.)

[Used in connection with a modification of Captain Belknap's sounding cylinder No. 2.]

The first device for detaching the sinker and bringing up a specimen of the bottom in deep-sea sounding was the invention of Passed Midshipman John M. Brooke, U. S. N., about 1852-'53. It consisted of a small iron rod carrying a trigger at the upper end, and a small tube at the other extremity, in which several goose-quills were placed for bringing up bottom specimens. The sinkers were much like those of the present day, a shot with a hole through it.

To prepare for a sounding the line was bent to the trigger, the goose-quills were adjusted in the tube, the sounding rod was inserted in the hole through the sinker, the slings were passed under the sinker and hooked to the trigger, which sustained the weight until the sounding line was slackened by its striking the bottom, when the trigger capsized by its own weight, the slings slipped off and the sinker was released.

Sands' cup was the next device brought into use in the Navy and Coast Survey, but Brooke's apparatus was in general use until the "Hydra" machine as improved by Staff Commander Baillie, R. N., was adopted.

The Fitzgerald machine was used to some extent in the British navy.

The next marked improvement is due to Capt. Geo. E. Belknap, U. S. N., who while in command of the U. S. S. Tuscarora made the most remarkable series of deep-sea soundings on record. Following in his footsteps Lieut.-Comdr. C. D. Sigsbee, U. S. N., made some modifications in the Belknap cylinder, and added to it a detaching trigger of his own, reducing it to its present form as shown in the plate.

If the various types of sounding cylinders and detachers made since Brooke's invention became known were examined, it would be seen that they are all modifications of his system, as in sounding with wire all recent improvements in that direction have been modifications of Sir William Thompson's admirable system.

NOMENCLATURE.

*a*. Cylinder.
*b*. Screw joint.
*c c*. Upper and lower guide stem.
*d*. Cylindrical ring.
*e*. Valve seat.
*f*. Poppet valve.
*g*. Valve stem.
*h*. Spiral valve spring.
*i*. Hollow cone.
*j*. Perforated plate.
*k*. Swivel.
*l*. Pawl.
*m*. Tumbler.
*n*. Spring.
*p*. Apertures for escape of water.
*q*. Sinker.
*r*. Iron wire bail.

A longitudinal sectional elevation of Sigsbee's detacher and his modification of Captain Belknap's sounding cylinder No. 2 is shown in Fig. 1; a side view is seen in Fig. 2, with the sinker hung. Fig. 3 shows a plan view of the cylinder and a longitudinal sectional elevation of the detacher. Fig. 4 shows a back view of the detacher. The perforated plate *j* and cylindrical ring *d* are shown in Fig. 5, and an enlarged view of the hollow cone *i*, cylindrical ring *d*, apertures *p* for the escape of water, and the upper end of the cylinder *a* are shown in Fig. 6.

The cylinder *a* (Fig. 1) is attached rigidly to the guide stem *c*, the poppet valve *f* is on its seat at *ee*, and the hollow valve stem encircles the guide stem *c*, and is held in place by the spiral valve spring *h*. The hollow cone *i* moves freely on the upper guide stem; *dd* is a cylindrical ring forming the base of the cone *i*, and, when raised during the descent of the sinker, as in Fig. 1, it permits the water to flow freely from the cylinder through the apertures *pp* into the cone at *dd* and out at *pp*; but during the ascent it rests on the top of the cylinder *a*, closing the apertures (Fig. 6) against all outward pressure.

To take a sounding and bring up a specimen of the bottom, bend the stray line to the swivel *k*, slip the sinker on and hook the bail *r* on the tumbler *m*; lock the pawl and tumbler and suspend the weight of sinker and sounding rod from *k*, where it will remain until the weight is relieved by the sinker striking the bottom. The pawl will then assume a horizontal position from its own weight (Fig. 3); the tumbler will be thrown out of action by the spring *n*, assisted by its excess of weight at the point of contact with the bail *r*, thus releasing the sinker.

When the cylinder strikes the bottom, the valve *f* will be forced up, and more or less of the interior space of the cylinder will be filled with a specimen of the bottom soil. As soon as the ascent begins the valve *f* reseats itself, and, the apertures at the top being closed, the specimen is hermetically sealed. On reaching the surface it is removed by unscrewing the cylinder at *b*.

This apparatus has performed its work perfectly; in fact it has never failed to detach the sinker and bring up a specimen when the bottom was reached. They were furnished by D. Ballauf, Washington, D. C., at $15 each.

## SINKERS.

All soundings exceeding the capacity of an ordinary hand lead-line are made with wire; in depths of over 2,000 fathoms a 60-pound detachable sinker is used; between 1,000 and 2,000, a 35-pound sinker, also detachable; and from 500 to 1,000 fathoms, an ordinary 35-pound ship's lead is used and reeled back. In depths less than 500 fathoms lighter leads, from 18 to 25 pounds weight, are used and reeled back, the bottom specimen being brought up by the arming.

The detachable sinkers are made of cast iron and are furnished by the ordnance department, navy-yard, Washington, D. C., fitted and bailed ready for use.

## SIGSBEE'S WATER-SPECIMEN CUP (PLATE XXXIV).

The Sigsbee water-specimen cup, or water bottle, is designed to bring a specimen of water from any desired depth for the purpose of analysis or to determine its specific gravity. The valves are closed mechanically and cannot be opened again, except by hand, therefore these cups may be used in series, any desired number being sent down on the same line.

### NOMENCLATURE.

*a.* Cylinder.
*b.* Lower valve seat.
*c.* Detachable upper valve seat.
*d.* Upper poppet valve.
*e.* Lower poppet valve.
*f.* Valve stem.
*g.* German silver compression spring.
*h.* The frame
*i.* German silver removable sleeve.
*j.* Brass pin.
*k.* German silver shaft.
*l.* Screw thread (44 to the inch).
*m.* Screw thread (44 to the inch).
*n.* German silver propeller.
*o.* Hub.
*p.* Inside screw thread (44 to the inch).
*q.* Guide cap.
*r.* Beveled lugs.
*s.* German silver bushing.
*t.* German silver screw cap with milled head.
*u.* Beveled slots.
*v.* Inside screw thread.
*w.* Clamp lugs.
*x.* Clamp pivot screw.
*y.* Phosphor bronze clamp wire.

The water bottle is made of brass, except such parts as are mentioned as being made of other metals.

The following remarks upon its working are taken from Sigsbee's Deep-sea Sounding and Dredging:

"To adjust the valves hold the upper valve firmly, and unseat the lower valve by screwing it upward," the key (Fig. 5) being applied to the lower end of the valve stem *f* for the purpose. "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 adjust the valve only after the cup has been taken apart for cleaning or 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 cap 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 is uncoupled, which prevents any mistake being made at this point by the person handling the cup; afterwards the screw cap may be turned in the same direction indefinitely without jamming or changing its position on 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 other preparation; yet it is a good practice first to 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 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 upward until, like the screw cap, it is uncoupled, after which it revolves freely on the shaft, impinging against the German silver sleeve *i*. If the propeller hub is allowed to come in contact with the sleeve while the screw threads are still engaged, it may 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 vessel's motion in a sea-way will cause the propeller, when engaged with the threads on the shaft, gradually to 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 is 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 the opposite motion. Even thus experiments have shown that with the alternating movement continued for a longer time than would probably be occupied by any stoppage, the propeller would screw down on the shaft only a small proportion of the distance to the screw cap. It is plain that in the event of such action the propeller would rise and uncouple each time 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 contains within its cylinder a specimen of the water from its locality at the time being, allowing a margin of 1 or 2 feet.

"As soon as 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 being thus 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. As shown in the drawing the propeller would probably not perform its work short of 50 fathoms. I settled on about 25 fathoms as the distance most convenient. With this distance it would not be prudent to require the uppermost cup to bring a specimen from nearer the surface than 50 fathoms. If the propellers were arranged to lock the valve in an ascent of about 25 fathoms, and the uppermost cup were lowered only to a depth of 10 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 12 fathoms, would not have become locked. Each cup, as soon as discharged, should be thoroughly rinsed in fresh water."

We have found these bottles to work satisfactorily for the purpose of collecting water specimens for specific gravity determinations; but they will not retain the gases, and are therefore not available for collecting specimens for chemical analysis.

Experience has taught us that it is advisable to reset the valves whenever the bottles are to be used, as their adjustment is liable to be impaired in releasing the screw cap from contact with the upper valve. Although Sigsbee states in the remarks quoted that the upper valve seat is detachable for purposes of cleaning, we find in practice that the accumulation of verdigris on the screw threads makes its safe removal impracticable. The valves and valve seats can be readily cleaned, however, without detaching the upper valve seat.

## IMPROVED WATER BOTTLE.

The improved water bottle, Plates XXXV, XXXVI, and XXXVII, is designed to bring up a specimen of water from any desired depth, retaining the free gases for the purpose of analysis. The valves close mechanically and cannot be opened again except by hand; therefore it may, like the Sigsbee water specimen cup, be used in series, either with others of the same kind or with any instrument that can be used in series.

NOMENCLATURE.

*a.* Cylinder.
*b b.* Frame.
*c c.* Clamps to secure apparatus to temperature rope.
*d.* Expansion chamber.
*e.* Cock.
*f f.* Guards.
*g g.* Propellers.
*h h.* Shafts.
*i i.* Sleeves.
*j j.* Guys.
*k k.* Slots.
*l l.* Valves.
*m m.* Valve seats.
*n n.* End pieces.
*o o.* Spanner holes.
*p p.* Spanner holes.
*q q.* Set screws.
*r r r.* Stay rods.
*s s.* Inner arms of propeller frames.
*t t.* Outer arms of propeller frames.
*u u.* Cylinder clamp.
*v v.* Pin for cylinder clamp.

All parts of this water bottle are of brass, except the propeller blades, which are of German silver. The cylinder is a tube of commercial pattern; the frames, valves, valve seats, &c., are cast brass.

PREPARATION FOR USE (PLATE XXXVI).

Cleanse the inside of the cylinder from all foreign substances, particularly verdigris, oil, or red lead, which is sometimes used for making joints. Clean the valve faces and valve seats with a soft cloth, avoiding brick-dust, emery paper, or other scouring substances, as the valves are very carefully ground in and any scratch on their faces renders them liable to leak.

The valve seats should be removed for cleaning and replaced again, using spanners in the holes *o p* for the purpose, and to insure tight joints without undue strain a little red lead may be used on the shoulder between *m* and *n*.

In cleaning the cylinder particular attention should be given to the cock *c* and the expansion chamber *d*.

The propellers should be examined to see that they work freely on the sleeves and the supporting screws on their outer extremities. The shafts should be run up and down by means of the milled heads at *k*, to ascertain if the screw threads work freely and the shafts move on their bearings without undue friction.

The propellers should then be moved outward until they clear the supporting screws, where they will revolve freely during the descent without moving the shafts or in any way affecting the valves. The shafts should then be screwed inward a little to allow free connection with the valve stems *l*.

The cylinder may now be placed in the frames *b*, the valve stems *l* connected with the shafts *h*, and the cylinder secured in place by the clamps *u* and the pins *v* (Plate XXXVII). The valves should then be opened inwards to their full extent by means of the milled head at *k*. Secure the bottle to the rope by the clamps *c* (Plate XXXV), with the expansion chamber pointing upwards, and it will be in readiness for use.

TO OBTAIN A SPECIMEN OF WATER.

The dredge rope is used, having a sinker weighing 150 pounds. The apparatus being clamped to the rope a few fathoms above the sinker, lower away as rapidly as desired to the intended depth, and in case of temperature instruments not having been sent down, reel in at once.

The propellers now being brought into action soon close the valves. The internal pressure which takes place as the apparatus ascends is relieved by the expansion chamber *d*. As soon as the bottle reaches the surface the valves are keyed to their seats through slots in the valve stems *l*. The cylinder is then removed from the frame and stowed in some cool place in a vertical position until such time as it can be delivered to the laboratory.

A vertical position is recommended in order to retain water on both sides of the piston in the expansion chamber to avoid possible drying and shrinkage of the packing.

TAKING CARE OF THE BOTTLE.

The water specimen having been procured and the cylinder removed, rinse the frame in fresh water and wipe it dry. Remove the set screws *q* and the shafts *h*, wipe them dry, and put a little oil on the screw threads.

Unscrew the sleeves *i* from the hubs of the propellers, wipe them dry inside and out, and oil them; wipe the propellers dry also and oil the inside of the hubs. Oil should be used sparingly, taking care that it does not drip into the cylinder.

Having cleaned and oiled the parts put them together and stow the frame in its packing box, which should be kept in a dry place.

