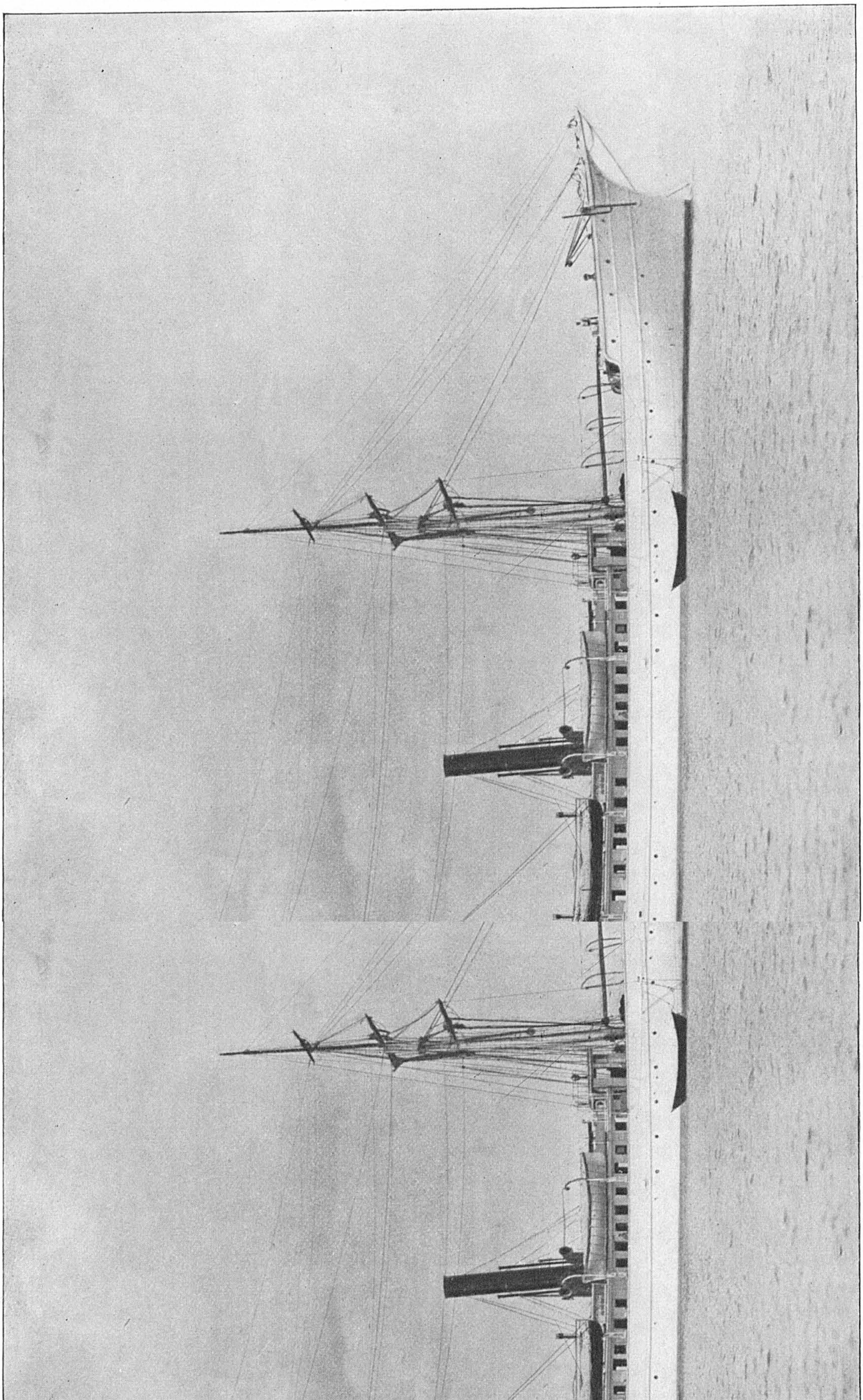
DEEP-SEA EXPLORATION:

A GENERAL DESCRIPTION OF THE STEAMER ALBATROSS, HER APPLIANCES AND METHODS.

By Z. L. TANNER,

Commander, United States Navy.



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INTRODUCTION.

Early in September, 1880, immediately after the return of the U. S. Fish Commission steamer *Fish Hawk* from her initial trip off shore, to the region subsequently known as the Gulf-stream slope, Prof. S. F. Baird was impressed with the necessity of a larger vessel for deep-sea investigations. The remarkable results of the *Fish Hawk's* operations, though limited to depths of a few hundred fathoms, convinced him that his investigations should be extended into more remote and deeper waters.

In discussing the subject with the writer he remarked, in effect, that the profitable study of useful sea fishes could not be prosecuted without a knowledge of their food, the food of their food, their respective friends and foes, the habitat of the several species, and their means of passing from one region to another in the embryonic as well as the adult stage; the temperatures, currents, and specific gravity of the waters of the ocean should be studied in connection with the migratory habits of pelagic forms, hence investigations must be extended seaward wherever life exists, until a complete history of both the economical and contributory species is obtained. To prosecute these researches a sea-going steamer, specially constructed and equipped to carry on this work, was an absolute necessity.

Subsequent off-shore trips made by the *Fish Hawk* further convinced him of the importance of having a larger ship. The subject was frequently under discussion, and a few months later he requested the writer to make general plans and estimates for the construction and equipment of a thoroughly seaworthy steamer, capable of making extended cruises and working with dredge and trawl in all depths to 3,000 fathoms.

A rough plan was accordingly prepared, showing the type of vessel contemplated, and distribution of weights and spaces, from which the final designs were made by the late Charles W. Copeland, an eminent marine architect and engineer, of New York. After the usual competitive bids required for Government work, the contract was awarded to the Pusey & Jones Company, of Wilmington, Del., in March, 1882, for the sum of $145,800, exclusive of outfit and special equipment, which cost an additional $45,000. She was launched August 19, 1882, was christened the *Albatross*, and went into commission on the 11th of the following November.

The writer was ordered to superintend her construction in addition to his duties as commanding officer of the *Fish Hawk*. Passed Assistant Engineer George W. Baird, United States Navy, superintended the construction of machinery and also had general supervision of all work in the absence of the writer. He rendered efficient service in devising and perfecting many novel mechanical appliances with which the vessel was provided, and was subsequently ordered as chief engineer, his cruise extending over the unusual period of five years.

The writer assumed command November 11, 1882, and was detached May 1, 1894, having made a continuous cruise of eleven and a half years.

This publication is essentially a revision and extension of the "Report on the construction and outfit of the U. S. Fish Commission steamer *Albatross*, 1883," and was undertaken at the instance of the late Commissioner, Marshall McDonald, who was desirous that the experience of the writer in deep-sea exploration, extending over a period of fifteen years, should be made available in a convenient form. It comprises an account of the important changes in appliances and improvement in methods, treating the several branches in detail, with a view of furnishing to the beginner such information as would have been most valuable to the writer when he first took up the work.

Brief historical sketches are given of the development of physical and biological researches during the last half century leading up through the evolutionary stages to the present time, and finally illustrating the modern science of deep-sea investigation as practiced on board the *Albatross*.

A change in the arrangement of fire-room and coal bunkers followed the installation of new boilers of a different type from those originally in the vessel; the ventilating apparatus has been much improved; ingeniously constructed counter balances have been applied to the main engines; and the maneuvering qualities of the vessel are much improved by the introduction of pneumatic annunciators which enable the officer on the bridge to observe the movements of the engines by reference to a conveniently placed dial and pointer. The old cast-iron propellers have been replaced by new ones of bronze, having finer pitch and less weight; a Baird evaporator greatly improves the quality of water distilled for drinking purposes and furnishes fresh feed for the boilers.

The changes and additions to the scientific apparatus will be described in detail.

Acknowledgments are made to the following authorities, who have been freely quoted:

Sir C. Wyville Thomson, "Depths of the Sea" and "The Voyage of the *Challenger*."

Rear-Admiral G. E. Belknap, United States Navy, "Hamersley's Naval Encyclopedia" and "Deep-Sea Soundings in the North Pacific."

Commander C. D. Sigsbee, United States Navy, "Deep-Sea Sounding and Dredging."

Lieut. Commander Seaton Schroeder, United States Navy, and Chief Engineer George W. Baird, United States Navy, "Report on the Construction and Equipment of the U. S. Fish Commission steamer *Albatross*."

The late J. H. Kidder, M. D., "Report on the thermometers of the United States Commission of Fish and Fisheries."

Mr. O. H. Tittmann, "United States Coast and Geodetic Survey Bulletin, No. 18."

The writer would also express his indebtedness to Dr. John Murray, of Edinburgh, Scotland, for a specially prepared paper on the methods of recognizing marine deposits, and to Prof. C. F. Marvin, United States Weather Bureau, for a paper on the method of correcting thermometers.

Special thanks are tendered to Mr. James E. Benedict, the first resident naturalist of the *Albatross*, and to Mr. C. H. Townsend, who succeeded Mr. Benedict after a short interval, and still holds that responsible position, for data kindly furnished for the chapter on the preparation and preservation of specimens.

FIG. 1. PLAN OF POOP, HOUSE & FORECASTLE DECKS.

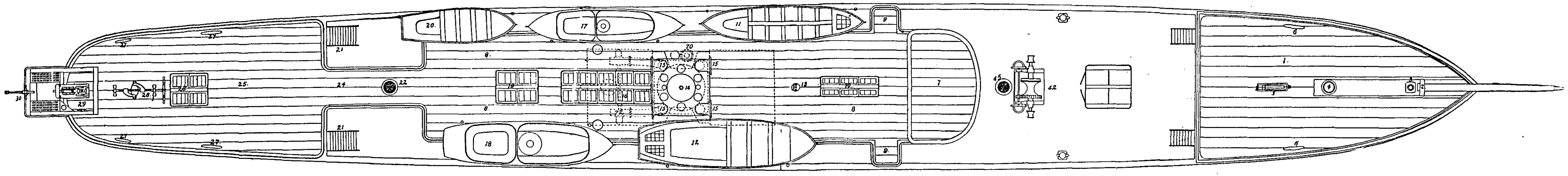


FIG. 2. PLAN OF MAIN DECK

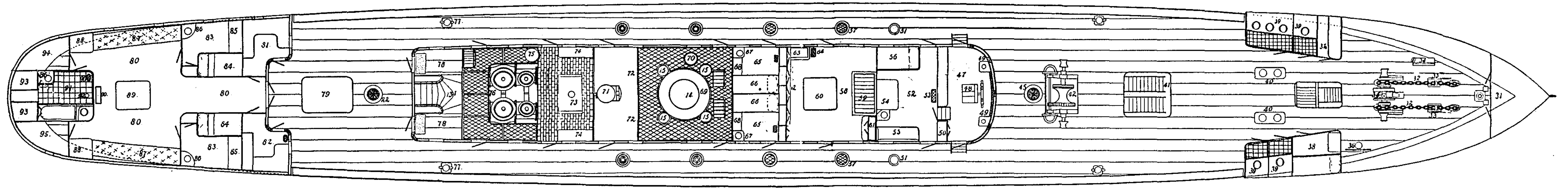


FIG. 3. PLAN OF BERTH DECK

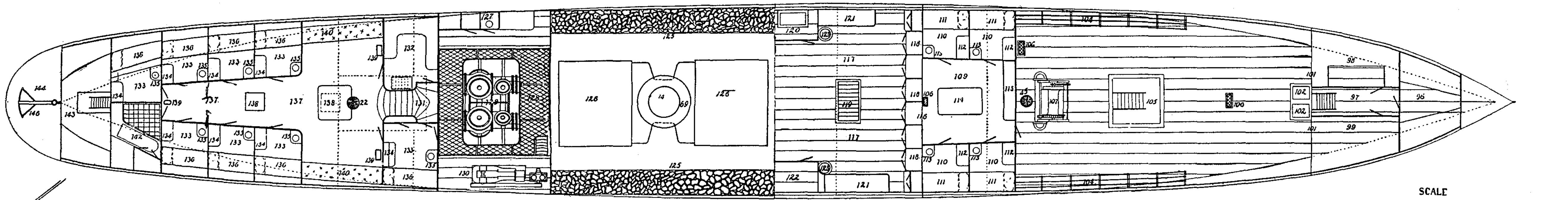
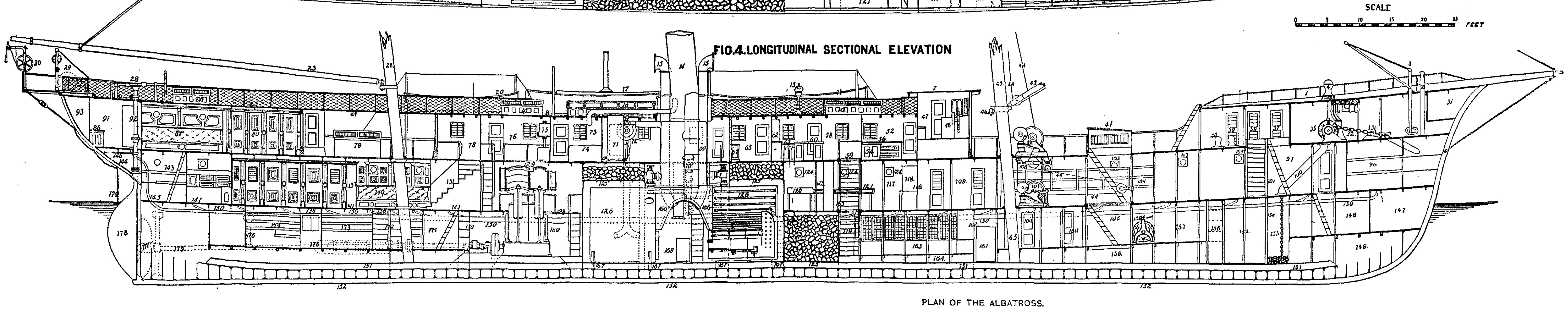


FIG. 4. LONGITUDINAL SECTIONAL ELEVATION



Poop, house, and forecastle decks.