As soon as the specimen has been removed from the bottle the latter should be rinsed in fresh water, the valve seats unscrewed, and the cylinder with its attachments carefully cleaned and dried as directed in its preparation for use. After the parts are put together clamp the bottle in the frame. Oil should never be used on the cylinder or its attachments.

ORIGIN OF THE IMPROVED WATER BOTTLE.

This water bottle as figured is the joint production of Dr. J. H. Kidder, of the United States Fish Commission; Surgeon J. M. Flint, United States Navy, attached to the United States Fish Commission steamer Albatross; and the writer.

It will be readily observed that it is a modification of the Sigsbee water specimen cup. The latter is well adapted for its purpose of collecting water specimens for specific gravities, but it will not retain the free gases in water intended for chemical analysis. Feeling the want of a bottle that would accomplish this desired end, Drs. Kidder and Flint devised one during the summer of 1884, which was made by D. Ballauf, of Washington, D. C., and sent to the Albatross for trial, and, after testing it, a few improvements suggested themselves to the writer and are embodied in the bottle figured.

We consider this bottle still in the experimental stage, although it has been very carefully constructed and has successfully withstood a pressure of 150 pounds per square inch. It is a well-known fact, however, that mechanism does not work as well under water as in the atmosphere, yet we anticipate good results from the apparatus in its present form.

THE NEGRETTI & ZAMBRA DEEP-SEA THERMOMETER.

The following description of this thermometer is copied, in part, from the catalogue of Negretti & Zambra, various eliminations and additions being made by the writer.

The construction of this thermometer will be readily understood by referring to Plate XXXVIII, Fig. 2, where it is shown in a vertical sectional elevation of Tanner's improved deep-sea thermometer case.

The thermometrical fluid is mercury; the bulb containing it is cylindrical, contracted in a peculiar manner at the neck *a*; and upon the shape and fairness of this contraction the success of the instrument mainly depends. Beyond *a* the tube is bent and a small catch reservoir at *b* is formed 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*, leaving, if the temperature is high, 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*, depending upon the existing temperature. The scale is accordingly made to be read upward from *c*.

To set the instrument for observation it is only necessary to place it bulb downward, when the mercury takes the temperature just as in an ordinary thermometer. If at any time or 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 the reading is taken. This may be done at any time afterward, for the quantity of mercury in the lower part of the tube which gives the reading is too small to be sensibly affected 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. In the latter case some mercury will pass the contraction *a* and may fall down and lodge at *b*, but it cannot go further so long as the bulb is upward, and thus the temperature to be read will not be affected.

Now, whenever the thermometer can be handled it can readily be turned bulb upward for reading the existing temperature. It must be clearly understood that this thermometer is only intended to give the temperature at the time and place where it is turned over; it is simply a recording thermometer. In its present state it cannot be used as a self-registering maximum and minimum, though, if required, it could be constructed to act as a maximum.

In order to make the thermometer perfectly satisfactory, it was necessary to protect it from pressure as well in shallow as in the deepest seas, for in either case the pressure would cause an error of greater or less degree in its indications. 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 thermometer, however thick the glass of the bulb. By the simple expedient of inclosing the thermometer in a glass shield, *e*, hermetically sealed, the effect of external pressure is entirely eliminated. The shield must of course be strong, but not exhausted of air. It will, however, render the inclosed thermometer less readily affected by changes of temperature, making it more sluggish.

To counteract this tendency mercury is introduced into that portion of the shield surrounding the bulb, and confined there by a partition, *d*, cemented in the shield around the neck of the thermometer bulb. This mercury acts as a carrier of heat between the exterior of the shield and the interior of the thermometer; and the efficacy of this arrangement having been experimentally determined, the instrument has been found far superior in sensibility to Sixe's.

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. Doubtless the shield will be slightly compressed under great pressure, but this can never cause an internal pressure sufficient to have an appreciable effect upon the thermometer. This method of shielding is, therefore, quite efficacious, and deep-sea thermometers so protected do not require to be tested for pressure in the hydraulic press. They simply require accurate tests for sensitiveness and for errors of graduation, because they are standard instruments adapted to the determination of very small as well as great differences in temperature, some one or two tenths of a degree in shallow water. The test for sensitiveness should determine the time the instrument requires to take up a change of 5°, rise or fall, and the time is found to be from five to ten seconds.

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

To make this instrument available for deep-sea use it is necessary to provide some reliable method of turning the bulb upward at the proper time; also, to prevent it from turning down again before the surface is reached and the temperature read.

Plate XXXVIII shows a metal frame devised by Commander Magnaghi of the Italian navy. It is described as follows in an advertisement of Messrs. Negretti & Zambra:

NEGRETTI & ZAMBRA'S PATENT IMPROVED FRAME STANDARD DEEP-SEA THERMOMETER.

"The apparatus will be best understood, short of inspection, by reference to Plate XXXVIII, Figs. 1 and 2. A is a metallic frame in which the case B containing the thermometer is pivoted upon an axis H, but not balanced upon it. C is a screw-fan attached to a spindle, one end of which works in a socket D, and on the other end is formed the thread of a screw E, about half an inch long, and just above it is a small pin or stop, F, on the spindle. G is a sliding top-piece against which the pin F impinges when the thermometer is adjusted for use. The screw E works into the end of the case B, the length of play to which it is adjusted. The number of turns of the screw into the case is regulated by means of the pin and stop-piece. The thermometer in its case is held in position by the screw E and descends into the sea in this position (Fig. 1), the fan C not acting during the descent because it is checked by the stop F. When the ascent commences the fan revolves, raises the screw E, and releases the thermometer which then turns over and registers the temperature of that spot, owing to the axis H being below the center of gravity of the case B as adjusted for the descent. Each revolution of the fan represents about 2 feet of movement through the water, so that the whole play of the screw requires 70 or 80 feet ascent; therefore, the space through which the thermometer should pass before turning over must be regulated at starting. If the instrument ascends a few feet by reason of a stoppage of the line while attaching other thermometers, or through the heave of the sea, or any cause whatever, the subsequent descent will cause the fan to carry back the stop to its initial position, and such stoppages may occur any number of times provided the line is not made to ascend through the space necessary to cause the fan to release the thermometer.

When the hauling in has caused the turn-over of the thermometer the lateral spring K forces the spring L into a slot in the case B and clamps it (Fig. 2) until it is received on board, so that no change of position can occur in the rest of the ascent from any cause.

The case B is cut open to expose the scale of the thermometer, and is also perforated to allow free entry of the water."

The thermometer (Fig. 3) has already been described.

The Magnaghi frame above described is a great improvement on the wooden cases formerly furnished by the makers, but even this did not prove entirely satisfactory in all respects, inasmuch as it could not be secured to sounding wire, and could not, therefore, be used in series. The fan failed to act occasionally, and the springs K and L were apt to hold the case B in a vertical position by friction, thus preventing the turn-over at the proper time.

Various devices have been used on the vessels of the commission for capsizing the thermometer; the Tanner case and the Bailie-Tanner case, described in former reports, were, however, the most successful. They were used with good results until the peculiar service of the Albatross demonstrated the necessity for some arrangement by which the thermometers could be used in series either on the sounding wire or the dredge rope, which is frequently used as a temperature rope. It was desirable also to reduce the weight and resistance as much as possible. We were troubled occasionally by the mercury shaking down from the catch reservoir into the tube, thus vitiating the reading. This was the result of jars of one kind or another. The speed of 600 to 800 feet per minute at which the sounding wire was hove in by steam was a fruitful source of trouble, causing great vibration, which was complicated by the jars incident to the rapid passing of centers by the single cylinder reeling engine. These difficulties were subsequently overcome in the manner hereafter described.

## THE TANNER IMPROVED THERMOMETER CASE WITH THE SIGSBEE CLAMP, USED WITH THE NEGRETTI-ZAMBRA DEEP-SEA THERMOMETER (PLATE XXXIX).

Fig. 1 shows the apparatus complete, and Fig. 2 a vertical sectional elevation of the metal case containing the thermometer.

### NOMENCLATURE.

*a.* Neck of the bulb.
*b.* Catch reservoir.
*c.* Small receptacle.
*d.* Partition confining mercury in shield surrounding bulb.
*e.* Glass shield inclosing thermometer.
*f.* Thermometer case.
*g.* Thimble with rubber lining.
*h.* Spiral springs.
*i.* Cap.
*j.* Pivot.
*k.* Slot for reading scale.
*l.* Frame of cast brass.
*m.* Guard.
*n.* Propeller.
*o.* Spindle.
*p.* Set screw.
*q.* Sigsbee clamp.

The entire apparatus is made of brass except the Sigsbee clamp, which is of phosphor bronze, and the rubber linings of the thimbles *g*.

To mount the thermometer unscrew the cap *i*, drop a spring *h* into the case, slip a thimble *g* over the glass shield at *d*, put the thermometer in the case, drop in another thimble, which will rest on the upper end of the shield, then place another spring on the thimble and screw the cap in place. The thermometer will then be suspended between delicate spiral springs at the ends and soft rubber rings which surround the shield. This arrangement has proved effectual in guarding the thermometer against jars incident to the service required of it on board of the Albatross.

To take a temperature set the spindle *o* into the hole in the cap *i* by screwing it down until the propeller blades strike the set screw *p*; then by means of the Sigsbee clamp *q* secure it to the temperature rope. The bulb will then be down and the mercury in the tube connected with it, the position required to take the temperature. The water acting on the propeller during the descent will keep it in position resting against the set screw *p*, but as soon as the reeling in begins the propeller is set in motion, bringing the screw on the upper end of the spindle into action, gradually raising the propeller until the lower end of the spindle is withdrawn from the hole in the cap *i*, when the thermometer promptly turns over and registers the temperature by breaking the column of mercury at the point *a*, the column then falling to the bottom of the tube.

It can be read at any time afterward, as changes of temperature do not affect the reading after the column is once broken.

The apparatus described above is simple and reliable.

### THERMOMETERS FOR AIR AND SURFACE TEMPERATURES.

These thermometers are made by J. & H. J. Green, New York. The tubes are 10 inches in length, extra strong, and the scales are distinctly marked on them. Two-tenths of a degree is the greatest error found in testing them.

### THE MILLER-CASELLA DEEP-SEA THERMOMETER.

Plate XL shows this thermometer in the copper case used for deep-sea work; also partially dismounted to show the form of construction. The magnet seen between the two instruments is used to adjust the indices.

The following description is from Sigsbee's Deep-sea Sounding and Dredging:

"A glass tube bent in the form of U is fastened to the vulcanite frame, and to the latter are secured white glass plates 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 pendant 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 end 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 the retreat of the mercury the index remains at the highest point attained. 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."

The large bulb of this thermometer is now protected from pressure by a glass shield which surrounds it; the space between the shield and bulb is nearly filled with alcohol, which acts as a transmitting medium for temperature performing the same function as the mercury in the shield of the Negretti & Zambra thermometer. The shield above mentioned has added much to the value of the instrument, as it has practically eliminated errors arising from varying pressures. This thermometer has been considered the standard for deep-sea work, and when several were to be sent down to great depths on the same line it was unrivaled until the present improvements in the methods of capsizing the Negretti & Zambra thermometers were introduced.

It is not as sensitive as the Negretti & Zambra, but under the above conditions a delay of a few minutes is not of great importance. The movable indices are a fruitful source of annoyance and vexatious delay. An index may, without an apparent cause, absolutely refuse to move in the tube; coaxing with the magnet is followed by lightly tapping the frame in the hand or swinging it rapidly about the head; and if this fails more vigorous tapping is apt to follow with various active measures, none of which tend to improve the general condition of the instrument.

The indices are also liable to move if the instrument is subjected to rough treatment, although this is not of frequent occurrence with careful handling. Most of the minor casualties to which the instrument is liable are apparent to the eye and are readily adjusted.

## WATER DENSITIES.

Hilgard's ocean salinometer (Plate XLI) is used on board of the Albatross for observing the density of sea-water.

An excellent description of the apparatus is given by Prof. J. E. Hilgard in the United States Coast Survey Report for 1874, and reproduced in Sigsbee's Deep-sea Sounding and Dredging, as follows:

"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 saltness are so small that it is necessary to have a very sensitive instrument. As the density of ocean water at the temperature of 60° Fahr. only varies between the limits 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. With a view to the convenient adaptation to practical use this apparatus 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 case, with a thermometer inserted within the cavity, which is glazed in front. In use the case is nearly filled with water, so as to overflow when the float is inserted, the reading then being taken with ease at the top of the liquid.

"For convenience and security, two such floats and a case are packed together in a suitable case, and a supply of floats and thermometers securely packed in sawdust 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 reduction 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 saltness 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.

| Temperature. | Coefficients for reduction to 60°. | Temperature. | Coefficients for reduction to 60°. | Temperature. | Coefficients for reduction to 60°. | Temperature. | Coefficients 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 | +0.008154 | 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 hindrance 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, shows the differences within the range of temperature covered by our table of corrections:"

| Temperature. | Volume. | |
|---|---|---|
| | Hubbard. | Thorpe and Rucker. |
| ° | | |
| 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 |

Plate XLII shows the bow of the Albatross with the sounding machine and dredging boom in position.

The Sigsbee deep-sea sounding machine *a* on the port side of the topgallant forecastle is shown in readiness for taking a sounding.

The working reels containing the sounding-wire are kept in the galvanized-iron tanks *b b* when not in use. Each tank contains sufficient sperm-oil to cover the reel.

The Tanner sounding machine *c* is shown in position on the port rail forward of the fore rigging.

The dredging boom *h* is shown in position for dredging. It is made of spruce, 36 feet in length and 10 inches in diameter, with brass fittings at the ends. The heel pivots in a heavy composition band on the foremast, and the head is held in position by the topping-lift *l* and the guys *m m*.

A beam trawl *d* is shown ready for lowering. The wing nets *e e* are shown in place. The bridle *f f* is seized to the eyebolts on the forward part of the runners, stopped lightly to their after ends, and lashed to the end of the trawl-net. The register *i* is attached to the heel of the boom, and is actuated by a worm wheel on the pulley shaft, thus indicating at all times the number of fathoms of dredge rope out.

The dredging block *g* is seen at the boom end; the accumulator, at *k*; the accumulator block, at *j*; the dredge rope, at *o o*; and the hoisting engine, at *n*.

When the dredging boom is not in use it is lowered, the forward end resting on the topgallant forecastle; the topping-lift is unshackled and secured abreast the foremast, and the guys unhooked and stowed away.

## DREDGING BLOCK.

The dredging block used by the Albatross is shown in Plate XLIII, Figs. 1 and 2. The shell *a* is made of two pieces of bar iron ½-inch thick, 5½ inches in width at one end, 4½ at the other, and 3½ in the center.

They are bolted to a block of wrought iron 5½ inches in length, 2½ inches in width, and 2½ inches in depth, having a hole 1⅜ inches in diameter through its center in which the shackle bolt *d* is secured. This bolt acts also as a swivel. The sheave *b* is made of composition 21½ inches total diameter, 18 inches at the bottom of the score, and 2¼ inches in width. The pin *c* is of cast steel, and is surrounded by six cast-steel friction rollers *i*, 1¼ inches in diameter, which work on the inner surface of a wrought-iron bushing in the sheave. The guards *h* are used on the block at the boom end, to prevent the dredge rope from flying out of the score, and the arm *j* is used on the accumulator block for the forward guy which hooks in the eye *k*. The absence of the guards *h* in one block, and the arm *j* in the other, constitute their only points of difference.

### THE ACCUMULATOR.

The apparatus shown in Plate XLIV performs the double function of accummulator and dynamometer for the dredge rope.

#### NOMENCLATURE.

*a*. Buffers.
*b*. Washers.
*c*. Guide rods.
*d*. Tension rod.
*e*. Link.
*f*. Swivel link.
*g*. *h*. Lock nuts.
*i*. Cross-heads.
*j*. Yoke.
*k*. Tie.

The accumulator is shackled to the topping-lift band 13 inches below the futtock band on the foremast, and is suspended directly forward of the mast. Its total length, including the links *e* and *f*, is 11 feet 1 inch.

The guide rods *c c* are made of one piece of round mild steel, 1 inch in diameter, bent at *e* and *k*, with screw threads and lock nuts at *h h*. The tension rod *d* is also of mild steel, round in section, 1¼ inches in diameter, and 9 feet 9 inches net length, that is, measured inside the cross-head *i* and yoke *j*, and it will take thirty-nine buffers without compression. It has a swivel link at the lower end, to which the accumulator block shackles, and a screw thread and lock nuts *g* at the opposite extremity.

The cross-heads *i i i*, the yoke *j*, and the tie *k* are of wrought iron; the former move freely on the guide rods, the upper one receiving the end of the tension rod, and the others support the guide rods. Figs. 3 and 4 show a front and side view of a cross-head.

There is a brass washer *b* between each pair of buffers, separating them from each other, and keeping them from contact with the tension rod, as seen in Fig. 2, where the washer and buffers are shown in section.

The washers are $6\frac{3}{8}$ inches in diameter, three-sixteenths inch thick, and have a hole in the center $1\frac{5}{16}$ inches in diameter. A hub one-half inch in length extends from each side of the washers (Figs. 5 and 6), except those in contact with the yoke and cross-heads, which have no hub on that side. The buffers were purchased of the New York Rubber Belting Company, and are composed of their compound No. 23. They are $5\frac{1}{2}$ inches in diameter, 3 inches thick, have a hole $1\frac{7}{16}$ inches in diameter through their center, weigh 4 pounds 3 ounces, and cost 67 cents per pound, or about $2.80 each.

A scale not shown in the plate is lashed to one of the guide rods, and marked to indicate the strain on the dredge rope to each 500 pounds by compression of the buffers.

The accumulator is useful, not only to relieve sudden strains brought upon the dredge rope by the vessel's motion in a sea way, but it insures a more uniform action of the hoisting engine, and gives the first indication of increased tension on the rope in case the trawl fouls or buries in the soft bottom when working in deep water.

The hubs on the brass washers, which prevent the buffers from coming in contact with the tension rod, were devised by Lieutenant-Commander Sigsbee, U. S. N., on board of the United States Coast Survey steamer Blake. Previous to their introduction the buffers were liable to grip the tension rod while they were compressed, making the apparatus sluggish in its action, a fault that no longer exists. It is, on the contrary, exceedingly prompt in expansion after being relieved of its load, and retains its elasticity under all conditions of service and temperature.

THE DREDGE ROPE.

Our rope is made of galvanized steel wire, and was manufactured by the Hazard Manufacturing Company, Wilkesbarre, Pa., C. M. Thompson, agent, 87 Liberty street, New York. It is three-eighths inch in diameter and has six strands, laid around a tarred hemp heart. The strands are composed of seven wires, each made according to a special gauge of the manufacturers, approximating to No. 18 American or No. 19 Birmingham gauge. It weighs 1.32 pounds per fathom in air, about 1.2 pounds in water, and its ultimate strength determined by the testing machine at the ordnance department, navy-yard, Washington, D. C., is 12,850 pounds. A kink reduces the strength about 50 per cent.

We first received 4,000 fathoms in one length wound on a heavy wooden reel, from which it was transferred to the working reel. The spare rope was supplied in lengths of 1,000 fathoms, each length wound on a wooden reel. Subsequently the rope was ordered in 500 fathom lengths, the reels being much more convenient for stowage and lighter to handle.

When transferring this rope from one reel to another or when it is in use for trawling or dredging, it is absolutely necessary to keep it under tension, for if slacked from any cause it will kink, continuing to do so until all the slack is absorbed. This is the one contingency that must be carefully guarded against in the use of this rope.

A "long splice" from 20 to 25 feet in length is used to join two pieces of rope. A man with an assistant will make a splice in about two hours, which, if well made, cannot be detected without close observation, and is as strong as other parts of the rope, at least we have found it to part quite as often away from the splices as at them.

We have used various forms of splice at the end of the rope and have finally settled upon an ordinary eye-splice turned around a large oblong thimble, the ends tucked three times, tapered, and trimmed the same as though it were a hemp or manila rope. We serve the splice occasionally with annealed iron wire when we wish to make a particularly neat job, but it is not at all necessary.

The rope being galvanized requires no preservation while new, but if from long service the zinc should be worn off and the steel wires exposed a coating of raw linseed oil will be of service. We have used no preservative, and have had no trouble from rusting.

### SAFETY HOOKS.

The safety hooks (Plate XLV) are designed for the purpose of detaching the trawl or dredge when, from any cause, such as fouling a rock or burying in the soft ooze of the ocean bed, the tension on the dredge rope exceeds the limit of safety.

The rope is spliced into the eye *c*, the spiral spring is adjusted by means of the nut on the end of the tension rod *d*, then placed in the cylinder *a* and the cap *b* screwed on. The shoulders *f f* on the hooks will rest on the inner surface of the lower extremity of the cylinder *a*. The trawl being shackled by passing the pin through the hooks, and the necessary tension being put on it, the spring *e* will be compressed, the shoulders *f f* will extend below the end of the cylinder, and the hooks will open, allowing the shackle pin to slip between them, thus detaching the trawl and relieving the rope from undue strain. The spring can be adjusted to release the trawl at any point between 3,000 and 6,000 pounds.

### THE DREDGING AND REELING ENGINES (PLATES XXIII, XXIV, and XXV).

A detailed description of these engines is given in the engineer department and need not be repeated. A brief mention of their design and construction may not, however, be out of place here.

During the summer of 1881, while the plans for the Albatross were being perfected, the writer examined every form of hoisting and reeling engine within reach, as well as models in the Patent Office and plans of engines constructed by various builders, but found nothing fulfilling our requirements. The type adopted on board the Fish Hawk, combining the hoisting and reeling engine, using the same drum for hoisting the trawl and reeling up the rope, was considered; but it was evident that a reel of sufficient capacity for 5,000 fathoms of dredge rope, with strength to withstand the enormous crushing strain it would have to endure, would be too heavy and unwieldy for our purposes, and was consequently discarded.

Having finally recognized the necessity for two separate engines, one for hoisting and another for reeling, we decided to place the former on the spar deck, forward of the foremast, and the latter directly under it on the berth deck, for the double purpose of protecting the machinery and dredge rope from the weather, and placing the weight as low as possible in the vessel. Various plans were considered and rejected for one reason or another, until finally the writer submitted rough pencil sketches of the types considered by him as most nearly answering the requirements, to Mr. Earle C. Bacon, of Messrs. Copeland & Bacon, 85 Liberty street, New York.

He reduced them to proper proportions and perfected such parts as were left to his discretion. They were subsequently ordered from the above-mentioned firm and constructed under the personal supervision of Mr. Bacon. They have performed their work admirably.

### THE GOVERNOR.

The hoisting engine being located on the spar deck, and the reeling engine on the deck below, entirely hidden from view, it became necessary to have some automatic device by which the movements of the latter would be governed by those of the former, not only to guard against parting the dredge rope, but to insure a uniform tension on it while being wound on the reel.

With that object in view the writer devised the governor (Plate XXV) described in connection with the reeling engine in the engineer department. The working drawings were made by Passed Asst. Engr. Geo. W. Baird, U. S. N., who superintended its construction. He also suggested attaching the bell crank to a pressure valve instead of the throttle, which is a great improvement, as it leaves the latter under control of the attendant at all times; and the former, once set to the desired tension, requires no further adjustment, and only occasional verification through the medium of a dynamometer.

### DEEP-SEA TRAWL.

The deep-sea trawl frame (Plate XLVI) is a slight modification of "the standard trawl for deep-sea work, No. 1," described by Sigbee in Deep-sea Sounding and Dredging, p. 151. It is necessary for the successful operation of the beam trawl that it should land on the bottom right side up. The officers of the Blake, having experienced some vexatious delays from capsizing, devised a double trawl which worked equally well either side up, and was subsequently used on board that vessel with excellent results.

The following are the dimensions of the frame and net in use on board of this vessel:

Beams:

Iron pipe, length, 11 feet.
Outside diameter, 2⅞ inches.
Thickness of metal, $\frac{3}{16}$ inch.

Collars, brass, width, 3 inches; thickness, ¾ inch; length of flange, 9½ inches; diameter of bolts, ⅝ inch.

Runners:

Length, 4 feet.
Depth, 3 feet 6 inches.
Width, 3 inches.
Thickness, ½ inch.
Weight of frame, 275 pounds.
Rope for bridle, manila, 3 inches.
Rope for roping, manila, 2¼ inches.

Trawl net:

Length, 17 feet.
Size of mesh, square, 1 inch.
Material, cotton, barked, 30-thread.

Pocket:

Length, 6 feet.
Size of mesh, square, 1 inch.
Material, cotton, barked, 21-thread.

Jacket:

Length, 6 feet.
Size of mesh, square, ¼ inch.
Material, cotton, barked, 16-thread.
Bottom lining of cheese-cloth for deep-sea work.

The length of the net, including jacket and pocket, is given when it is mounted and on a stretch.

The runners are made of flat bar-iron with a small rod running around their inner surfaces to which netting is laced to fill the spaces and prevent the escape of fish, &c., from the trawl. The runners are tied together rigidly by two beams of wrought-iron piping having a brass collar screwed on each end. These are secured to the runners by screw-bolts.