1. Forecastle.
2. Wooden bitts.
3. Fish davit.
4. Steam capstan.
5. Hotchkiss revolving cannon.
6. Iron cleats.
7. Top of pilot-house.
8. Top of deck-house.
9. Bridge.
10. Skylight over chart-room and laboratory.
11. Whaleboat.
12. Ten-oared cutter.
13. Standard compass.
14. Smokestack.
15. Ventilators to fire-room.
16. Skylight over drum-room and galley.
17. Steam gig (Herreshoff).
18. Steam cutter (Herreshoff)
19. Engine-room skylight.
20. Dingey.
21. Poop ladders.
22. Mainmast.
23. Mainboom.
24. Bridge from poop to deck house
25. Poop deck.
26. Cabin skylight.
27. Iron bitts.
28. Auxiliary steering gear.
29. Sigsbee deep-sea sounding-machine.
30. Tanner sounding-machine.

Main deck.

31. Paint locker.
32. Chain cables.
33. Stopper for chain cables.
34. Compressor for steel-wire hawser.
35. Steam windlass.
36. Forecastle pump.
37. Lamp-room.
38. State-room for petty officers.
39. Water-closets.
40. Iron bitts.
41. Fore hatch.
42. Dredging engine.
43. Dredging boom.
44. Dredge rope, rove for use.
45. Foremast.
46. Ship's bell.
47. Pilot-house.
48. Steering gear, hand and steam.
49. Binnacle.
50. Signal locker.
51. Deck lights.
52. Chart-room.
53. Steam heater.
54. Chart table.
55. Chronometer box and lounge.
56. Berth.
57. Bunker plate and coal-chute.
58. Upper laboratory.
59. Hatch to lower (or main) laboratory.
60. Work table for naturalists.
61. Chemical case for preservative mixtures.
62. Bookcase; scientific library.
63. Sink.
64. Steam heater.
65. Naturalist's state-rooms.
66. Berth.
67. Washstand.
68. Bureau.
69. Steam drum.
70. Ash-chute.
71. Baird's evaporator.
72. Exhaust fans for ventilating the vessel.
73. Galley.
74. Sink.
75. Baird's distiller.
76. Upper engine-room.
77. Iron bitts.
78. Ward-room companion-way.
79. Ward-room 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. China 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 lockers.
101. Collision bulkhead.
102. Hatch to ice box.
103. Air port.
104. Bag rack.
105. Hatch to mainhold.
106. Steam heater.
107. Reeling engine.
108. Governor.
109. Steerage.
110. Steerage state-rooms.
111. Berth.
112. Bureau.
113. Washstand.
114. Table.
115. Open pantry.
116. Water-tight iron bulkhead.
117. Lower (or main) laboratory.
118. Lockers with movable trays for specimens.
119. Ladder to laboratory store-room.
120. Photographer's dark room.
121. Table.
122. Dispensary.
123. Coal-chute.
124. Air ports.
125. Coal-bunkers.
126 Boilers.
127. Oil-tanks.
128. Iron floor grating.
129. Main engines.
130. Dynamo and engine (Edison system).
131. Ward-room companion stairs.
132. Ward-room pantry.
133. State-room.
134. Bureau.
135. Washstand.
136. Berth.
137. Ward-room.
138. Table and water-tight doors.
139. Steam heater.
140. Lounge.
141. Iron water-tight deck.
142. Bath-room.
143. Cabin store-room.
144. Quadrant-room.
145. Ventilating pipe.
146. Quadrant of rudder.

Holds.

147. Magazine.
148. Magazine passage.
149. Fore peak.
150. Ventilating pipe with branches.
151. Keelson.
152. Keel.
153. Chain lockers.
154. Collision bulkhead.
155. Ice box.
156. Cold-room.
157. Main hold.
158. Lower hold.
159. Steel-wire hawser and reel.
160. Store-room.
161. Fresh-water tanks.
162. Water-tight iron bulkhead.
163. Laboratory store-room.
164. Ballast and sinkers.
165. Water-tight iron bulkhead.
166. Uptake.
167. Boiler leg.
168. Fire-room.
169. Lower engine-room.
170. Water-tight iron bulkhead.
171. Ward-room, store-room, and shaft alleys.
172. Water-tight iron bulkhead.
173. Paymaster's store-room.
174. Equipment and navigation store-room.
175. Propeller shaft.
176. A-frame for propeller shaft.
177. Propeller.
178. Rudder.
179. Rudder chains.

PLAN OF THE ALBATROSS.

THE ALBATROSS: HER DIMENSIONS, GENERAL DESIGN, AND METHOD OF CONSTRUCTION.

The *Albatross* is an iron twin-screw steamer constructed in accordance with Lloyd's rules for vessels of her class, except where extra strength and protection were given her in view of the severe strains and unusual exposure to which she would be subjected in the prosecution of her special work. She was built by the Pusey & Jones Company, of Wilmington, Del., launched August 19, 1882, and went into commission on the 11th of the following November.

Her general dimensions are as follows:

Length over all, 234 feet.
Length at 12-foot water-line, 200 feet.
Breadth of beam, molded, 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.

She is rigged as a brigantine, carrying sail to a foretop-gallant sail. The spars are white pine and spruce.

Spars.			Sails.		
Name.	Feet.	Diameter in inches.	Name.	Canvas.	Square feet.
Mainmast above main deck	56	20	Mainsail	No. 2	1,488
Maintop-mast above cap	32	9½	Gaff-topsail	No. 7	578
Foremast above deck	52	21	Foresail (27-foot drop)	No. 2	1,156
Foretop-mast above cap	30	10½	Fore trysail	No. 2	872
Fore yard, length	50	11	Foretop-sail (24⅔-foot hoist)	No. 4	934
Foretop-sail yard, length	40	9	Foretop-gallant sail (14½-foot hoist)	No. 6	389
Foretop-gallant yard, length	27½	5½	Fore staysail	No. 2	660
Fore gaff	27	7½	Jib	No. 5	918
Main boom	56	12½	Flying jib	No. 6	526
Main gaff	36	9½			
Dredging boom	36	10	Total sail area		7,521

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

Anchors and chains: One 1,900 pounds, 120 fathoms, 1⅝-inch chain; one 1,288 pounds, 120 fathoms, 1 3/16-inch chain; one 1,030 pounds; one 600 pounds; 250 fathoms Bullivant's elastic steel wire cable, 3⅛ inches circumference.

DETAILS OF CONSTRUCTION.

Hull: The *Albatross* has a "bar" keel of the best hammered iron, 8 by 2¼ inches, scarfs 25 inches in length. There is one bilge keel on each side, 10¼ feet from center line, parallel thereto, of two angle-irons 4 by 6 by ⅝ inches, with a ⅞-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, 7½ by 2½ inches; and the stem is of the same material, 7½ by 2¼ inches. The frames are of angle-iron; those under the engines and boilers 4 by 3 by 7/16 inches; forward and aft of these they are 3½ by 3 by 7/16 inches. Frames and floor spaces, 21-inch centers.

The floors are in one piece, 18 inches deep and 8/16 inch thick for three-fifths the vessel's length amidships, 7/16 inch thick forward and aft. They are on every frame extending 20 inches above top of floor amidships, molding to size of 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 $\frac{6}{16}$ 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 long, 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. Additional intercostal keelsons are placed under the engines.

Deck beams: 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 $\frac{1}{2}$ 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 $\frac{1}{2}$ 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 $\frac{1}{2}$ 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 $2\frac{1}{2}$ by $\frac{3}{8}$ 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.

PLATE III.

THE CABIN.

THE CABIN.

Bulkheads: One collision water-tight bulkhead about 25 feet from the stem; one at the after end of the forehold, connected by deck plates as shown on the plan; one forward of boilers, connected by iron deck; one between the engines and boilers; a water-tight compartment abaft the engines between the shafts, the after end extending to the after collision bulkhead, which is at the forward end of the stern pipes; it is attached to the cross keelson which sustains the stern pipes, and extends to the berth deck with a plate-iron covering over the beams so as to make the after compartment entirely water-tight; the other bulkheads extend from the floors to the main-deck beams. Bulkheads are of $\frac{5}{16}$ iron butt-joints; strakes run in one length from floors to deck beams, 30 inches wide. The lap strips of joints are of T iron, $3\frac{1}{2}$ by 3 by $\frac{5}{16}$ inches; laps single-riveted with $\frac{5}{8}$ rivets. The after collision bulkhead has recently been extended up to the main deck. Sluice valves are provided; bilge suction-pipes from the several compartments connect to a manifold in the engine compartment, and each pipe has a foot valve.

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 $\frac{5}{16}$ 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 $3\frac{1}{2}$ 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. Along the whole length of the upper edge of the bulwark plates, on the outside, is run an angle-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{3}{8}$ 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 $\frac{4}{8}$ inch thick at midship length, gradually reduced to $\frac{7}{16}$ inch forward and aft. The remaining side plating is $\frac{6}{16}$ 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 $\frac{4}{8}$ 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, etc., 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 by 5 feet overhead.

Deck-house: Forward of the cabin there is a clear space of 16 feet containing the ward-room 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, etc., being of galvanized iron. Beginning aft, it is divided into the following apartments:

(1) Entrance to ward-room: 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 ward-room 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 20 feet in length, and the width of the house. It is fitted with doors and windows like those of the engine-room, has a skylight 5 by 10 feet overhead, and communicates by a stairway 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. It also contains the ventilating apparatus and Baird evaporator.

(5) State-rooms: Forward of the drum-room the wooden part of the deck-house commences with two state-rooms, one 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, etc. 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 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 chemical case.

PLATE IV.

UPPER LABORATORY.

UPPER LABORATORY.

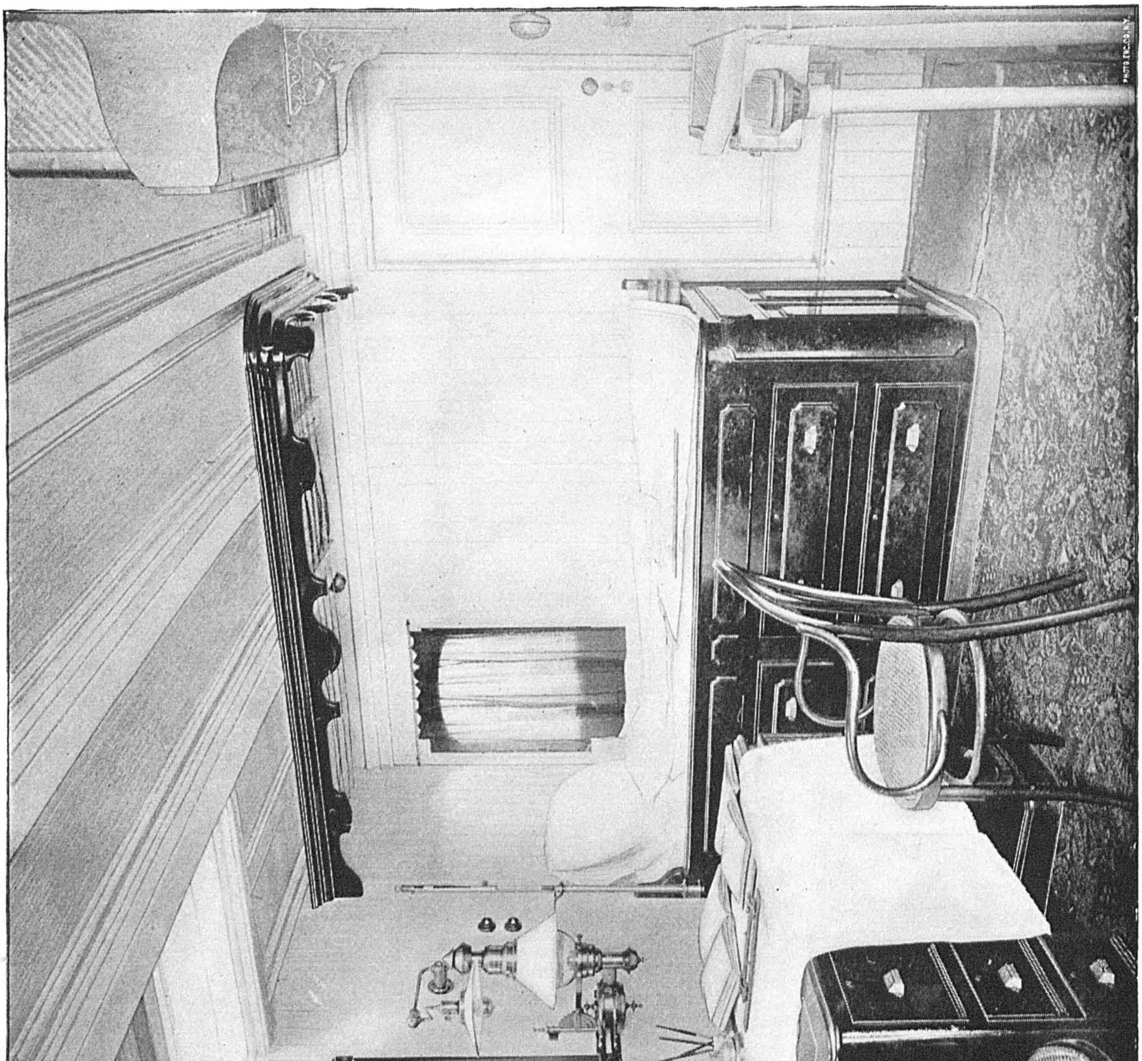


CHART ROOM.

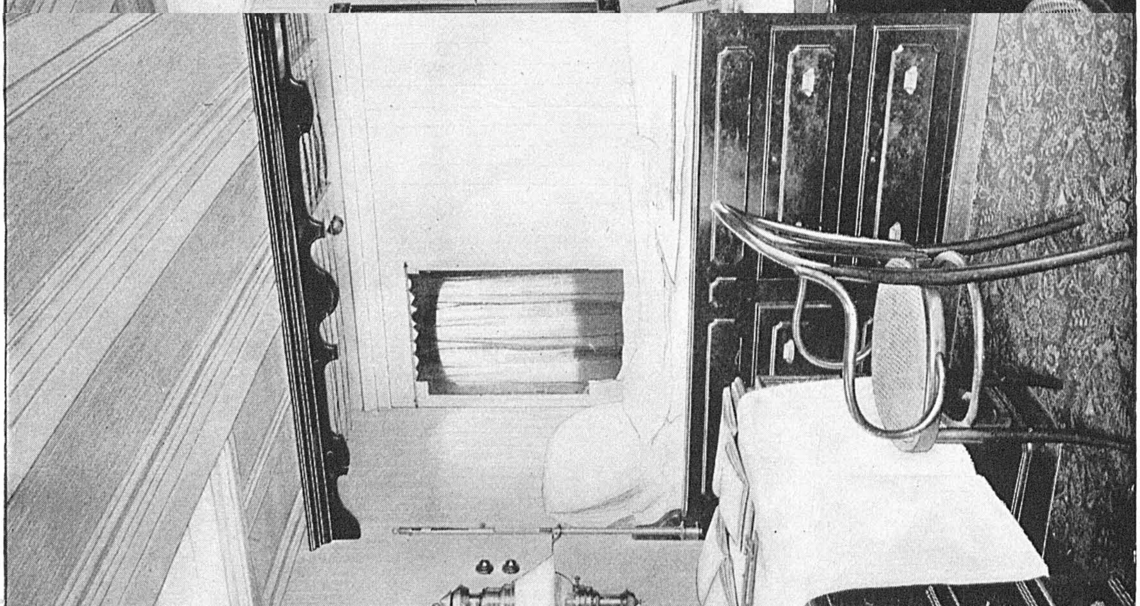
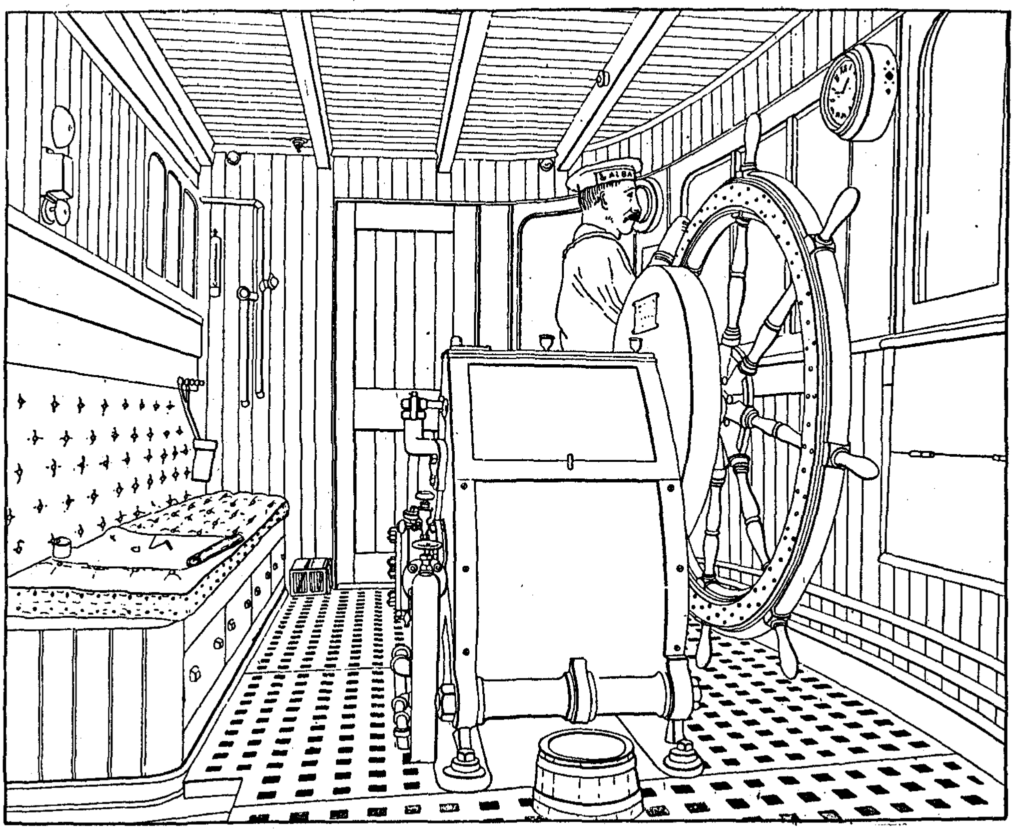


CHART ROOM.

(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, etc., a berth, washstand, lockers, bookshelves, 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: 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.



CUT 1.—Interior of pilot-house, steam steering engine.

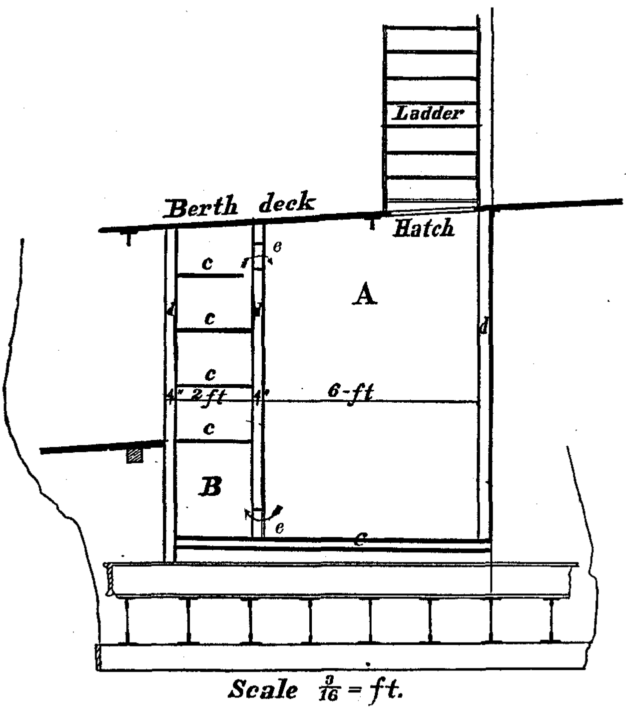
The pilot-house is raised about 3 feet above the main deck and projects the same distance above the top of the house, with which it communicates by two windows. Suitable bell pulls and speaking tubes furnish the necessary means of communication with the engine-room, and instead of the ordinary ship's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

Topgallant forecastle: The topgallant 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 directly underneath, and just abaft the capstan is a 37 mm. Hotchkiss revolving cannon, mounted on a tripod.

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

Berth deck: 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 in the hold 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 4 inches, which is filled with proper nonconducting 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 bilge. The capacity of the ice boxes is about 3 tons each, 6 tons in all.



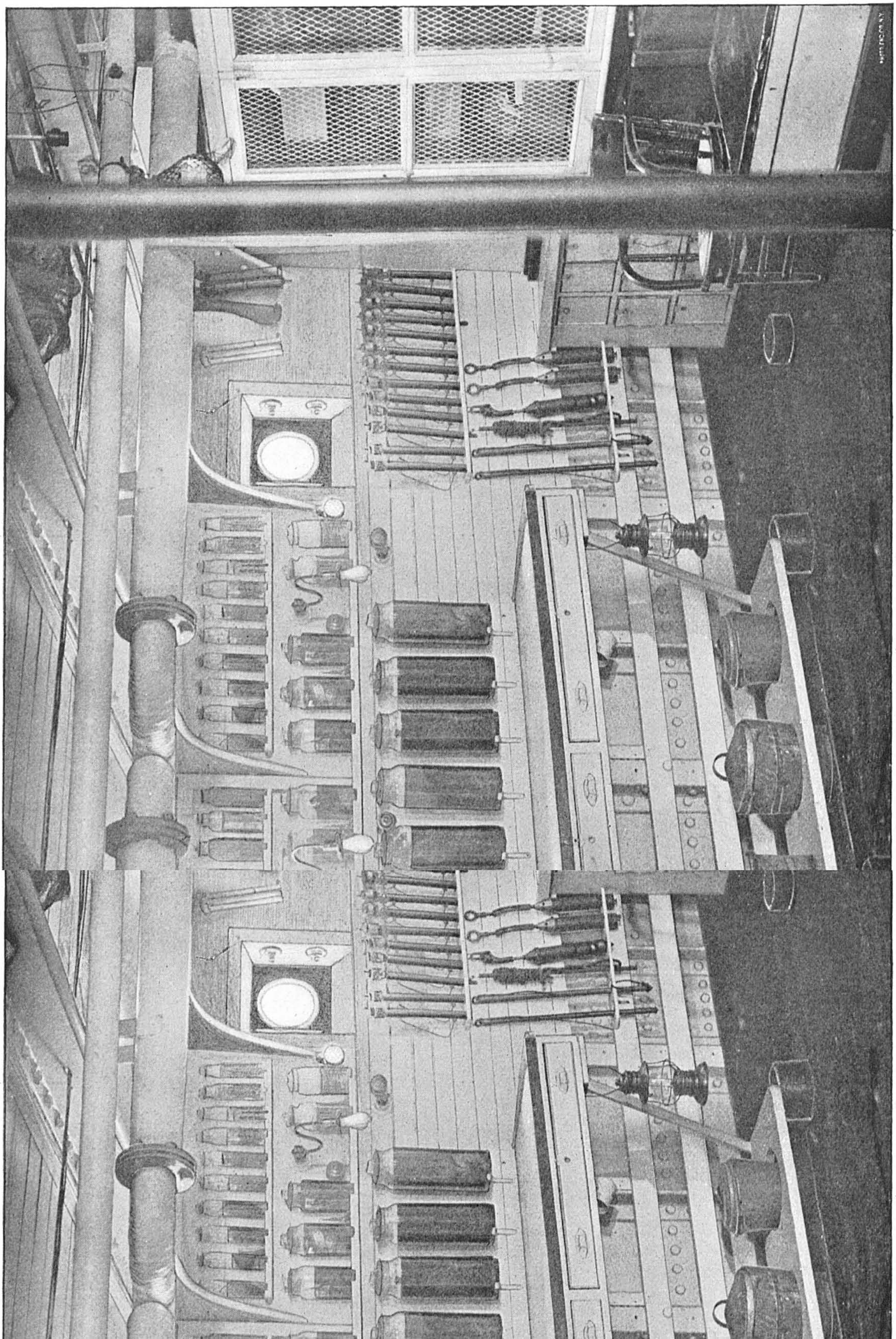
CUT 2.—Ice-boxes and cold-room.

Cold-room: The after part of the spaces in the ice-boxes A for 2 feet is partitioned off by an athwartship bulkhead to form the cold-rooms or refrigerators B, to which access is gained by doors which open into the forehold. Six-inch openings *e*, at the top and bottom of the cold-rooms, communicate with the ice-lockers A, 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 reenters the cold-rooms by the lower openings, to become warmer again and rise as before. Rack shelves *c* to hold whatever is desired are fitted against the bulkheads *d*.

Store-rooms, magazine, brig, etc.: Forward of the berth-deck, and separated from it by the collision bulkhead, is a fore-and-aft passageway 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.

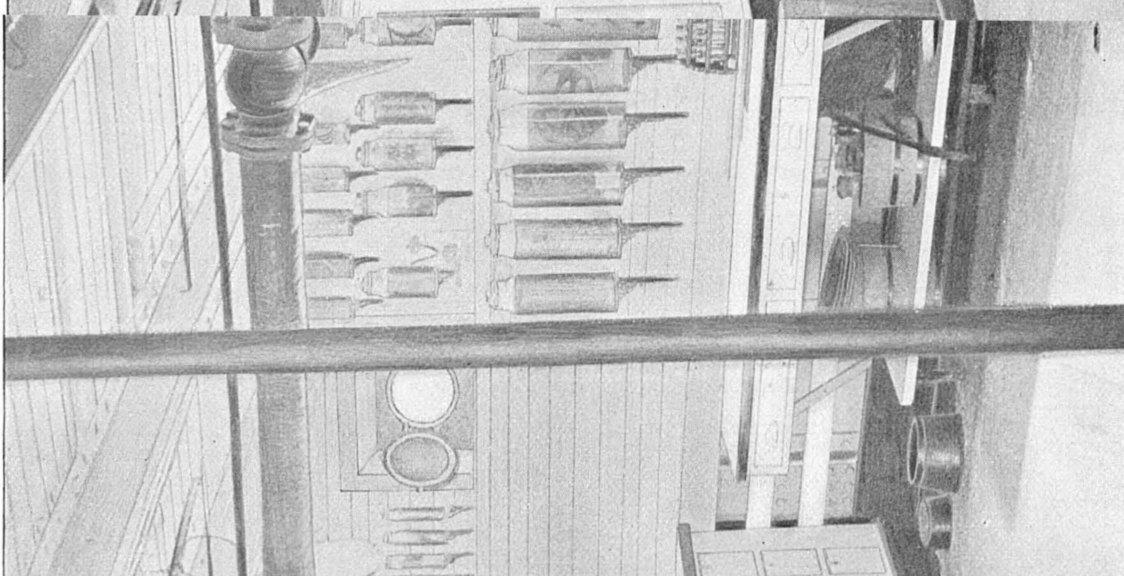
Through this passage, also, the chain pipes pass down and aft, taking the chain from the windlass to the lockers below, and from the forward end of the passage a



LOWER LABORATORY, PORT SIDE.