The netting used for trawl and dredge nets, as well as pockets and jackets, is purchased by the bolt. The net is cut from the bolt, the width of which represents the length of the net; the edges are then joined by a seam running lengthwise on the upper side of the bag, forming an open-mouthed net which is roped with 2½-inch manila. That portion forming the loop, intended to drag on the bottom between the runners, is loaded at intervals with lead weights.

The pocket is stitched to the main bag about 3 feet below the lead rope, and the jacket is laced its width above the lower end of the net, so that the edges of both come together. The bag is attached to the rear ends of the runners by strong seizings at the four corners, leaving the lead ropes sufficiently slack for the upper one to touch the beam. A netting is usually stretched between the beams.

Floats are attached to the net a few feet from the lead rope by means of a slack line, to prevent the upper part of the bag from falling and obstructing the mouth while dragging.

The bridle is practically the same as suggested by Sigsbee. Large eyes are spliced in the ends of a 3-inch rope, a thimble turned in the middle, and an overhand knot taken in each leg at the point of contact with the eyebolts on the front of the runners. Seizings are passed through the eyebolts and around the bridle legs forward of the knots, and the ends of the legs are securely lashed to the tail of the trawl net. Should the trawl foul on the bottom or take in a dangerously heavy load it is intended that the seizings shall part, and the trawl be drawn up tail foremost. The strength of seizings required for this purpose at the forward end of the runners is determined by experiment.

We have used the trawl described above with good results in deep water. It is not, however, adapted for use on the hard sandy bottom usually encountered in shoal water, for the reason that sufficient sweep cannot be given the lead rope. It has another fault which has practically driven it out of use on board of this vessel. It will be seen by reference to the plate that the mouth of the trawl will be extended equal to the depth of the runners while being hove up; consequently the wash of water through the meshes of the net must be very great; so great, in fact, that in a sea-way it often seriously injured the specimens.

BEAM TRAWL.

The beam-trawl frame, Plate XLVII, shows the form in use on board of this vessel, both for shoal and deep-water work.

The following are the dimensions of the frame and net:

Beam:

Iron pipe, length, 11 feet.

Outside diameter, 2⅞ inches.

Thickness of metal, $\frac{3}{16}$ inch.

Collars, brass, width, 4 inches; thickness, ¾ inch; length of flange, 9¼ inches; diameter of bolts, ⅝ inch.

Runners:

Length, 5 feet.

Height, 2 feet 5 inches + 4 inches; total, 2 feet 9 inches.

Width, 4 inches.

Thickness of metal, ¾ inch.

Weight of trawl frame, 365 pounds.

Rope for bridle, 3 inches.

Rope for lead rope, 2 inches.

Rope for head rope, 1½ inches.

Trawl net:

Length, 17 feet.

Size of mesh, square, 1 inch.

Material, cotton, barked, 30-thread.

Pocket, length, 6 feet.

Pocket, size of mesh, square, 1 inch.

Pocket, material, cotton, barked, 21-thread.

Jacket, length, 6 feet.

Jacket, size of mesh, square, ½ inch.

Jacket material, cotton, barked, 16-thread.

Bottom lining of cheese-cloth for deep-water work.

## WING NETS.

Various forms of nets have been used to collect minute specimens at intermediate depths, but Capt. H. C. Chester was the first, I believe, to attach the net to the trawl frame. This he did by hanging a small cheese-cloth net to a piece of iron pipe, one end of which was inserted in

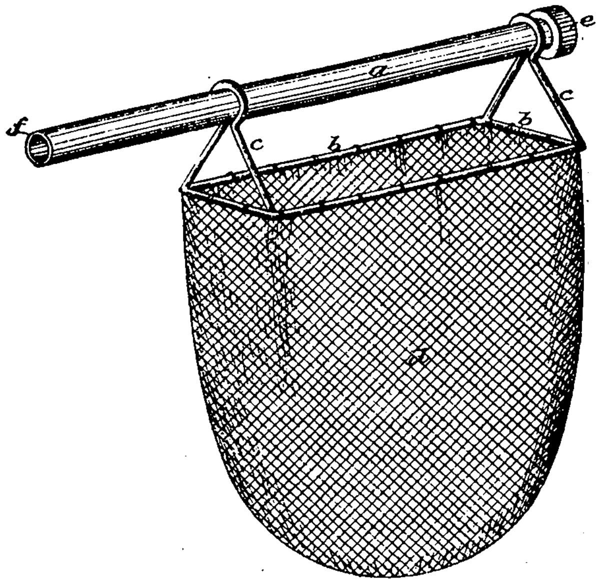



FIG. 19.—Chester's wing net.

the trawl beam, and held in place by a set screw. The iron pipe *a* has a ring *e* at its outer end to prevent the arms *c c* from slipping off. The arms, the frame *b*, and the net *d* are suspended from the pipe which is inserted into the end of the trawl beam at *f*. The arms swing freely on the pipe.

DIMENSIONS.

Iron pipe, *a*, length, 3 feet.
Iron pipe, *a*, diameter, 2 inches.
Iron cap, *e*, length, 1 inch.
Iron cap, *e*, diameter, 2¾ inches.
Frame, length, 2 feet.
Frame, width, 8 inches.
Frame, diameter, round iron, ½ inch.
Arms, length, 6 inches.
Arms, diameter, round iron, ½ inch.
Bag, length, 2 feet.
Bag, size of mesh, square, $\frac{3}{16}$ inch.
Bag, material, cotton, 3-thread.
Bag, bottom-lining, cheese-cloth.

Subsequently the bottom lining was discarded and an ordinary surface towing net inserted, the ring seized to the sides of the net *d*. This net has proved a valuable adjunct to the trawl.

## MUD BAG.

The mud bag used by us with the trawl is simply a boat dredge with the net removed and the rear end of the canvas shield closed, making a water-tight bag. We lash this to the tail of the trawl net and usually find it filled with a compact mass of mud or ooze when it comes up. This affords many interesting specimens besides enabling us to determine the character of the bottom more accurately than we could by examining the small amount brought up in the specimen cup.

## IMPROVED BEAM TRAWL.

This trawl, Plate XLVIII, was introduced by the writer in 1884* and is the latest form used on board the Albatross. It is a modification of the one shown in Plate XLVII.

### NOMENCLATURE.

*a*. Beam, iron pipe.
*b*. Runners.
*c*. Trawl net.
*d*. Pocket.
*e*. Jacket.
*f*. Bridle.
*g*. Shackle.
*h*. Lashings.
*i*. Mud bag.
*j*. Lead rope.
*k*. Arms, wood.
*l*. Wing nets.
*m*. Guard nets.
*n*. Dredge rope.
*o*. Dredging block.
*p*. Dredging boom.
*q*. Bridle stops.
*r*. Collars, brass.

### DIMENSIONS.

Beam:
- Iron pipe, length, 11 feet.
- Outside diameter, $2\frac{7}{8}$ inches.
- Thickness of metal, $\frac{3}{16}$ inch.

Collars:
- Brass, width, $3\frac{1}{2}$ inches.
- Thickness, $\frac{3}{4}$ inch.
- Length, $9\frac{1}{2}$ inches.

Bolts:
- Iron, round, diameter, $\frac{3}{4}$ inch.
- Set screws, in collars, iron, square heads, diameter, $\frac{3}{4}$ inch.

Runners:
- Iron, flat-bar, length, 5 feet.
- Height, 2 feet 5 inches.
- Height, including collars, 2 feet 9 inches.
- Width, $3\frac{1}{2}$ inches.
- Thickness of metal, $\frac{1}{2}$ inch.

---

* Owing to delay in printing we are able to introduce this and other late improvements into this report.

Jackstays:
- Iron, round, diameter, ¼ inch.
- Eyebolts, brass; diameter of metal, ⅝ inch.

Arms:
- Wood, for wing nets, length, 2 feet 6 inches.
- Wood, for wing nets, diameter, 2¼ inches.

Weight:
- Frame, 275 pounds.

Bridle:
- Rope, circumference, 3 inches.

Net:
- Lead rope, circumference, 2 inches.
- Head rope, circumference, 1½ inches.
- Length, 17 feet.
- Size of mesh, square, 1 inch.
- Material, cotton, barked, 30-thread.
- Pocket, length, 6 feet.
- Pocket, size of mesh, square, 1 inch.
- Pocket material, cotton, barked, 21-thread.
- Jacket, length, 6 feet.
- Jacket, size of mesh, square, ½ inch.
- Jacket material, cotton, barked, 16-thread.

Bottom lining of cheese-cloth for very deep water work.

It will be observed that there is no change in the beam, and the runners remain the same in height and length, but they are much reduced in weight and so modified in form as to avoid sharp angles in the net, thus equalizing the strain over its various parts and largely increasing its limit of safety.

The jackstays on the inner surfaces of the runners and the guard nets which are laced to them are not new, but we have confined their use heretofore to the small beam trawls and deep-sea trawls. There is no doubt that they prevent the escape of many fish and other quick moving objects.

The trawl-net is the same in every particular as that already described for the beam trawl, and the bridle is fitted and secured precisely in the same manner. The mud bag is also the same.

## WING NETS.

The wing nets shown in Plate XLVIII were devised by the writer in 1884, and the pocket introduced to prevent the escape of specimens after having entered the nets. They are made of cheese-cloth in the following manner:

The material is laid on deck and folded once lengthwise, a pattern is then placed over it and the two halves cut from the piece at the same time; the side seams are sewed up, the ends hemmed, and one end turned in over a galvanized-iron ring, thus forming the pocket. The double bridle is seized to the ring through the net and serves to hold it in place. The lashing is stopped to the lower end of the net to prevent its loss when cast adrift. And to prevent the pocket from turning wrong side out a small piece of twine, with a knot on its lower end, is allowed to hang down from it far enough to be gathered in with the end of the net and secured with the lashing.

The bridles are seized in scores cut in the arms for the purpose. When required for use the arms are inserted in the ends of the beam and held in place by the set screws in the collars.

### DIMENSIONS OF WING NETS.

Galvanized-iron ring, diameter, 1 foot.
Galvanized-iron ring, diameter of iron, $\frac{5}{8}$ inch.
Net, length, 3 feet.
Pocket, length, 2 feet.

### SMALL BEAM TRAWL.

The small beam trawl is used during bad weather, being easier to handle and bringing less strain on the dredge rope. The dimensions of the frame and net are as follows:

Beam:
- Iron pipe, length, 7 feet 6 inches.
- Outside diameter, $2\frac{1}{4}$ inches.
- Thickness of metal, $\frac{3}{16}$ inch.

Collars, brass, width, 2 inches; thickness, $\frac{1}{2}$ inch; length of flanges, 7 inches; diameter of bolts, $\frac{5}{8}$ inch.

Runners:
- Length, 4 feet.
- Height, 2 feet 3 inches + 3 inches; total, 2 feet 6 inches.
- Width, 2 inches.
- Thickness of metal, $\frac{5}{8}$ inch.

Weight of trawl frame, 140 pounds.
Rope for bridle, $2\frac{1}{2}$ inches.
Rope for lead rope, 2 inches.
Rope for head rope, $1\frac{1}{2}$ inches.

Trawl net:
- Length, 17 feet.
- Size of mesh, square, 1 inch.
- Material, cotton, barked, 21-thread.
- Pocket, length, 6 feet.
- Pocket, size of mesh, square, 1 inch.
- Pocket material, cotton, barked, 21-thread.
- Jacket, length, 6 feet.
- Jacket, size of mesh, square, $\frac{1}{2}$ inch.
- Jacket material, cotton, barked, 16-thread.

The method of attaching the beams to the runners is the same with both the deep-sea and beam trawl frames. Heavy brass collars are secured to the ends of the beams by screw threads, and to the runners by two bolts and nuts through each collar and runner, thus giving the frames the required rigidity. The parts can be assembled and dismounted in a few minutes; in fact, so readily that it has become a custom with us to dismount and stow the frames away whenever they are not required for immediate use.

### THE DREDGE.

The dredge in ordinary use on shipboard, Plate XLIX, Fig. 1, is composed of two jaws or mouth pieces, flaring about 12 degrees, and joined together by an iron stud at each end, which is welded to the jaws. The net is laced through holes along the back of the mouth-pieces, and is protected from chafing on the bottom by a canvas shield drawn over it and laced through the same holes.

Short iron arms serve as a bridle, one being a few inches longer than the other and secured to it by a seizing, which is intended to part whenever undue strain is brought upon it and allow the dredge to be drawn up end on, in which position it would be most likely to free itself from an obstruction. The dredge used on board the Albatross is of the following dimensions:

Jaws:
- Length, 2 feet.
- Width, 2½ inches.
- Opening between, 8 inches.
- Angle of, 12 degrees.

Stud:
- Length, 6 inches.
- Diameter, round iron, ¾ inch.