LOWER LABORATORY, PORT SIDE.

LOWER LABORATORY, STARBOARD SIDE.



LOWER LABORATORY, STARBOARD SIDE.

scuttle and stairs lead down to the magazine passage and magazine, and to the fore-peak below them.

Mainhold: Below the berth-deck the space from the cold-room aft is taken up by the mainhold, 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: 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, etc. On the forward bulk-head of the mess-room is an open pantry.

Lower or main laboratory (plates VI and VII): 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; work tables are fitted along each side; in the port after-corner is a photographic dark-room with a lead-lined sink and running water; on the opposite side is a medical dispensary, 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.

Laboratory store-room: A hatch and stairs lead to the store-room below, a closed iron box, 20 feet in length and the whole width of the vessel, 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, etc., for which suitable 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.

Engine-room, fire-room, and bunker space: The engineer's department is abaft the laboratories, and occupies 57 feet 8 inches in the hold, 47 feet 8 inches on the berth deck, and 20 feet in the deck-house.

Ward-room (plate VIII): The whole space from the laboratories aft to the ward-room is occupied by the engines, boilers, bunkers, etc. The ward-room 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 furnished as a bath-room, the others containing a berth, bureau, washstand, drawers, lockers, etc.

Two iron doors, with water-tight joints, in the ward-room floor, give access to the paymaster's, navigator's, and equipment storerooms below, which are in a water-tight compartment. A scuttle in the pantry floor leads to the ward-room 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 exhaust fans and conduit pipes to every compartment below the main deck.

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 rudderstock a little below the main-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 a little above the water line is a short tiller, to which are attached the rudder chains ordinarily carried by steamers.

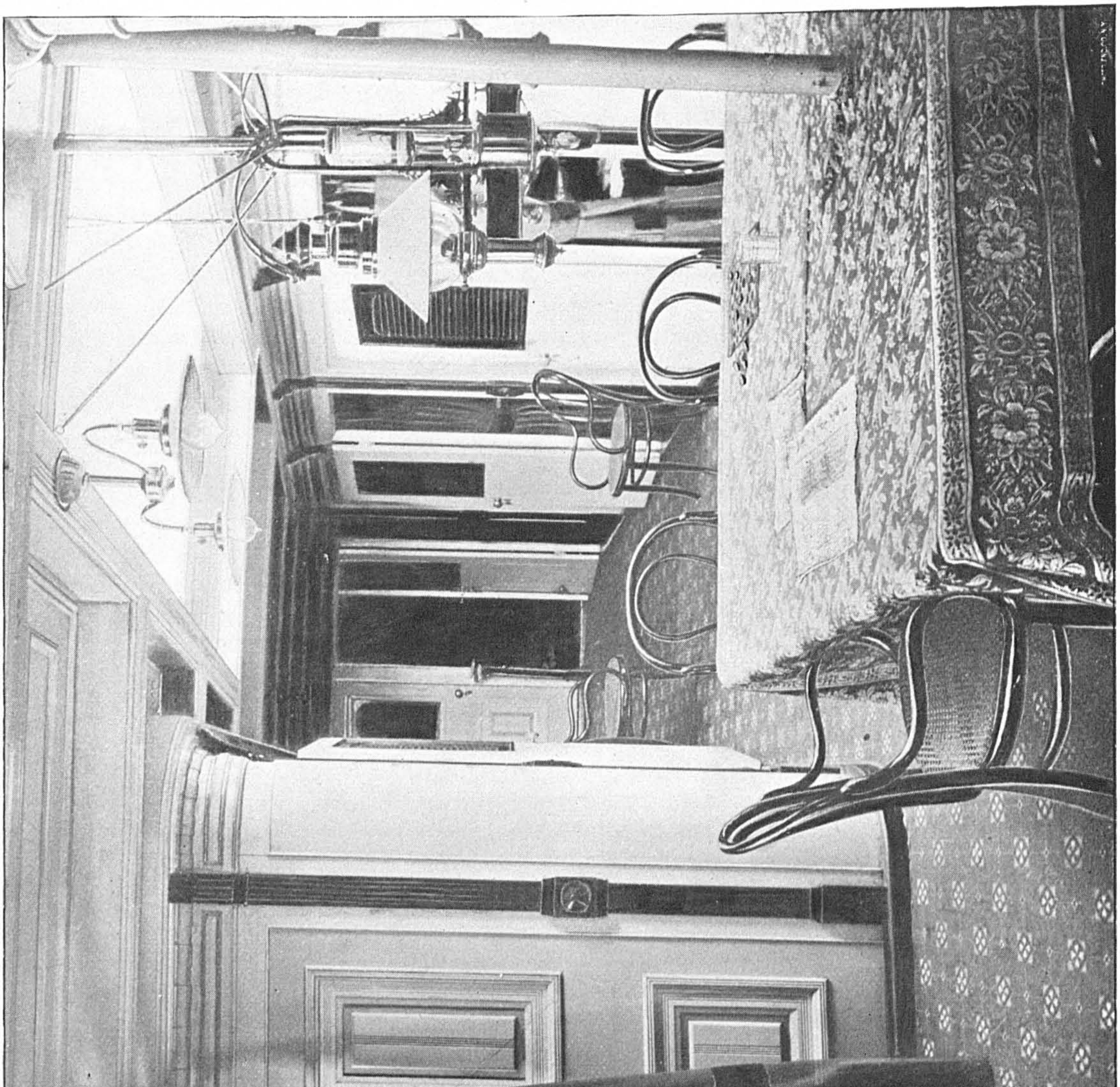
STEAM STEERING GEAR.

The steam steering gear, known as Higginson & Co.'s "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 4¼ 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

PLATE VIII.

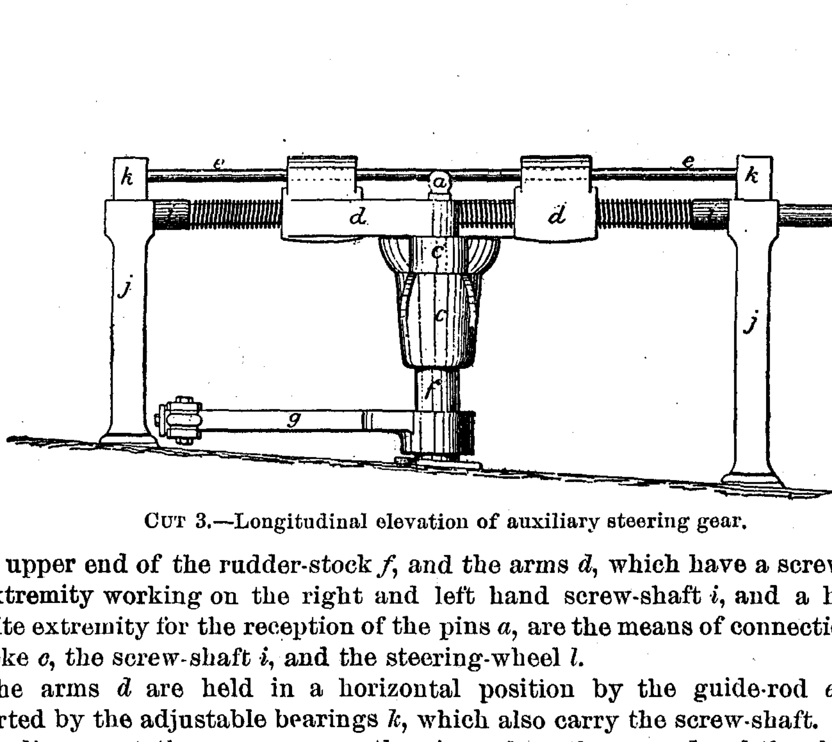


WARD ROOM.

WARD ROOM.

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 which the crank-pin and crank-shaft journals ever receive must come with the steam worked through the cylinders. 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.

Auxiliary steering-gear: This powerful screw gear is used when it is thought necessary to put the vessel stern to a heavy sea, as in sounding, and is designed to hold the rudder rigidly, thus relieving the ordinary steering-gear from unusual strains. It locks the rudder securely, and is also an efficient steering-gear which can be connected in a moment, and as quickly disconnected. A compass is conveniently placed in the cabin skylight to steer by when the after-wheel is used. Cut 3 is a longitudinal elevation, and cut 4 a plan view of the apparatus. The yoke *c* is keyed



CUT 3.—Longitudinal elevation of auxiliary steering gear.

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*.

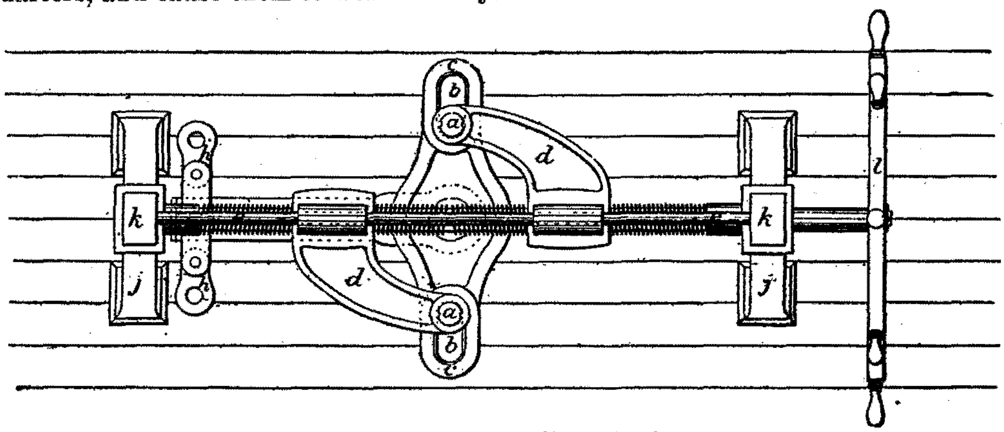
The arms *d* are held in a horizontal position by the guide-rod *e*, which is supported by the adjustable bearings *k*, which also carry the screw-shaft.

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

Spare tiller: Cut 3 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, and are usually carried at the forward end for convenience in hooking in case of accident to the steering-gear.

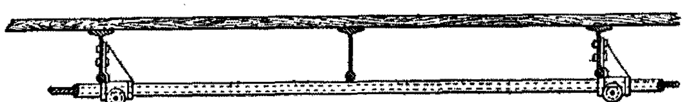
Rudder chains: The rudder chains are shackled to the short tiller projecting from the rudder, seized to an eyebolt in the stern, and carried along the quarters in the usual manner.

The tiller ropes are conducted forward through tubes and carriers, depending from the main-deck beams, which protect them from injury in the coal bunkers, do away with the annoyance and unsightly appearance of exposed tiller ropes in officers' quarters, and cause them to work silently.

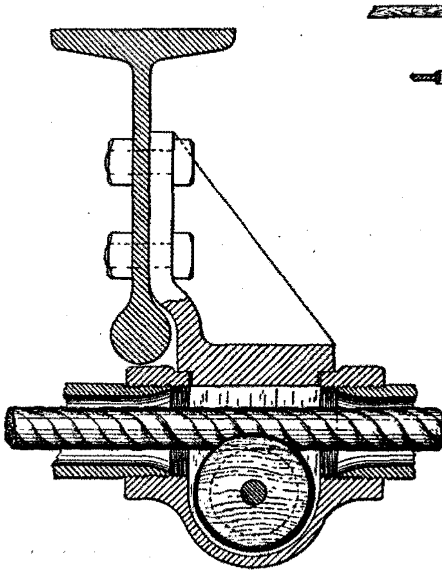


CUT 4.—Plan view of auxiliary steering gear.

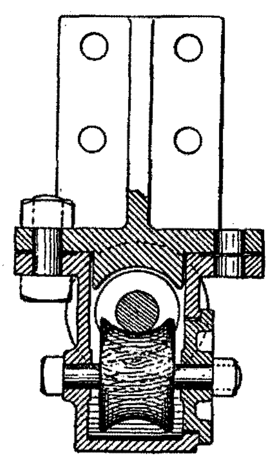
The tiller ropes are elastic steel wire, served with marline, which is thoroughly tarred. They are connected to the yoke, or quadrant, by chains spliced to the ropes and secured to the yoke by adjustable screw bolts, by means of which their tension can be regulated at will. From the yoke they are carried to the ship's side, thence



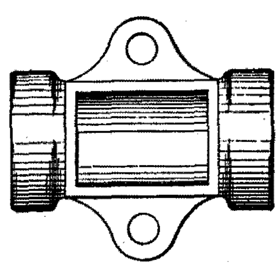
CUT 5.



CUT 6.



CUT 7.



CUT 8.

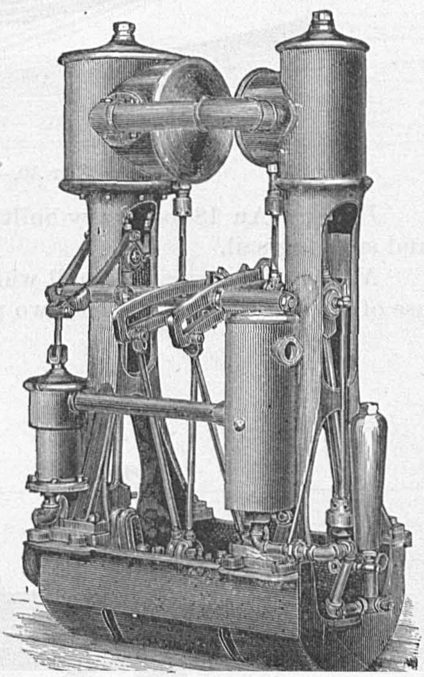
Iron tubes and carriers for the tiller ropes.

directly forward, under the main-deck beams, and spliced to the ends of a chain, which, being brought amidship through appropriate sheaves, is carried up and over the "wild-cat" of the steam steerer designed to take the links and prevent slipping.

BOATS.

The *Albatross* carries eight 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 square, tubulous boiler and compound engine, cylinders 6 inches and 3½ inches in diameter and 7-inch stroke, developing 16 horsepower 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, coppered bottom, weighs 6,124 pounds, including coal and water, 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 square, tubulous boiler, compound engine, 4¼ inches and 2½ inches diameter of cylinders, and 5-inch stroke, developing 7½ horsepower with 100 pounds of steam. It has the general form of a whaleboat, 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, including coal and water, is 2,907 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

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, coppered bottom, weighs 6,124 pounds, including coal and water, and has a speed of 8 knots.

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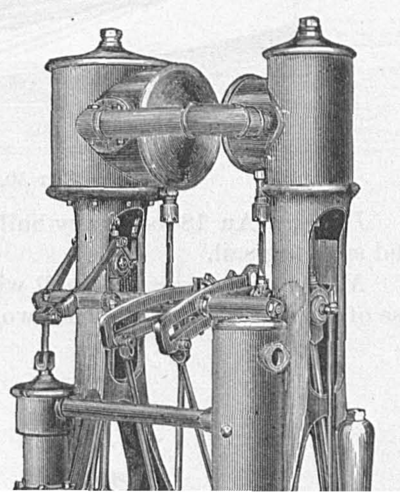
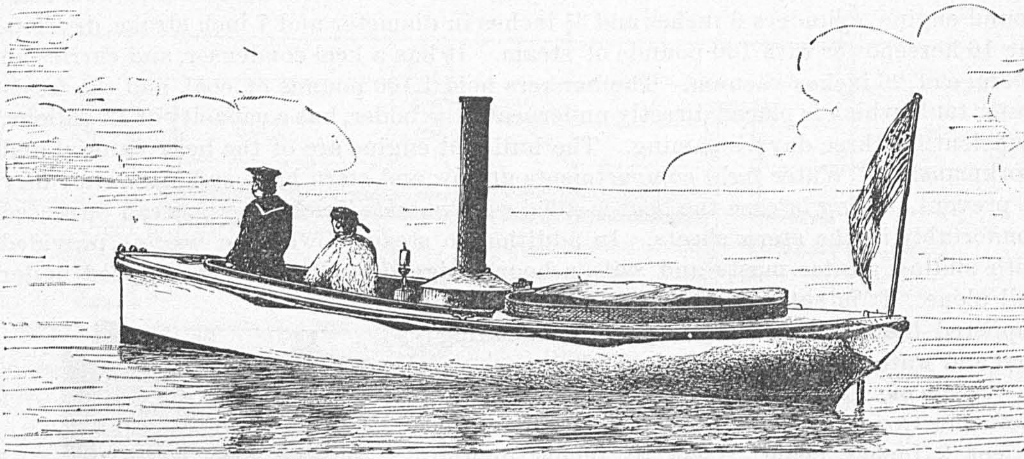


Cutter: This boat is 26 feet in length, navy pattern, pulls 10 oars, is schooner-rigged with sliding gunter masts; she pulls and sails well, and is a good carrier.

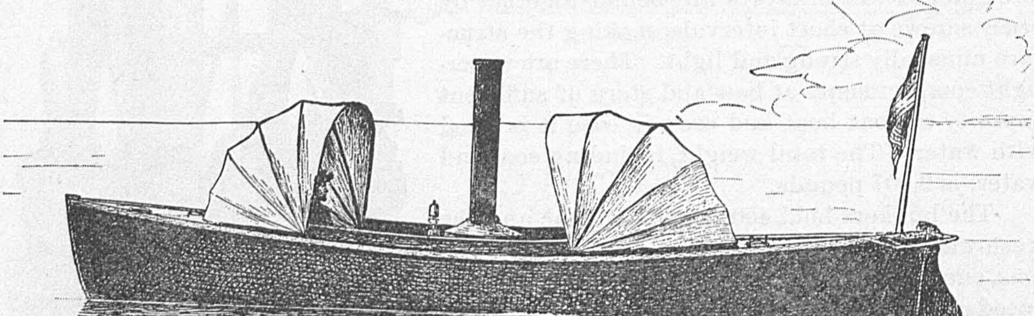
Whale-boat: A navy-built boat, 26 feet in length, pulls 6 oars, and, like the cutter, is schooner-rigged with sliding gunter masts.

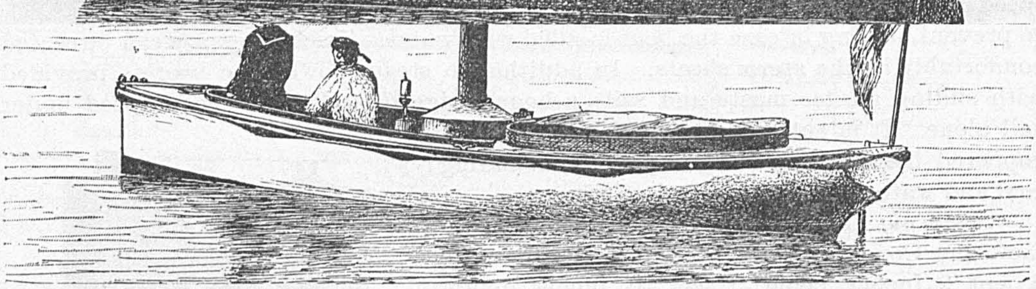


CUT 10.—Herreshoff steam cutter.

Dingey: An 18-foot navy-built boat, pulls three pairs of sculls, has one mast and split lug sail.

Naturalist's boat: A small whitehall, clinker-built, centerboard boat for special use of the naturalists. It has two pairs of sculls and one mast with spritsail.





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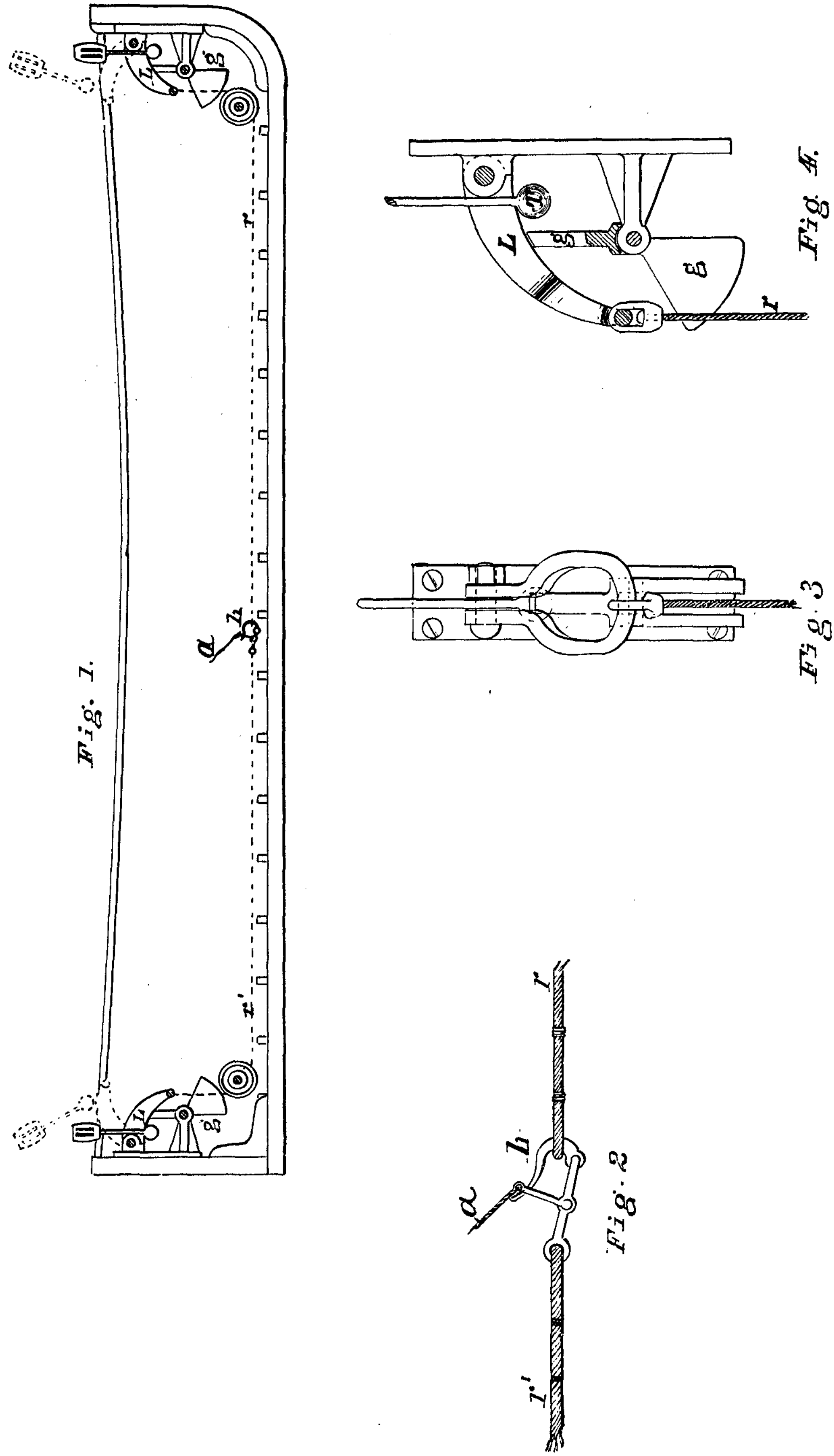


LIEUT. W. M. WOOD'S BOAT-DETACHING APPARATUS.

Principal dimensions of the boats and machinery.

	Cutter.	Gig.
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
Draft of water, exclusive of keel:		
Forward ... do	1.667	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	89.29	46.86
Weight of hull and fittings ... pounds	3,300	1,700
Weight of boiler ... do	910	470
Weight of coal and water ... do	1,394	550
Weight of engine, including screw ... do	520	182
Weight of the boat complete ... do	6,124	2,902
Number of boilers ...	1	1
Diameter of casing of boiler ... inches	35	27
Extreme height of boiler from ash-pit to base of smoke-pipe ... do	29 1/2	23 1/8
Diameter of furnace ... do	30 3/4	22 3/4
Area of grate surface ... square feet	6.7	3.4
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	3 1/2	2 1/8
Diameter of low-pressure cylinder ... do	6	4 1/4
Stroke of pistons ... do	7	5
Diameter of the piston rods ... do	5/8	7/16
Diameter of the air pump (single-acting) ... do	2 1/2	2 3/4
Stroke of air pump ... do	2 3/8	2 1/8
Diameter of circulating pump-plunger ... do	7/16	3/8
Diameter of feed pump-plunger ... do	7/16	3/8
Stroke of pumps ... do	7	5
Length of condensing pipes ... feet	15	13 1/12
Condensing surface ... square feet	9.83	4.95
Main journals ... number	3	3
Diameter of main journals ... inches	1 1/2	1 3/4 and 2 1/4
Length of main journals ... do	3	2 1/8
Crank-pin journals ... number	2	2
Diameter of crank-pin journals:		
High-pressure ... inches	1 1/2	1 1/8
Low-pressure ... do	7/8	9/16
Length of crank-pin journals:		
High-pressure ... do	1 1/2	1
Low-pressure ... do	1 3/4	1 1/4
Space occupied by the engine:		
Length fore and aft ... do	24 1/2	21
Width ... do	21	18
Height ... do	44	26
Diameter of the screw propeller ... do	28	16 1/2
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 ...	0.49	0.2
Helicoidal area of the screw blades ... square feet	3.69	1/2
Weight of the screw ... pounds	45	6

BOAT-DETACHING APPARATUS.

The whale-boat and dingey are kept hanging at the davits ready for emerg encies, and are provided with a unique detaching apparatus (plate IX), the invention of Lieut. 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, 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.

STEAM MACHINERY AND ITS ACCESSORIES.

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 toward each other 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.