Bridle:
- Diameter, round iron, ¾ inch.
- Weight of metal part, 26 pounds.

Net:
- Length, 3 feet 6 inches.
- Size of mesh, square, 1 inch.
- Material, cotton, barked, 30-thread.
- Jacket, length, 2 feet 6 inches.
- Jacket, size of mesh, ½ inch.
- Jacket material, cotton, barked, 16-thread.
- Bottom lining, cheese-cloth.

Shield, length, 3 feet 8 inches.
Shield, material, No. 2 cotton canvas.

The dredge described above, having its jaws set at an angle, is inclined to plow the bottom, and, where the latter is soft, bury itself beneath the surface. This is a necessary feature on a hard sandy bottom, but in the soft ooze of the deep sea it is a serious detriment. Various devises were resorted to by Lieutenant-Commander Sigsbee on board the Blake, and finally the following form was adopted and called the "Improved dredge." It is known here as the "Blake dredge," and will be referred to under that name, Plate XLIX, Figs. 3 and 4.

The following description is from Sigsbee's Deep-sea Sounding and Dredging:

"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 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 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 heavy 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 THE BLAKE DREDGE AS USED ON BOARD OF THIS VESSEL.

Jaws:
- Length, 4 feet.
- Width, 6 inches.
- Thickness of metal, ⅝ inch.
- Distance of holes from edge, three-eighths of an inch.
- Distance between holes, 2 inches.
- Depth or opening between jaws, 9 inches.

Skeleton frame:
- Length, including width of jaws, 4 feet.
- Diameter of round iron, one-half inch.
- Diameter of braces, three-fourths of an inch.

Long arm, length 4 feet.
Short arm, length 3 feet 9 inches.
Diameter of round iron, both arms, three-fourths of an inch.
Weight of dredge and frame, 81 pounds.
Shield, cotton canvas, No. 2.
Net:
- Length, 5 feet.
- Size of mesh, square, 1 inch.

Net material, cotton, barked, 30-thread.
Jacket:
- Length, 3 feet.
- Size of mesh, square, one-half inch.

Jacket material, cotton, barked, 16-thread.
Bottom lining, cheese-cloth.

### THE CHESTER RAKE DREDGE.

Plate XLIX, Fig. 2, shows the Chester rake dredge designed for the purpose of obtaining mollusca, annelids, crustacea, &c., which burrow beneath the surface out of reach of any other apparatus in use by the United States Fish Commission.

The rake is shackled to the dredge rope, and a Blake dredge, secured to eyebolts on the rear of each end of the frame, following it as it is dragged over the bottom, picking up whatever is turned over by its strong harrow-like teeth.

#### DIMENSIONS OF THE CHESTER RAKE.

Frame:
- Length, 3 feet.
- Depth of opening, 10 inches.
- Width of metal, 2½ inches.
- Thickness of metal, one-half inch.

Teeth:
- Length, 7 inches.
- Width of base, pointed, 2½ inches.
- Thickness of metal, base, one-half inch.

Arms:
- Length of long arm, 3 feet 5 inches.
- Length of short arm, 3 feet 3 inches.
- Diameter, round iron, three-fourths of an inch.

Weight, 79 pounds.

This admirable instrument was devised by Capt. H. C. Chester, to whom the Commission is indebted for many practical suggestions as well as for some of its most valuable apparatus.

### BOAT DREDGE.

The boat dredge is essentially a miniature form of the ordinary ship's dredge already described, and is designed for use from boats where it must be worked by hand.

#### DIMENSIONS OF THE BOAT DREDGE.

Jaws:
- Length, 1 foot 7 inches.
- Width, 2½ inches.
- Opening, 7½ inches.
- Angle, 12 degrees.

Stud:
- Length, 6½ inches.
- Diameter, round iron, five eighths of an inch.

Bridle:
- Diameter, round iron, one-half inch.
- Length, 1 foot 5 inches.

Weight, 15 pounds.

Net:
- Length, 1 foot 8 inches.
- Size of mesh, square, three-sixteenths of an inch.
- Material, cotton, 3-thread, bottom double.

Shield:
- Length, 2 feet 8 inches,
- Material, No. 3 cotton canvas.

## TRAWL WEIGHTS.

It is customary with us to attach one or more trawl weights to the tail of the trawl net, and, in shoal water, one to each runner. Two or three are also used with the dredge and tangles.

### DIMENSIONS.

Length, 11 inches.
Diameter of base, square, 4 inches.
Diameter 8¼ inches above base, 3 inches.
Size of hole, 1 inch by 1⅝ inches.
Thickness of metal around hole, three-fourths of an inch.
Material, cast iron.
Weight, 27 pounds.

## THE TANGLE BAR (PLATE L).

The form of tangle bar used was devised by Prof. A. E. Verrill in 1873, and consists of an iron bar supported at each end by a fixed wheel, or iron hoop. Six chains about 12 feet in length are attached to the bar at intervals of 1 foot. To these chains are secured deck swabs, or bundles of rope yarns, at intervals of about 18 inches.

It is very useful on rocky bottoms where it will capture specimens when no other device could be made available.

### DIMENSIONS.

Wheels:
- Diameter, 1 foot 2 inches.
- Width, 2½ inches.
- Thickness of iron, one-half inch.
- Width of cross-bars, 2½ inches.
- Thickness of cross-bars, three-fourths of an inch.

Chain bar:
- Length, 6 feet.
- Width, 2½ inches.
- Thickness, 1 inch.
- Rings for drag rope, diameter, 4 inches.
- Rings for drag rope, diameter of iron, five-eighths of an inch.

Tangle chains:
- Diameter of iron, three-eighths of an inch.
- Length, 12 feet.

Tangles, hemp, length, 3 feet.

## THE TANGLES.

The tangles, Plate LI, were devised by the writer in 1884 as an improvement on the tangle bar, being less liable to foul on the rough rocky bottoms where it is generally used.

### NOMENCLATURE.

*a*. Bow.
*b*. Tangle bars.
*c*. Tangles.
*d*. Eyebolts.
*e*. Bolts and nuts.

*f*. Arm.
*g*. Eyebolt.
*h*. Sinker.
*i*. Dredge rope.
*j*. Dredging block.
*k*. Dredging boom.

DIMENSIONS.

Bow (steel):
 Diameter, 11 inches.
 Width at center, 3 inches.
 Width at ends, 2½ inches.
 Thickness at ends, one-half inch.
 Thickness at center, one-fourth of an inch.
Tangle bars (iron):
 Length, 5 feet.
 Width, 2½ inches.
 Thickness, one-half inch.
 Number of holes for tangles, 5.
 Diameter of holes, five-eighths of an inch.
Eyebolts for tangles (iron), diameter, one-fourth of an inch.
Tangles (hemp), length, 4 feet.
Tangles (beckets), 21-thread ratlin stuff.
Arm (mild steel):
 Semi-circular, diameter, 1 foot 6 inches.
 Width of metal, 2½ inches.
 Thickness of metal, one-half inch.
Eyebolt (iron), diameter of metal (square), five-eighths of an inch.
Sinker (cast-iron):
 Diameter, 9 inches.
 Weight, 150 pounds.

The first tangle of this form was improvised at sea, after expending the last tangle bar, by bending a bar of iron in the form of a V, the tangles being seized to a 3-inch rope, which was drawn around the frame and secured to it by lashings. It worked so well that we used it the remainder of the cruise and finally adopted the present form.

The bow *a* is made of spring-tempered steel and permits the bars to close with a pressure of between 300 and 400 pounds applied to their extremities, so that the apparatus will pass between rocks or other obstructions which permit the passage of the bow and sinker.

Each tangle is secured to its bar by a one-fourth inch eyebolt, which draws at a tension of about 1,000 pounds, releasing its tangle when irretrievably fouled on the bottom without endangering the loss of the whole apparatus. The tangle bars were made separately from the bow and attached by bolts and nuts at *e* to secure better stowage and make the parts lighter to handle. The semicircular arm *f* is intended to raise the forward end of the tangle frame a few inches off the bottom; also to act as a shoe in dragging over rocks or other uneven surfaces. It is held in position by the eyebolt *g*, which is square and fits snugly in square holes in the arm and bow.

The tangles are, in material, size, and structure, practically the same as the deck swabs in general use on board ship.

THE TABLE SIEVE.

The table sieve in its present form, Plate LII, Fig. 2, is an outgrowth of the cradle sieve, Plate LII, Fig. 1, which was formerly used in washing the contents of the dredge, the more bulky loads of the trawl having been emptied on deck.

The first table sieve was devised by Capt. H. C. Chester and Prof. A. E. Verrill, and consisted of a rectangular table supporting a fine sieve, and over it the hopper with its coarse wire netting.

The canvas bottom and chute were added by Mate James A. Smith, U. S. N., executive officer of the U. S. S. Speedwell, while in the employ of the United States Fish Commission, about 1877.

To prepare the table sieve for use, place the sieve *c* in the frame *a* on cleats provided for it a few inches above the canvas bottom *d;* then place the hopper in the frame over the sieve and carry the chute *e* to a scupper.

DIMENSIONS.

Table frame:
- Length, 5 feet 6 inches.
- Breadth, 3 feet 2 inches.
- Depth, 1 foot.
- Height from deck to top of frame, 3 feet 2 inches.
- Thickness of planks, 1 inch.

Hopper:
- Length, top, 5 feet 9 inches.
- Length, bottom, 4 feet.
- Width, top, 3 feet 5 inches.
- Width, bottom, 2 feet 6 inches.
- Depth, 1 foot 1 inch.
- Thickness of planks, 1 inch.
- Size of mesh, galvanized-iron wire netting, five-eighths of an inch.

Sieve:
- Length of frame, 5 feet 3 inches.
- Breadth, 2 feet 11½ inches.
- Depth, 2½ inches.
- Thickness of planks, 1¼ inches.
- Size of mesh, galvanized-iron wire netting, one-twelfth of an inch.

Bottom, No. 4 cotton canvas.

The table legs are now made detachable, which materially reduces the space required for stowage.

THE CRADLE SIEVE.

This sieve was devised by Prof. A. E. Verrill in the early days of the United States Fish Commission, for the purpose of rapidly washing out the mud brought up by the dredge. It has wooden ends nearly semicircular in form, joined by narrow strips which are let into the end pieces so as to present a smooth surface. A fine netting is drawn over the surface, and supported by an outer netting of coarse mesh secured firmly to the ends and side pieces. An inner sieve with coarse mesh rests on and partially inside of the main sieve. It is intended to be hung over the vessel's side by means of a rope bridle attached to iron straps on the end pieces.

In use it has been superseded by the table sieve.

DIMENSIONS OF CRADLE SIEVE.

Length, 3 feet.
Breadth, 1 foot 6 inches.
Depth, 1 foot.
Width of side pieces, 3½ inches.
Thickness of side pieces and ends, 1 inch.
Depth of inner sieve, 8 inches.

### THE STRAINER.

The strainer, Plate LII, Fig. 3, was introduced by Mr. James E. Benedict, resident naturalist of the Albatross, for the purpose of passing all water used for washing the mud out of the table sieve through strainers fine enough to retain minute annelids, foraminifera, &c., which would otherwise be lost.

Its construction is very simple. An oil barrel was cut down until it would slide under the table sieve. Three iron drain-pipes are inserted in the side, one diagonally over the other, and attached to them are three strainers, *a*, *b*, and *c*, Fig. 3, made of linen scrim, through which the water is drained as it rises successively to the level of each. The combined areas of the three are sufficient to carry off the water supplied by the steam hose under ordinary circumstances. When it is to be used in connection with the table sieve the long chute *e* is removed, and a short one about a foot in length substituted, the water being discharged directly into the strainer.

### DREDGING QUADRANT.

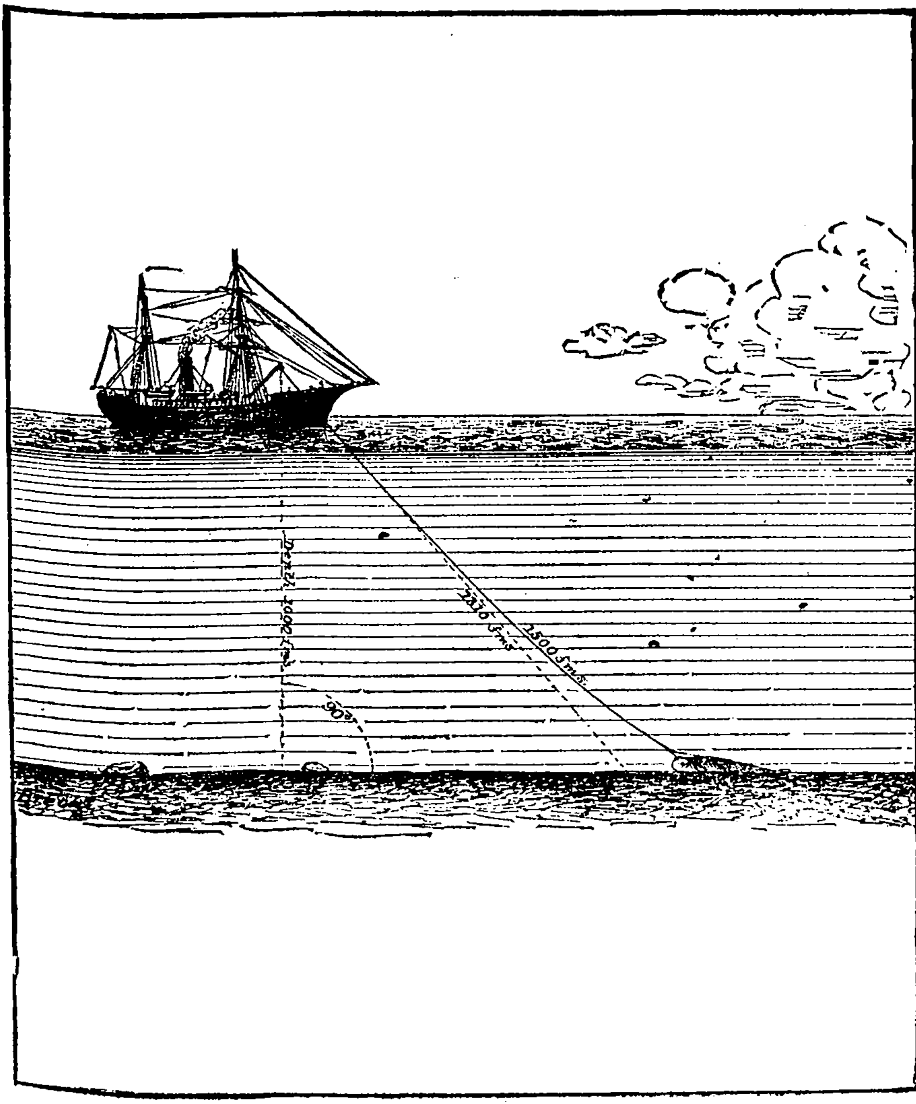
The dredging quadrant, Plate XXVIII, was devised by the writer for the purpose of ascertaining approximately the position of the trawl when working in deep water by observing the angle of the dredge rope. The instrument was improvised while working in over 2,500 fathoms in the Gulf Stream, where the necessity for a guide of some sort was seriously felt.

It is made of black walnut, 2 feet in length and three-quarters of an inch in thickness; the arms are 2 inches in width and the graduated semicircle or double quadrant is 8 inches in diameter. The graduation is on the periphery from 0, when the instrument is held vertically, to 90 degrees to the right and left. The pointer is made of lead one-sixteenth inch in thickness, and swings freely on its pivot.

The figures were stamped with ordinary dies and the depressions filled with white lead. The original instrument is still in use, it having answered the purpose so well that we have had no disposition to replace it.

THE ANGLE AND SCOPE OF DREDGE ROPE.

Its use will be readily understood by reference to the above cut where the vessel is backing and the rope trending ahead. The officer in charge, taking the quadrant in both hands and placing himself in proper position, glances along its straight-edge, inclining it until it is parallel with




the dredge rope. The pointer retains its vertical position by gravity, and consequently indicates the angle from the perpendicular at which the instrument is held or the angle of the dredge rope, which, in this case, is 40 degrees. Enter Table II, Bowditch, with this angle as a course, and find the depth, 1,000 fathoms, in the difference of latitude column (taking one-tenth of the amount), 100.4 being the nearest number. Opposite to this, in the distance column, is 131, which being multiplied by 10 gives 1,310 fathoms, the hypotenuse of the right triangle we have constructed. As the rope has a catenary curve it is necessary to make an allowance in order to insure the trawl reaching and remaining on the bottom. Experience has taught us that about 200 fathoms is sufficient with the above depth and angle; therefore, with a scope of 1,500 fathoms, and the angle of the rope maintained between the limits of 35 degrees and 40 degrees, a successful haul may be anticipated as far as the landing and dragging of the trawl on the bottom is concerned. The speed can be easily regulated, after a little practice, so as to confine the rope between the above limits.

The quadrant is made double in order that it may be used on either side of the vessel, whether steaming ahead or backing.

## SIGSBEE'S GRAVITATING TRAP (PLATES LIII, LIV, AND LV).

The tow net was among the first apparatus used by naturalists to obtain minute animal forms from the surface of the sea, and the same apparatus has been used for collecting at intermediate depths, various methods being employed for sinking it. The range was confined within narrow limits, generally not exceeding a few fathoms below the surface, and even then it was not altogether satisfactory, as specimens might be taken while sinking the net, or hauling it up, their habitat still remaining a mystery.

The dredge rope was brought into requisition on the Challenger, the tow net being secured at the point required to sink it to the desired depth, but the same cause for doubt still existed as to the locality in which specimens were caught in the open-mouthed net, which was twice dragged through the intervening space between the surface and the working depth. The same practice was followed on board of the Fish Hawk until we improved upon it by adopting the wing nets, which were secured to the ends of the trawl beam and acted as collectors from the surface to the bottom, along the bottom as far as the trawl was dragged, and again from the bottom to the surface. There was no pretense of locating the habitat of the myriads of specimens taken in this manner, the nets being used for the simple purpose of making the capture.

The specimens procured by any of the methods above mentioned cannot be assigned to determinate depths. Feeling the need of some device by which this desirable end could be obtained, Prof. Alexander Agassiz, in 1880, requested Lieut.-Commander C. D. Sigsbee, U. S. N., to co-operate with him in devising the necessary apparatus.

Sigsbee says, with reference to the matter (Bulletin of the Museum of Comparative Zoology, Cambridge, vol. vi, pp. 155–6):

"It occurred to me that by using an apparatus in connection with a line and lead, paid out vertically as in sounding, and by dragging vertically instead of horizontally, as formerly, there would be 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 flat 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 process 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 therefore closed, and it is kept closed thereafter by the weight of the messenger, clamp, and cylinder. The friction buffer, which is 4 inches long, may be regulated on board to give as many feet of cushioning as desired.'"

The following is a detailed description of the apparatus:

NOMENCLATURE.

A. Cylinder, copper.
B. Frame, wrought iron.
C. Flap or clapper valve.
D D. Levers.
E. Pivot.
F. Wire sieve (60 wires to the inch).
G. Wire sieve (27 wires to the inch).
H. Wire funnel or trap (27 wires to the inch).
I I. Loops on fairleaders.
J J. Rollers.
K. Frame of friction clamp.
L. Sliding chock.
M. Sliding chock.
N. Adjusting screw.
O. Sling.
P. Eccentric tumbler.
Q. Frame of friction buffer.
R. Sliding chock.
S. Sliding chock.
T. Adjusting screw.
U. Compression spring.
V. Regulating screw.
W. Key.
X. Messenger, cast-iron.

Plate LIII shows the apparatus properly adjusted on the steel-wire dredge rope ready for use. The cylinder A is suspended to the friction clamp by the tumbler P, and confined to the dredge rope by means of the fairleaders I I. The friction buffer is clamped to the rope beneath the cylinder, and the messenger is shown above the apparatus in the act of descending.

Plate LIV shows a detailed plan of the cylinder as follows: Fig. 1, a vertical sectional elevation; Fig. 2, a side view; Fig. 3, a top view; and Fig. 4, a bottom view. The copper cylinder A is secured to the wrought-iron frame B by brass screws, and at the bottom of the frame there is a flap or clapper valve C, which is pivoted at E and opened inwards. It is actuated by the levers D D. The wire sieve F is clamped to the top of the cylinder A; the sieve G is inside of the cylinder A, and is supported on the top of the frame or trap H; the latter being supported on a brass ring secured to the inner surface of the cylinder A, and is held in place by brass clamps. Both the sieve G and the trap H are readily removed.

The steel-wire dredge rope on which the cylinder travels is seen in the fairleaders I I, where it is held in place by the rollers J J.

Fig. 1 of Plate LV is a side view of the friction buffer; Fig. 2 is a sectional elevation; Fig. 3 is a top view; and Fig. 4 is also a top view with the steel face-plate removed.

The frame A of the buffer is made of brass; the sliding chocks R and S, adjusting screw T, compression spring U, and regulating screw V are of steel. The sliding chocks work in the apertures in the frame as shown in Figs. 2, 3, and 4. Their bearing surfaces are corrugated and their inward movement is limited by studs which are part of the frame and fit loosely within a slot in the chocks.

* "In clamping the buffer to the rope the chock R is always screwed in until stopped by its stud; the steel rope is therefore always pressed between the two chocks by the elastic force of the spring, which may be regulated as desired. To regulate the buffer for any definite frictional resistance, clamp it to the rope, and move the regulating screw V well inward; then suspend from the buffer a weight equal to the resistance decided upon. Move the regulating screw outwards until the buffer slides down the rope under the influence of the suspended weight.

"Since the chock R is always screwed down in clamping the rope, the buffer remains regulated for prolonged use with the same resistance; and if the latter proves satisfactory it is probable that the regulating screw need not be touched again for a whole cruise, if the buffer is rinsed in lye-water each time after use."

Fig. 5 is a top view of the friction clamp, and Fig. 6 a side view. The frame K is of brass; the sliding chocks L and M, adjusting screw N, and eccentric tumbler P are made of steel.

Fig. 7 is a side view of the messenger X, Fig. 8 a sectional elevation,

* Sigsbee.

and Fig. 9 a cross-section. The messenger is made of cast iron in two parts, which are held in position on the rope by lashings passed in the scores prepared for the purpose. The key is shown in Fig. 10.

## WORKING THE APPARATUS.

* "It is necessary first to regulate the buffer to cushion the stoppage of the falling weights, which are, cylinder and frame, 38 pounds, clamp 4 pounds, messenger 8 pounds, total 50 pounds. The Blake adopted a resistance of about 80 pounds (this resistance being of course constant during the whole movement of the buffer), it having been found that a blow of that force resulted in no injury to the apparatus.

"On the ascent the buffer must withstand not only the weight of the 50 pounds of metal, but also the resistance which the water offers to the passage through it of the several parts of the apparatus. Moreover, when the cylinder emerges from the water it is full of that liquid and with this increased weight would overcome the stated resistance of the buffer and force the latter downwards until the lead was reached. To meet these conditions it was not thought advisable to increase the resistance of the buffer, which would involve a heavier blow against the apparatus, but a rope-yarn seizing or stop was placed on the rope about 15 or 20 feet below the buffer, beyond which the latter could not pass.

"Having secured the buffer to the rope about 5 or 6 fathoms above the lead (a very heavy lead to keep the rope straight) and paid out the length of rope required to span the stratum to be explored by the cylinder, the clamp and cylinder are attached, the latter being suspended from the former as follows:

"The rope having been placed between the two sliding chocks of the clamp, the arm of the eccentric tumbler is thrown up, which moves the chock M inwards; then, by means of the adjusting screw, the chock L is pressed against the rope, securing the clamp in position. The cylinder hangs 4 or 5 inches below the clamp and is supported by a loop of soft wire which rests on the lip of the tumbler; the ends of the wire, being run through holes in the upper part of the frame of the cylinder, are fastened permanently to the outer arms of the lever D, to which the valve is screwed. It is seen that by this method of suspension the weight of the cylinder and its frame is used to keep the valve closed while paying out. The cylinder should be filled with water, poured down through the upper sieve, to maintain the valve on its seat while the cylinder is being immersed. Rope is then paid out slowly until the cylinder is at the desired depth, when the rope is stoppered and the messenger sent down. The messenger strikes the arm of the eccentric tumbler, throwing it down and tripping the cylinder. The tumbler in falling relieves the pressure on the sliding chock M, which is then free to recede from the rope.

"Messenger, clamp, and cylinder fall together, the valve being held

---

* Sigsbee.

open by the resistance of the water. A current is established through the cylinder, and specimens which enter are retained by the upper sieve. When the buffer is reached, the valve is closed by the pressure against the outer arms of the lever.

"A very slight pressure on the adjusting screw of the clamp, after the chocks are bearing against the rope, is enough to prevent the clamp from slipping, but by an increased pressure on the screw a greater force is required to trip the tumbler, and by this feature the arm of the tumbler is utilized to break the force of the blow which the body of the clamp receives from the falling messenger.

"A few rings of sheet-lead may be laid on the top of the clamp and buffer respectively."

## E.—GENERAL DESCRIPTION OF THE METHOD OF SOUNDING, TAKING SERIAL TEMPERATURES, SPECIFIC GRAVITIES, AND A HAUL OF THE TRAWL.