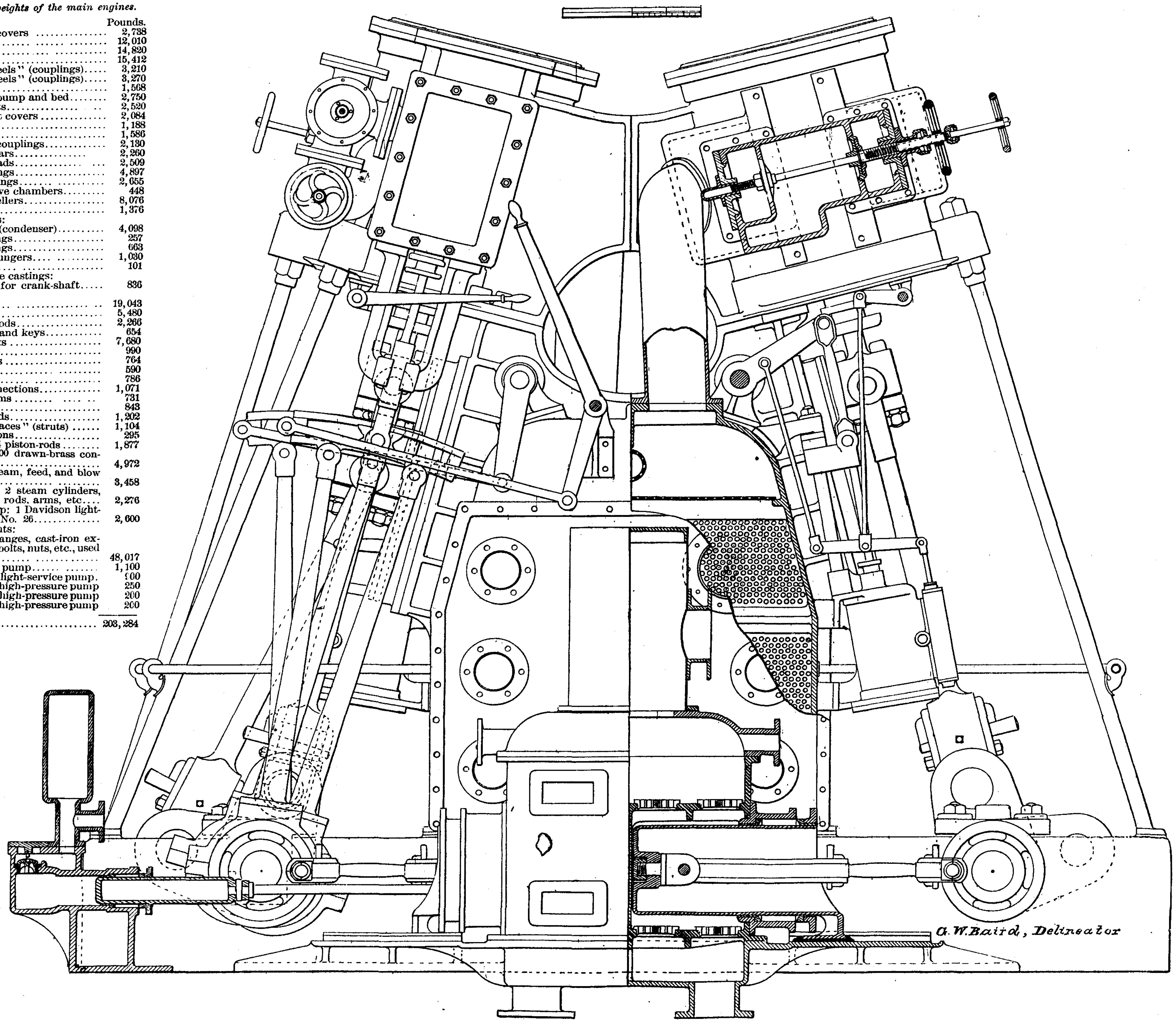
The valves of the high-pressure cylinders are locomotive slides, over which gridiron cut-off valves are placed, while the low-pressure valves are double ported and are without cut-offs. All these valves are actuated by eccentrics and Stephenson links, in the usual manner.

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 (cut 19).

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
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, etc	2,276
Circulating-pump: 1 Davidson light-service pump, No. 26	2,600
Additional weights:	
Floor-plates, flanges, cast-iron exhaust-pipes, bolts, nuts, etc., used in fitting up	48,017
No. 5 Davidson pump	1,100
No. 5 Davidson light-service pump	900
No. 2 Davidson high-pressure pump	250
No. 1 Davidson high-pressure pump	200
No. 1 Davidson high-pressure pump	200
Total	203,284



COMPOUND TWIN-SCREW ENGINES.

Principal dimensions of the engines.

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

	Ft.	In.
Diameter of high-pressure crank-pins		5¼
Length of high-pressure crank-pins		7⅛
Diameter of low-pressure crank-pins		7¼
Length of low-pressure crank-pins		9
Diameter of high-pressure crosshead pins		3
Length of high-pressure crosshead pins		4½
Diameter of low-pressure crosshead pins		3½
Length of low-pressure crosshead pins		5
Diameter of line shafts (wrought iron)		8
Length in vessel occupied by engines	9	4
Breadth in vessel occupied by engines	15	6
Height of engines above center line of shafts	12	6

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 shaft brackets are of wrought iron; one is placed near the hub of the screw and the other halfway between this and the hull. The journals of the brackets 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 being bored to receive them, and the frames bent round them. The stern bearings are likewise of cast iron, with flanges fitting the hull; they are 3 feet 4 inches in length, are 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.

There are two escape pipes, one for each boiler, and a steam whistle forward of the smokestack. The exhaust from steam radiators and all auxiliary machinery is carried to the main condenser, the hot well, or to the atmosphere through the escape pipes, as preferred.

Engine signals are made by ordinary bell pulls on the bridge and in the pilot house, connections being made to gongs on the engine-room platform by means of wires and bell cranks.

There are three gongs, the large or main one in the center, a small one on the port side, and another of the same size, but of different tone, on the starboard side of it, all inclosed within a brass hood which is connected with a return sounding tube to the pilot house. Verbal orders are transmitted through a speaking tube having branches to the bridge, the pilot house, and sounding machine.

The following are the engine signals in regular sequence, both engines being at a stand, and to be worked together as one:

1. Jingle bell.—Cautionary. Stations for working the engines.
2. One bell, main (gong).—Ahead slow.
3. Jingle bell.—Full speed.
4. One bell, main.—Half speed.
5. One bell, main.—stop.
6. Two bells, main.—Back, ordinary full speed.
7. Jingle bell.—Back hard, open throttle.
8. One bell, main.—Stop. One bell always stops a backing engine.
9. Jingle bell, with engines at a stand.—Have finished with the engines.

The foregoing signals apply also to the starboard and port engines when they are worked independently, their respective gongs being used.

Illustrative example.—The vessel being underway and both engines at a stand, to turn sharp to starboard:

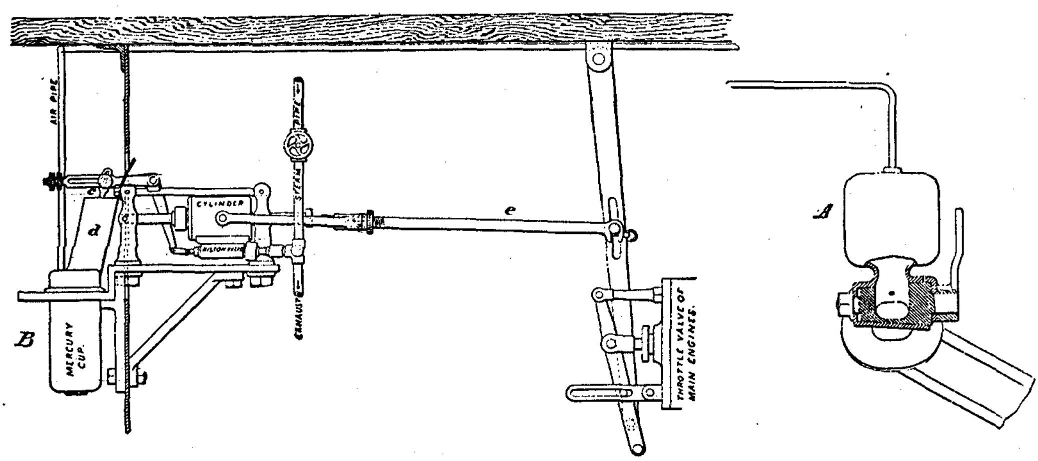
1. One bell port, two bells starboard.—Helm hard aport; engines working alike at half speed.
2. Jingle bell.—Full speed; port ahead, starboard back.
3. One bell, main.—Slow port, stop starboard.
4. One bell port.—Stop port engine.

Modifications of speed other than half or full power are effected through the speaking tube.

SVEDBERG'S MARINE GOVERNOR.

In a heavy seaway 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 it when the engine began to speed up (to "race"), and open the valve 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 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, is made on the principle of a Wolf jar, and besides



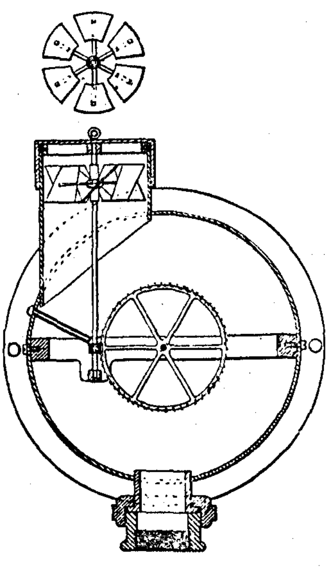
CUT 12.—Svedberg's marine governor.

mercury it contains a wooden float on the lower end of the rod *c*, 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 *c*) 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.

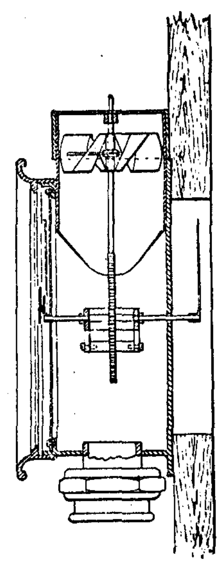
The action of the machine is as follows: The water, rolling from underneath the stern, causes a diminution of the pressure in the air-chamber, which is transferred to the mercury-cup, lifts the float and rod *c*, and, through the levers, communicates a definite amount of motion to the valve; steam is thus admitted to the cylinder and moves it to the right until its motion 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.

BAIRD'S PNEUMATIC INDICATOR.

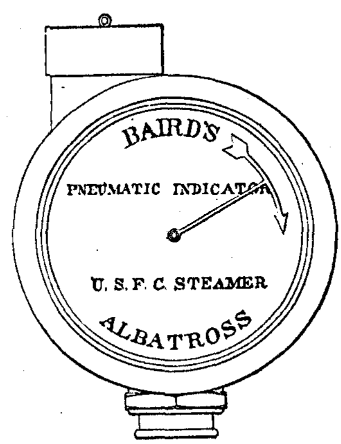
It is well known that the inertia of a steam vessel in motion is considerable, and that it requires some little time to change her direction even after the engines are reversed, and it often occurs in sounding and dredging that opposing winds and



CUT 13.



CUT 14.

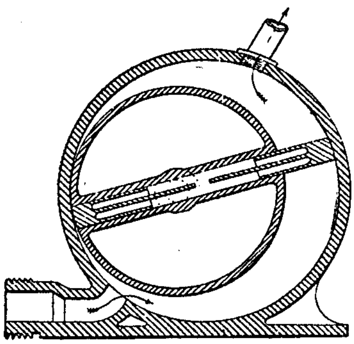


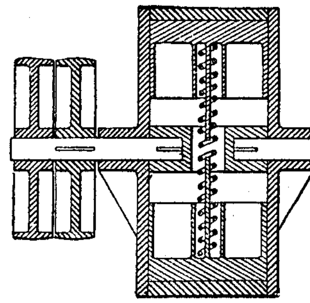
CUT 15.

currents carry the ship from the desired position with reference to sounding wire, or dredge rope; hence it becomes imperative for the officer in charge to know promptly whether the engines are running in the right direction. The object of the indicator is to give him this information, also to show whether they are going fast or slow, or standing still.

There is an indicator for each shaft, and, having twin screws, the *Albatross* has two. Cut 13 is a sectional view of the back, cut 14 of the side, and cut 15 is a view of the face; cut 16 is a sectional view of the side, and cut 17 the end of the blower for the indicators; cut 18 is a general view of the indicator and its connections.

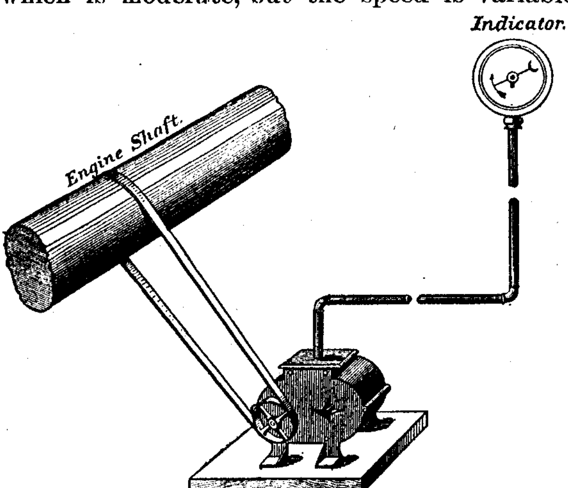
The indicators are of brass with steel shafts and spindles and glass faces; they are secured with their backs to the after bulkhead of the pilot-house, as seen in cut 14 with a circular hole in the wood large enough for the index arm to move in; the arrows on the faces of the indicators are visible from the deck, or bridge, those on the backs from the interior of the pilot-house.


CUT 16.


CUT 17.

The index arms revolve in the direction in which their arrows point when the engines are working ahead; upon reversing them the motion of the arrows is also reversed. The index arms are mounted upon each end of a horizontal shaft carrying a toothed wheel, cut 14, which is turned by the revolution of a fan or propeller on a vertical spindle that has a worm or endless screw, the threads of which mesh with the teeth of the wheel.