Having explained the apparatus in use on board the Albatross for deep-sea exploration, a general description of the operations at a single station will be given. We will suppose the depth to be about 1,000 fathoms, scope of dredge rope 1,500 fathoms, wind and sea moderate.

If the working reel is still in its tank it should be suspended and allowed to drain at least a half-hour before being mounted on the machine. We suspend it in its own tank by laying two strips of wood across the top and resting the axle on them, the lower part of the reel being an inch or two above the surface of the oil.

The officer of the deck warns the engineer of the watch half an hour before a station is to be occupied in order that the fires may be regulated. He then makes the necessary preparations on deck; has the reel mounted and the Sigsbee sounding machine rigged for use, the trawl mounted, bridle stops put on, wing nets adjusted, trawl net lashed (the ends of the bridle being made fast by the same lashing), and the mud bag secured to the eyes in the end of the bridle. If the trawl is dry a 27-pound weight is usually included with the mud bag. He has the dredging blocks overhauled and oiled, the register for the dredge rope adjusted, the hoisting and reeling engines oiled and prepared for use, the topping-lift shackled to the dredging boom, and the guys hooked. The end of the dredge rope which is on the drum of the reeling engine on the berth deck, Plate XXIV, is rove through the guide, thence forward through the leading-block, Plate II, Fig. 4, and under the governor pulley, 108, to the large winch-head of the hoisting engine on the upper deck, 40. Five turns of the rope are then taken around the winch-head, and the end carried aloft and rove through the accumulator block, Plate XLII, thence under the register pulley in the heel of the boom and through the dredging-block at the boom end. A thimble is then spliced in and the rope shackled to the trawl.

The boom is then topped up to an angle of about 50°.

When the vessel reaches the intended station the officer of the deck stops her with her stern to the wind, has the patent log hauled in, and then takes his station on the grating at the sounding machine, where he superintends the sounding, and maneuvers the vessel to keep the wire vertical during the descent. Having satisfied himself that the specimen cup is properly bent to the stray line, the sinker adjusted, the thermometer and water bottle clamped, the friction rope properly attended by a careful man detailed for the purpose, a man forward of the machine at the brake, one abaft it with the crank shipped, and another on the grating to attend the guide pulley, he will lower away gently until the apparatus is under water, then seize the small lead to the stray line, caution the record keeper to look out, have the pawl thrown back and the crank unshipped, and order "Lower away!" The speed of descent is regulated by him, and the record keeper reports and records the time at every 100 fathoms, the average being about $1^m\ 8^s$ with a 30-pound sinker, which would be used in the depth mentioned above.

The navigator determines the position. As soon as the sinker reaches bottom the reel is stopped by the friction rope, the record keeper notes the number of turns indicated by the register, the men stationed at the right and left of the machine ship the cranks and heave in a few turns to clear the specimen cup from the bottom, then throw the pawl into action, unship the cranks, unreeve the friction rope, and throw the belt on and set it up by means of the tightening pulley and belt tightener. A fireman, or machinist, has in the meantime prepared the reeling engine and shipped the ratchet crank on the crank shaft. When all is ready, and after the thermometer has had time to record the bottom temperature, the throttle is opened gradually, the engine being assisted over the centers with the ratchet crank, until a uniform speed is attained. The wire is reeled in at the rate of 100 to 125 fathoms per minute, each 100 fathoms being reported and the time noted by the record keeper.

When the stray line appears above water the engine is stopped, the cranks shipped, and the remaining few fathoms reeled in carefully by hand, stopping first to take off the small lead, then the water bottle, which is unclamped by the officer and handed to the man at the guide pulley to be delivered to the medical officer, who either takes its specific gravity or carefully seals it in a bottle prepared for the purpose to be forwarded to the laboratory at Washington for analysis.

The officer then unclamps the thermometer, reads the temperature, which is verified by the record keeper, who resets the instrument and sends it to the pilot-house, where it is suspended from a hook provided for the purpose.

The specimen cup is next removed from the end of the stray line and sent to the laboratory, where its contents are examined by a naturalist who informs the record keeper of the character of the bottom to be entered in his book. The officer of the deck makes this examination himself at times when the naturalists are otherwise engaged.

As soon as the specimen of ocean soil is removed the cup is carefully rinsed in water and adjusted for use.

A small portion of each bottom specimen is preserved in a vial whenever we are working on new ground, or if anything unusual is discovered, and at the end of each season the specimens thus collected are sent to the laboratory at Washington.

## SERIAL TEMPERATURES AND SPECIFIC GRAVITIES.

As soon as the wire is in, the wind is brought a trifle on the starboard quarter by stopping the port engine and backing slowly on the starboard, turning ahead on the port if necessary.

There are two cast-iron sinkers provided for the temperature rope, one 520 and the other 150 pounds weight. One of these is shackled to the end of the dredge rope, swung over the side, and lowered a fathom or two under water, to steady it, the boom being rigged in until the rope rests against the side, inclining a little inboard above the rail.

The vessel having been placed in position, a thermometer and water bottle are sent to the officer of the deck, who clamps them to the temperature rope, the former lower down, in order that, in capsizing to register the temperature, there will be no danger of its striking the water bottle. The navigator sets the valves of the water bottles, and examines the thermometers before they are sent out.

The dredging boom is swung out far enough to clear the rope from the ship's side, and 100 fathoms veered, another thermometer and water bottle clamped on, and the operation repeated to 800 fathoms; the next and last 100 fathoms has instruments at 50 and 25 fathoms.

When sufficient time has elapsed for the thermometer at 25 fathoms to take the temperature the rope is reeled in and the boom swung in as the instruments appear above the rail. The officer of the deck unclamps the thermometer and reads it, then hands it to the record keeper who verifies the reading and notes it, as well as the number of the instrument, in the record book. The boatswain's mate of the watch unclamps the water bottle and delivers it to the surgeon or apothecary, who disposes of it as before mentioned. The instruments are rinsed in fresh water and returned at once to their proper receptacle.

The process is repeated as each pair of instruments reaches the surface until they are all on board, when the sinker is removed and the trawl shackled to the dredge rope. The rate at which the instruments are lowered and hoisted is from 50 to 75 fathoms per minute, depending somewhat upon the state of the sea.

It may not be out of place to mention here the care with which the temperatures are read when the deep-sea thermometers are used. It is well known that an error of parallax arising from the thickness of the thermometer tube is liable to occur; and, in order to reduce it to the minimum, the writer devised a sight block, which is simply a piece of close-grained wood an inch and a half in length, an inch wide, and three fourths of an inch thick. A score is cut on one end which conforms in shape to the outside of the metal case inclosing the thermometer. To read the thermometer (Negretti and Zambra's) hold it at the height of the eye and toward the strongest light. Place the score of the sight block against the metal case, below the point of reading, and raise it carefully until the line of sight corresponds exactly with the upper surface of the block and the top of the column of mercury in the tube, when the temperature may be read with much greater accuracy than could be attained without the block.

### DREDGING OR TRAWLING.

As soon as the sinker is on board, the port engine is started with a caution to the engineer of the watch to "Go slow for dredging!"

The vessel will naturally swing to starboard, which she is allowed to do until the intended course is reached, the wind on the starboard bow, or abeam, being the most favorable if it is intended to steam ahead while dredging.

In the meantime the trawl has been hoisted to the boom end and swung out ready for lowering as soon as the vessel is steadied on her course. It is first landed on the surface of the water and held there until the frame assumes a horizontal position, the net extending aft, at full length, the mud bag floating clear of the bridle ends, and the wing nets towing aft and clear. Then the order is given, "Lower away!" The speed of lowering is regulated by the record keeper, who stands, watch in hand, ready to check or increase the rate of descent, which is never allowed to exceed 25 fathoms per minute in depths over 300 fathoms. The machinist attending the hoisting engine calls out each 100 fathoms, so that the officer in charge knows at all times the amount of rope out.

The port swinging boom is rigged out and towing nets put over as soon as the vessel is steadied on her course, the speed for dredging (about 2 knots per hour) being admirably adapted for surface work. The nets are in charge of a man detailed from the crew, who works under the direction of a naturalist.

While the trawl is being lowered the officer in charge watches the angle of the rope, regulating the speed to keep it between 30° and 60°. He notes the trend of the rope also, whether it is toward or from the ship, and in the former case changes the course a trifle to starboard, which tends to carry it from the side. It frequently happens that the vessel will not steer with the port engine turning at a speed of 2 knots or less, especially after much rope has been veered out. In this case the starboard engine is started and the port one stopped. There is no difficulty while the starboard engine is in motion, as the inclination to turn to port is counteracted in a great measure by the drag of the trawl. This engine would be used at all times when steaming ahead were it not for the danger of the trawl or dredge rope fouling the propeller before they sink below the surface.

The angle of the rope will gradually decrease as the trawl descends, and if it is 60° at starting it should be about 40° when the limit of 1,500 fathoms is reached. Should it exceed that angle after the engine has been running "dead slow," as may happen with a current in the direction of the course, it is advisable to stop until the angle is between 30° and 35°, then move ahead slowly with the same engine, regulating the speed so as to keep the angle between 35° and 40°. If there is no current the requisite speed will be readily attained with the engine; but if there should be a current with the wind, and the lowest speed attainable be too great, the engine should be stopped and the vessel allowed to drift, the rate being increased, if desirable, by the use of sail. In exceptional cases we have found it necessary to retard the drift by backing one of the engines.

The accumulator is watched closely after the trawl is landed, and any increase in weight is carefully noted. Should the increase be gradual and not excessive, the trawl is undoubtedly performing its functions normally; but a sudden addition of 2,000 or 3,000 pounds indicates that the trawl has either encountered some obstacle or buried itself in the soft ooze of the ocean bed. In either case instant relief is required and is received, first, from the hoisting engine, which, having its friction lever properly set, allows the dredge rope to run out when the limit of safety is reached; then the engine is stopped and reversed, and, as as soon as the headway is checked, preparations are made for heaving in.

The vessel is then backed slowly toward the trawl, the slack rope reeled in, keeping a tension on it equal to or somewhat greater than the weight of rope out, in order to guard against slack which would result in kinks. In this manner the vessel will be placed directly over the trawl and the rope hove short. If the trouble has arisen from an ordinary obstruction it can be cleared usually by backing in the opposite direction from which it was laid out. Should this maneuver fail it is pretty safe to conclude that the trawl has buried, and in this case we heave in until we reach the limit of safety and allow the vessel to ride by the rope until the tension decreases; then heave again, until the trawl is gradually worked out of its bed. We then steam ahead slowly, washing the mud from the net until it can be hove up safely.

Should all efforts fail to clear it, as sometimes happens, we make everything fast and steam ahead until either the bridle-stops part and the trawl comes up tail first, or the rope parts, the trawl and its attachments being lost.

The most trying position is when we get an overload of stones, clay, or tenacious mud which will not wash through the meshes of the net, and must be hove up with the greatest care, consuming hours of valuable time, and not infrequently parting the bridle-stops or the rope just as the trawl heaves in sight, losing the entire contents or the trawl itself, as the case may be.

Supposing everything to have worked satisfactorily and the trawl been dragging half an hour, the order is given to get ready for heaving. The hoisting engine is moved to work the water out of the cylinders, and the moving parts are oiled. The reeling engine is likewise put in readiness, the guide connected, and the governor brought into action. Everything being ready the order is given to heave away, and the rope reeled in at the rate of 25 fathoms per minute, the vessel being allowed to retain her headway until the trawl is known to be well clear of the bottom.

This is done for the double purpose of avoiding the danger of the trawl settling in the mud if allowed to remain stationary for any length of time, and to prevent fish or other specimens which have not already found their way to the pocket from floating or swimming out of the mouth of the trawl.

The speed at which it is hove up is varied according to circumstances, not exceeding 30 fathoms per minute under the most favorable conditions when the specimens are from a greater depth than 500 fathoms; although in shoal water a speed of 35 fathoms per minute is at times admissible. The machinist at the hoisting engine reports each 100 fathoms as in veering out, and the record keeper notes it in his book.

After the trawl is off the bottom and the engine stopped, the dredge rope will sometimes draw under the bottom, even though the vessel has her starboard broadside to the wind and is drifting rapidly. In this case we would back the starboard engine, go ahead on the port, and put the helm hard a-port, which would soon clear it. This trouble usually occurs in reeling in after the trawl has been laid out, steaming head to wind or backing stern to it, and the vessel has been allowed to fall off with the dredge rope to windward, a position which at first sight seems to be the proper one. Such is not the case, however, for the vessel is lying at right angles to her former course, and consequently with the rope trending under her bottom. If it is reeled in faster than the vessel is drifting, it will be drawn still more closely under the keel.