The propellers are rapidly revolved by an air current when the engines move, transmitting motion through the spiral gearing to the index arms, the movement of which is moderate, but the speed is variable with the speed of the engines and incidentally affords a means of estimating by the eye their speed as well as the direction in which they are moving.



CUT 18.

The air current is derived from small rotary blowers, cuts 16 and 17, placed near the main shafts and belted to them, as shown in cut 18. When the engines are moving ahead the blowers draw the air in and force it through the pipes to the propellers in the indicator case, thence it escapes to the atmosphere.

When the engines are backing, the air is drawn in at the top of the case, reverses the propellers, and, after traversing the connecting pipes and blowers, it is exhausted into the atmosphere as before. The connecting pipes are of drawn brass of commercial pattern.

The indicators were installed early in 1886. They are simple and effective, and have greatly improved the maneuvering qualities of the vessel.

BOILERS.

There are two single-ended, horizontal return tubular boilers of the Scotch type, constructed of American charcoal flange iron and placed fore and aft on the midship line, with the fire-room athwartships between them. An annular steam drum is placed vertically over the fire-room, between the boilers, supported by wrought-iron girders which rest upon the latter, and is connected with an uptake common to both boilers.

There is a single smokestack, 10 feet of its base being formed by the steam-drum, which acts as a superheater. The grate bars are double and in two lengths.

The following are the general dimensions of the two boilers and accessories:

Number, 2.
Length, 10 feet 3 inches.
Diameter, 12 feet.
Number of furnaces each, 3; type, plain cylindrical, 3 sections, Adamson's rings.
Length of furnaces, 7 feet; diameter, 3 feet.
Grate surface, 21 square feet for furnace, 63 square feet for boiler; total grate surface, 126 sq. ft.
Heating surface, 1,467 square feet; total heating surface, 2,934 square feet.
Ratio of heating surface to grate surface, 23.3 to 1.
Number of tubes in each boiler, 197; material, brass; length, 7 feet 4 inches; diameter, external, 3 inches; thickness, No. 12 wire gauge.
Thickness of shell, $\frac{3}{4}$ inch; of heads, $\frac{9}{16}$ inch; of tube sheets, $\frac{3}{4}$ inch; of furnaces, $\frac{1}{2}$ inch; of connection sheets, $\frac{1}{2}$ inch.
Weight of each boiler, exclusive of grate bars, 62,333 pounds.
Weight of water in each boiler (6 inches above tubes), 31,833 pounds.
Weight of grate bars, each boiler, 4,000 pounds.
Total weight of both boilers, with water and grate bars, 196,332 pounds.

Working pressure above atmosphere, 80 pounds.
Steam drum:
- Material, American charcoal iron.
- Length, 10 feet.
- Diameter, 7 feet 4 inches.
- Diameter of flue, 4 feet 4 inches.
- Capacity, 256 cubic feet.

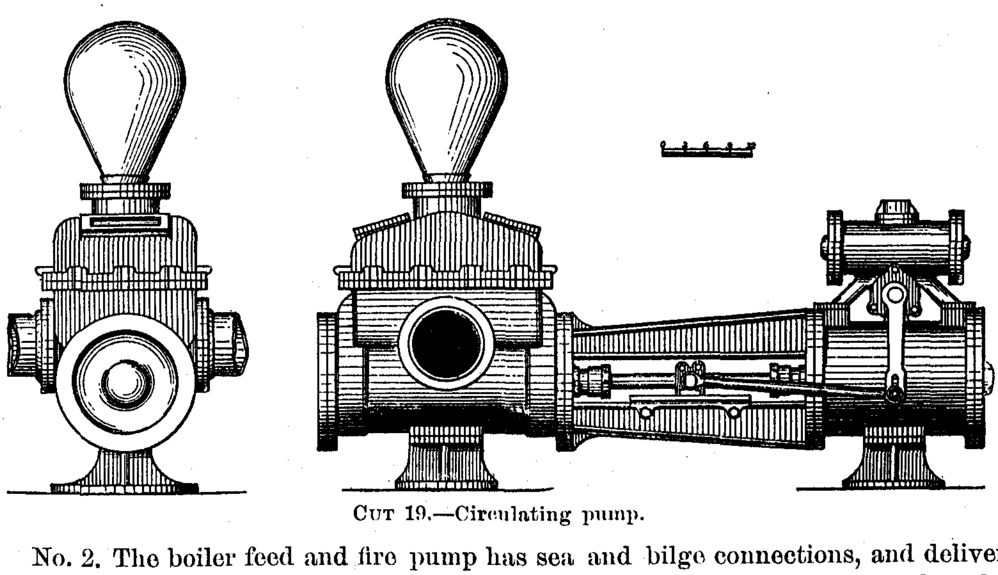
Smokestack:
- Total length above the grate bars, 50 feet.
- Diameter, 4 feet 4 inches.
- Weight, 3,600 pounds.

Propellers:
- Number, 2.
- Type, 4-bladed, twin-screw, right and left.
- Material, composition, 88 cu. 10 sn. 2 zn.
- Pitch: Port, 13 feet 11 inches; starboard, 14 feet $\frac{4}{10}$ inch.
- Diameter: Port, 8 feet 11$\frac{3}{4}$ inches; starboard, 9 feet $\frac{1}{8}$ inch.
- Helicoidal area: Port, 30 square feet; starboard, 30 square feet.
- Weight: Port, 3,277 pounds; starboard, 3,223 pounds.

STEAM PUMPS.

The *Albatross* is provided with six Davidson steam pumps, as follows:

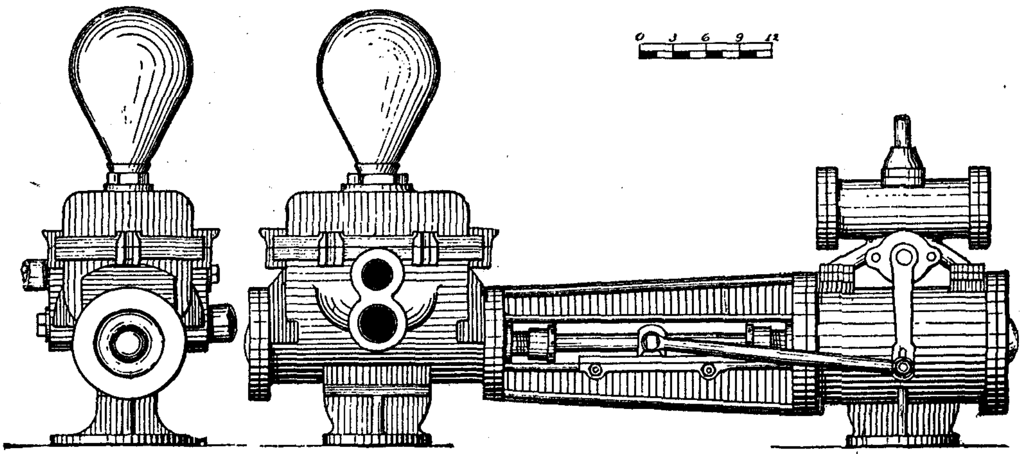
No. 1. The circulating pump is piped to take water from the sea or from the bilge, and to discharge into the condenser. Its speed may be varied from 1 to nearly 200 strokes per minute.



CUT 19.—Circulating pump.

No. 2. The boiler feed and fire pump has sea and bilge connections, and delivers to the boilers, to the hydrant pipe, engine-room, fire-room, ash-chute, and overboard at pleasure. It is designed to work under great pressure. The hydrant pipe runs fore and aft under the main-deck beams and has connections at convenient intervals on both sides of the deck-house for fire and general purposes.

No. 3. The hydrant pump is piped to take water from the sea or the bilge, and delivers to the boilers, hydrant pipe, ash chute, or overboard. It is used for the general purposes of the ship and can be worked in connection with No. 2 in case of fire or leak. The bilges are pumped through a manifold system which is common to both of these pumps.



CUT 20.—Boiler feed and fire pump.

No. 4. The auxiliary boiler feed is a vertical bulkhead pump, piped to take water from the sea, hot well, and drain tank, and delivers to boilers, ash-chute, and fire-room.

No. 5. The evaporator feed pump takes water from the sea or from the discharge pipe of the distiller and delivers it to the evaporator.

No. 6. The aquarium pump has a sea connection, and delivers water to the aquaria and bath tubs.

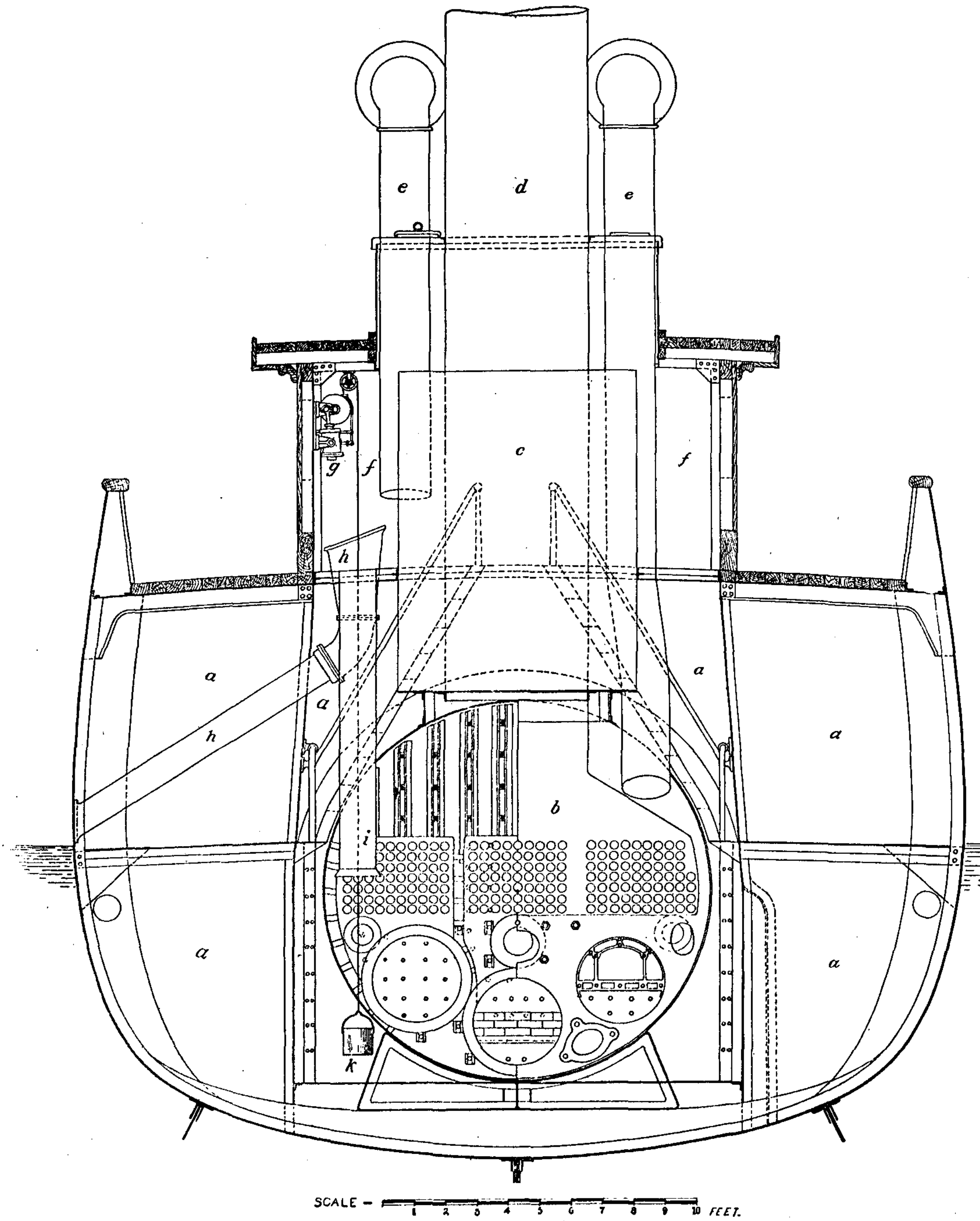
Table showing the size and power of steam pumps.

Ship's number.	Maker's number on size.	H. P.=high pressure. L. S.=light service.	Diam. of steam cylinder.	Diam. of water cylinder.	Inches stroke.	Gallons per stroke.	Capacity per minute at given speed, ordinary service.		Capacity per minute severe service, in case of emergency.		Weight in pounds.
							Strokes.	*Gallons.*	*Strokes.*	*Gallons.*	
1	26	L. S.	14	16	14	12.18	86	1,047	172	2,094	2,600
2	5	H. P	9	5¼	12	1.12	100	112	200	224	1,100
3	5	L. S.	7	5	10	.85	120	102	240	204	900
4	2	H. P	4½	2½	6	.13	150	19½	300	39	250
5	1	H. P	3½	2	4	.05	150	7½	500	15	200
6	1	H. P	3½	2	4	.05	150	7½	300	15	200

Approximate data of best four hours run (June 27, 1893).

Hours and minutes	8
Mean speed	11.52
Steam pressure	71
Receiver pressure	24
Revolutions	87.6
Vacuum	25
Throttle, holes	8
Cut-off, in decimals of stroke	.12
Temperature:	
On deck, degrees	50
In engine-room, do	106
Injection water, do	47
Temperature—continued.	
Discharge water, degrees	76
Feed water, do	106
Barometer	30.15
Mean draft of water, feet	12
Displacement in tons, tons	1,074
Pounds of coal consumed per hour (Nanaimo)	1,740
Square feet of grate surface in use	126
Square feet of heating surface in use	2,934
Ratio of heating surface to grate surface	23.3 to 1

PLATE XI.