If the trawl has been laid out against the wind, heave to with the dredge rope to leeward, when the drift will assist the operation of reeling in. It should be borne in mind, however, that the vessel must be turned with the dredge rope to windward by backing the starboard and going ahead on the port engine before it draws under the bottom, which it will do as soon as the vessel has drifted over the position of the trawl.

When the trawl is up, the boom is rigged in until the bag swings against the ship's side, when a strap is passed around it and it is hoisted on board by means of a stay tackle. If the load is very heavy, the afterboom guy is used to help to get it over the rail, the lower block being hooked usually to the eye in the end of the bridle.

The mud bag is removed first, then the lashings taken off, and the contents emptied into the table sieve. The naturalists then collect the specimens, the steam hose being used to wash the mud from them.

The trawl is lowered on deck after being relieved of its contents, the wing nets and trawl nets carefully attended to, the lashings replaced, bridle-stops examined or renewed, and everything made ready for another haul.

The vessel resumes her course as soon as the trawl leaves the water.

The handling of the trawl and the maneuvering vessel while trawling is under the personal supervision of the commander or executive officer.

The time consumed in sounding, taking serial temperatures, and a haul of the trawl as described is about three and one-half hours.

## F.—OTHER APPARATUS.

The fishing gear, collecting apparatus, and laboratory outfit are quite extensive. The following summary includes the most important articles:

### FISH LINES RIGGED FOR USE.

12 squid lines.
10 whiting lines.
2 boat-cod hand-lines, 2-pound leads.
2 boat-cod hand-lines, 3-pound leads.
2 boat-cod hand-lines, 4-pound leads.
5 red snapper lines.
5 bluefish lines for trolling.
4 sea-bass lines, style used in Southern States.
4 sea-bass lines, style used by New York smackmen.
5 bluefish lines for still-baiting.
1 shark line.
8 skates halibut trawl line.
4 tubs haddock trawl line.
60 mackerel hand-lines.

In addition to the lines ready for use, the laboratory contains a quantity of spare lines and a large assortment of hooks, sinkers, jigs, &c.

### MISCELLANEOUS APPARATUS USED IN FISHING.

Anchors, snug stow net.
Anchors, snug stow trawl.
Baskets.
Buoys, halibut trawl.
Buoys, keg net.
Compasses, dory.
Fish forks.
Fish pew.
Floats, covered glass.
Gaffs, deck, cod.
Gaffs, dory, cod.
Gaffs, iron, halibut.
Harpoons, assorted.
Hooks, ice.
Hurdy-gurdy or trawl winch.
Jigs, mackerel.
Jigs, squid.
Knives, codfish bait.
Knives, codfish throating.
Knives, dory.
Knives, halibut bait.
Knives, mackerel splitting.
Knives, oyster.
Lance, shark-killer.
Lance, whale.
Leads for net lead-line.

Mill for grinding bait.
Mold for lead-line sinkers.
Mold for mackerel jigs.
Nippers, woolen.
Scoops, bait.
Scoops, ice.
Splicers, iron line.
Swivels, snood.
Swivels, slot.
Shovel, ice.
Sling ding spreaders.
Tubs, dressing.
Tubs, gib.
Whale gun.
Whale line.

NETS.

| Kinds. | Length. | Depth. | Size of mesh. | Twine. |
|---|---|---|---|---|
| | *Fath.* | *Fath.* | *Inches.* | |
| Trammel net (2) | 15 | 2½ | { 2<br>6 | 35-3<br>12-16 |
| Mackerel gill net | 30 | 2⅜ | 3¾ | 16-6 |
| Do | 30 | 2¼ | 3 | 16-6 |
| Do | 30 | 2⅜ | 2¼ | 16-6 |
| Menhaden gill net | 15 | 2 | 3⅜ | 16-6 |
| Do | 15 | 2 | 2⅜ | 16-6 |
| Shad gill net | 50 | 4 | 4⅞ | 35-3 |
| Do | 50 | 4 | 4½ | 35-3 |
| Cod gill net | 100 | 2 | 7 | 40-10 |
| Do | 100 | 2 | 8 | 40-10 |
| Herring gill net (2) | 20 | 2½ | 2¾ | 20-6 |
| Do | 20 | 2⅜ | 2⅜ | 20-6 |
| Red snapper gill net (2) | 50 | 3 | 9 | |
| Capelin seine | 40 | 3½ | { 0¾<br>2⅝ } | 12-6 |
| Casting net | | | | |

DIP AND SCOOP NETS.

| Kinds. | Bow diameter. | Handle length. | Number in outfit. |
|---|---|---|---|
| | *Inches.* | *Feet.* | |
| Dip nets for mackerel seine | 20 | 10 | 2 |
| Dip nets for torching, linen | 23 | 7 | 2 |
| Scoop nets with round bows for handling fresh fish | 15 | 4½ | 6 |
| Scoop nets with straight edge | 14 | 4½ | 2 |

LABORATORY OUTFIT.

Antimony.
Arsenic.
Alum.
Acids, picric, chromic.
Anvil.
Brushes, water.
Bags, rubber.
Boxes, small assorted paper.
Boxes, nests, assorted.
Buckets.
Cloth, cotton cheese.
Clay for making casts.
Chisels, cold.
Chisels, mortising.
Cutters, wire.
Camera lucida.
Dippers, galvanized-iron.
Dippers, galvanized-iron, fine wire-cloth bottom.
Dishes, assorted, glass and earthenware.
Drills, twist, assorted.
Hammers, blacksmith's.
Hammers, riveting.
Hatchet.
Jars, with corks, eight sizes.
Jars, fruit, 1-pint, 1-quart, 2-quart.

Jars, butter, 2-pound, 4-pound.
Knives, cartilage.
Knives, dissecting.
Microscope, with accessories.
Nets, surface, silk bolting cloth.
Nets, surface, linen scrim.
Nets, tub strainer, linen scrim.
Paper, manilla.
Paper, straw.
Paper, English white tissue.
Pans, large, galvanized-iron.
Potash.
Plaster for molds and casts.
Presser, cork.
Rings, galvanized-iron, surface net.
Rings, brass, surface net.
Rule, millimeter.
Rule, common, 2-foot.
Rifle, 32 caliber.
Shotguns, 12 bore (2).
Shotguns, 10 bore (1).
Spades, trenching.
Spades, common.
Shovels, common.
Seives, assorted.
Scissors.
Tubs, wash, large size.
Tanks, copper alcohol, in boxes, 17 16-gallon, 20 8-gallon, 40 4-gallon.
Vise, hand.
Vise, bench.
Vials, homeopathic, assorted.

### THE LIBRARY.

The ship's library contains over 300 volumes. Under the head of natural history, &c., there are 58 volumes; scientific, 57 volumes; publications of the United States Fish Commission, Smithsonian Institution, and National Museum, 48 volumes; miscellaneous, 36 volumes; navigation and nautical astronomy, 19 volumes; history and biography, 18 volumes; steam, 6 volumes; &c.

It was the intention to provide such works as would be useful in all the branches of investigation carried on by the vessel, text-books and professional works required for reference by naval officers, besides a few standard volumes of history and biography.

### REMARKS ON THE OUTFIT, MESS FURNITURE, ETC.

It is customary in the naval service to provide a recruit with bag and hammock free of charge, his mattress and blankets being furnished by the paymaster and charged to his account. This expense although not very serious for a three years' recruit assumes greater importance when the term is for one year only, as with us, and to avoid running the men in debt to that amount we have adopted the plan of supplying them with mattresses and blankets without charge, holding them responsible for their proper care while in use, and their return to the ship before they receive their discharge.

Mess furniture for the cabin, wardroom, and steerage was furnished by the Commission as the simplest solution of a rather complicated situation which may be briefly stated as follows:

The officers of the ship detailed from the naval service would be expected to furnish their own mess furniture, bed linen, &c., according to custom, but the Commission would be obliged to provide for the naturalists, from one to half a dozen, who come and go as occasion requires, as it would be obviously unjust to require the officers of the ship to furnish them with the necessary outfit. Even this arrangement would prove unsatisfactory from the difficulty of properly apportioning the mess expenses, hence the necessity for the following plan which has worked to the satisfaction of all concerned:

The Commission furnishes the quarters and mess furniture complete, as stated above, and pays to the officers' mess the uniform sum of $1 per day for subsistence of each person sent on board by competent authority. The same provision is made for them as for officers regularly attached to the vessel, and they are accorded equal privileges in the mess while temporarily attached to it.

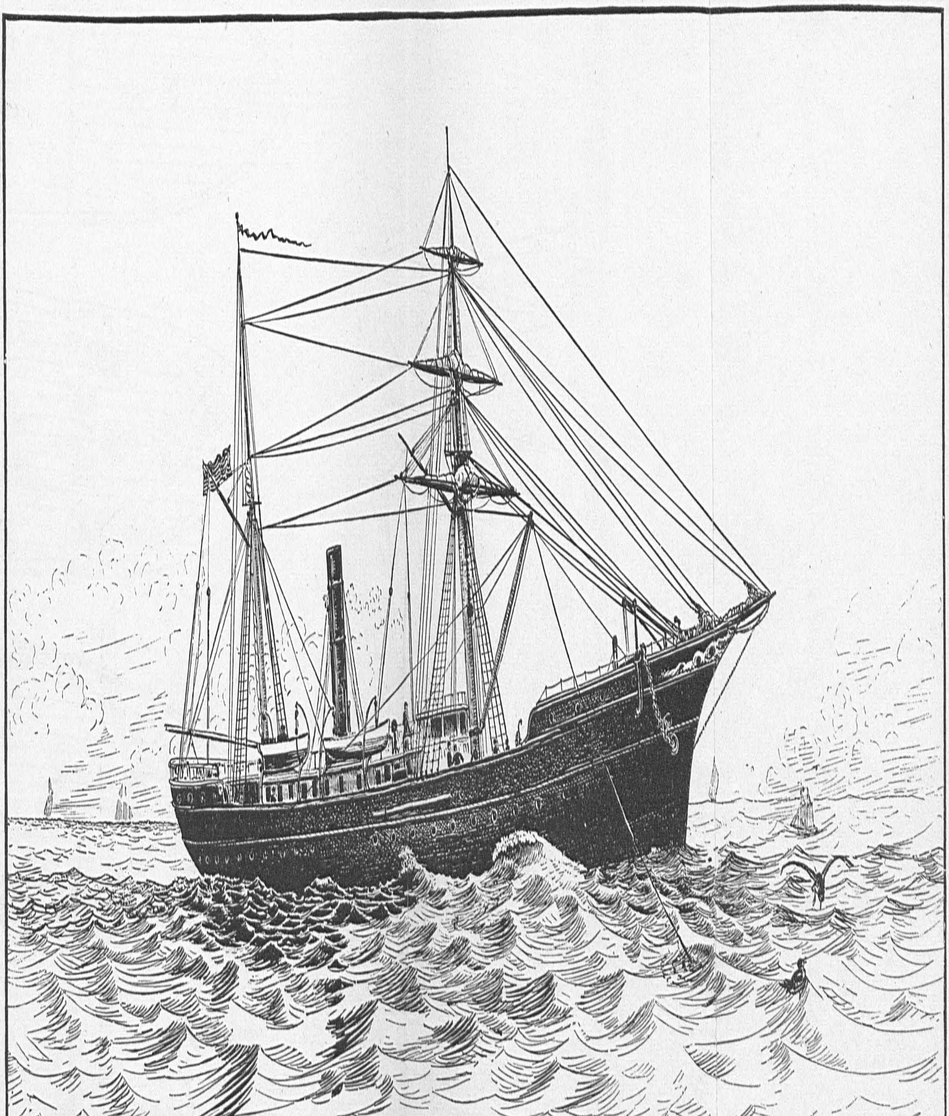
## G.—CO-OPERATION OF THE NAVY DEPARTMENT.

The officers and crew were furnished by the Navy Department in accordance with the act of May 31, 1880, and acting under Sec. 4397, act of February 9, 1871.

The Bureau of Equipment and Recruiting furnished anchors and chains, including mooring swivel, chain hooks, extra club link, spare shackles, implements, &c.

The Bureau of Navigation furnished 1 azimuth circle, 2 tripods, 2 liquid compasses, 1 set of navigation books, 1 set of charts, 1 hack chronometer, 1 course indicator, and 2 boxes of Very's night signals, with pistols, pouches, and frogs.

The Bureau of Ordnance furnished 1 3-inch B. L. rifle with complete outfit, including 75 charges of powder, 25 shells, 25 shrapnel, 50 boxer fuses, &c.; 6 Hotchkiss rifles with 1,200 cartridges, 9 revolvers and frogs, with 240 cartridges.



The Albatross dredging.