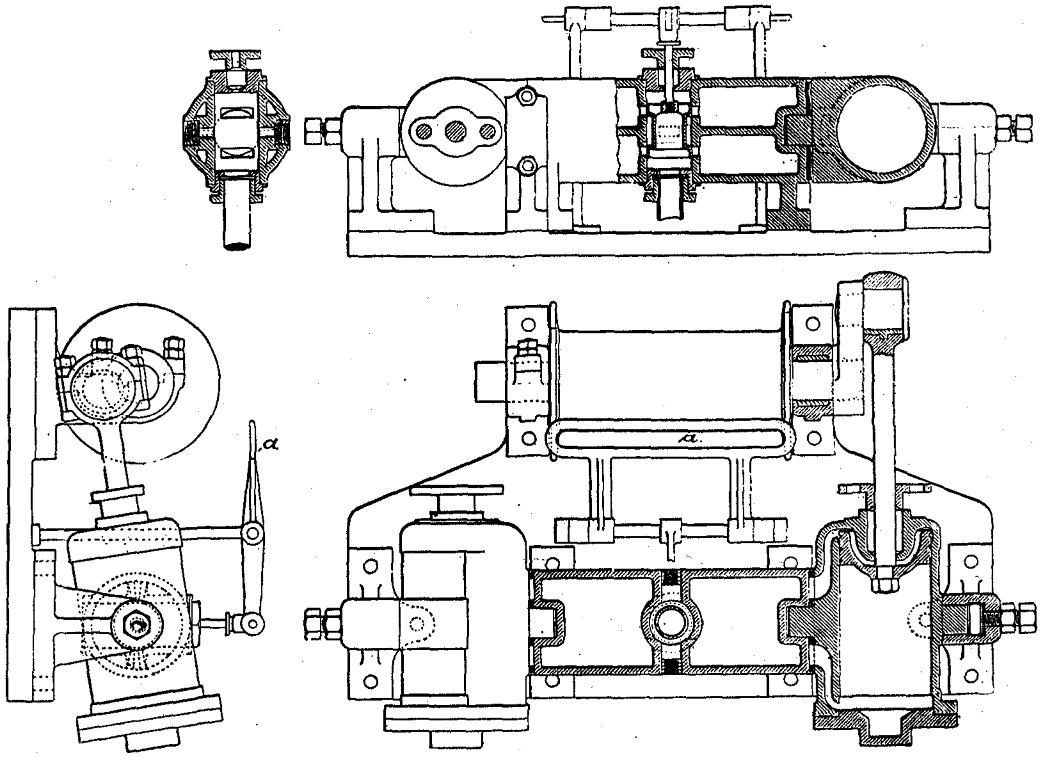


MIDSHIP SECTION OF THE ALBATROSS, SHOWING BAIRD'S ASH ELEVATOR AND CHUTE.

a. Coal bunkers.
b. Forward boiler, sectional view.
c. Steam drum.
d. Smoke stack.
e. Forward ventilators.
f. Drum room.
g. Baird's ash-hoisting engine.
h. Ash chute and hopper.
i. Vertical tube for ash bucket.
k. Ash bucket.

BAIRD'S ASH ELEVATOR AND CHUTE.

A midship section of the vessel is shown through line of fire-room, and Baird's ash-hoisting apparatus, including hoisting engine and chute, is seen on the port, or left side. 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; Chief Engineer George W. Baird, U. S. N., designed the diagonal tube *h* (a 10-inch wrought-



CUT 21.—Baird's ash-hoisting engine.

iron boiler flue), surmounted by a hopper, and the engine *g* referred to. A stream of water (1¼ 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.

Cut 21 shows several views and sections of the hoisting engine.

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 parts the crank shaft and hoisting drum are one and the same piece of cast iron; the cylinders are oscillating, their ports being on 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*, cut 21) through which the hoisting rope passes; on the rope there are two stops (knots), so situated that one will press and move the lever when the bucket *k* 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 the second one moves the lever, the bucket rises to its stop and is brought to rest; the second man dumps the bucket into the chute, and pulls the lever, when the bucket descends to the floor and is again automatically stopped. The machine is noiseless and rapid in its action, works with certainty, and requires but little attention.

COAL BUNKERS.

The boilers are fore and aft on the midship line, and wing bunkers extend the whole length of the boiler space, 40 feet in the hold and 32 feet above the berth deck, on both sides, from the floor to the main deck. The forward and after sections are connected by arches over the boilers. The capacity of the wing bunkers is 125 tons.

The forward bunker lies between the boiler space and laboratory store-room; it extends from floor to berth deck and across the whole beam of the vessel, with a capacity of 40 tons, a total bunker capacity of 175 tons of bituminous coal. There are 8 coaling scuttles, 4 on each side, at convenient intervals on the main deck.

An auxiliary bunker has been improvised upon several occasions from the laboratory store-room by removing from it everything except the inclosed lockers, which were protected by rough boarding, leaving stowage room for 45 tons, in bags; and a gain of 15 tons could be effected by removing the lockers. Coal carried in this space is passed through the laboratory hatch. A deck load of 25 tons may be safely carried in bags, giving a total coal capacity as follows:

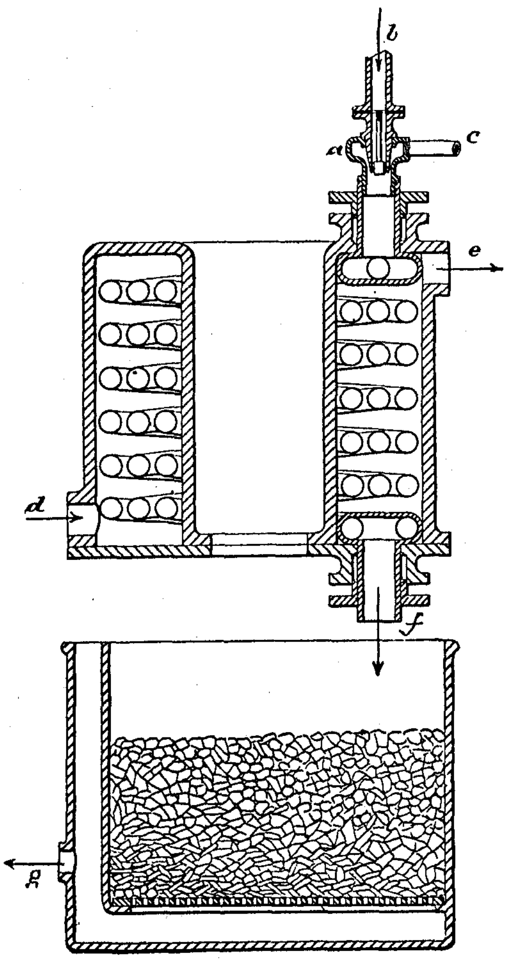
Wing bunkers	tons..	125
Forward bunker	do...	40
Auxiliary bunker, bagged	do...	45
Deck load, bagged	do...	25
Total coal capacity	do...	235

The auxiliary bunker can be utilized only by landing a portion of the scientific outfit. The steaming radius, with 235 tons of good bituminous coal, a fairly clean bottom, and good weather, is 4,500 miles at an 8-knot speed, which can be maintained on a consumption of 10 tons of coal per day.

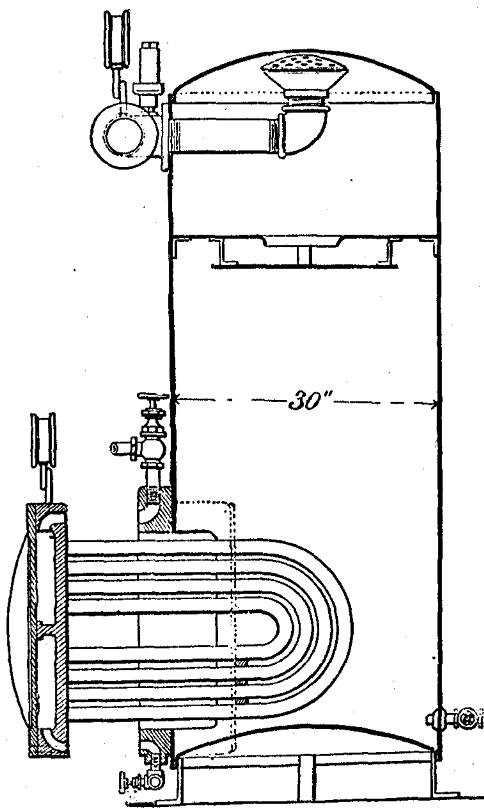
BAIRD'S FRESH-WATER DISTILLING APPARATUS.

The distiller (cut 22) is patented by the inventor, Chief Engineer George W. Baird, U. S. N., and is the form generally used on board American steamships.

The object of the apparatus is to distill 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. 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, are 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, condensing the steam within. The fresh water and air rush out of the coils at *f* and into a filter of animal charcoal, from which it is delivered to the ship's



CUT 22.—Baird's fresh-water distilling apparatus.



CUT 23.—Baird's evaporator, No. 3, Type C.

tanks through the opening *g*. The fresh water will absorb (dissolve) only a small portion of air (less than 2½ per cent of the volume under pressure of the atmosphere), but the large excess of air injected into the steam serves to oxidize organic matter which is brought over by it, 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 the 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 distill 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, particularly since the evaporator came into use in connection with this apparatus.

BAIRD'S EVAPORATOR.

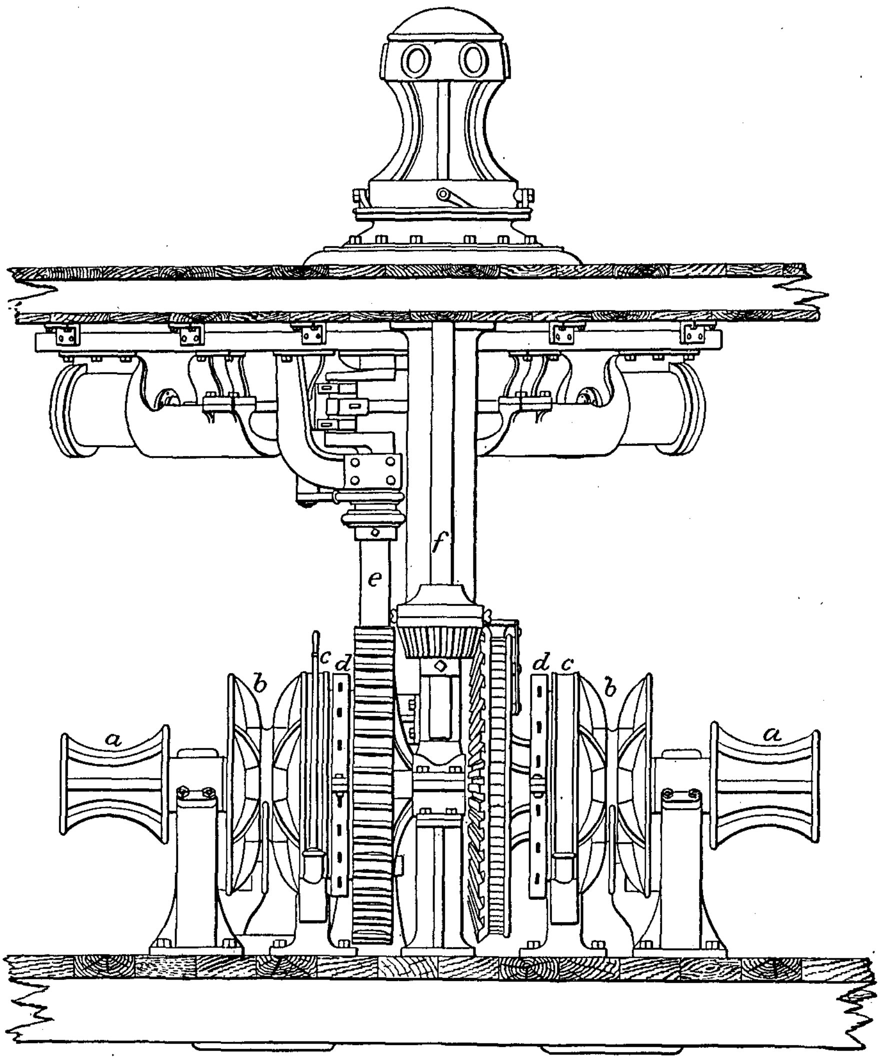
This valuable adjunct to the condensing apparatus has greatly improved the quality of the drinking water, besides providing fresh feed for the boilers. Cut 23 shows a sectional elevation of the *Albatross's* evaporator, known as No. 3, Type C. It has a cylindrical shell of steel 2 feet 6 inches in diameter and 7 feet in height. On one side is a cast-iron door and frame, the former containing a steam chest in which the ends of the copper tubes terminate. But one joint need be broken in order to remove the tubes for cleaning. They are shown partially withdrawn.

The method of operation is as follows: Sea water is pumped into the evaporator until the tubes are covered; live steam from the boilers enters at the top of the steam chest, the lower end draining to the hot well. As steam forms from the sea water it ascends through the baffle plate to the steam pipe, and thence to the distiller, or main condenser, according as it is to be used for drinking purposes or for boiler feed. Excellent results have been obtained from its use on board the *Albatross*.

THE STEAM WINDLASS AND CAPSTAN.

This machine 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 wildcats, *b b*, and friction-brakes, *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 wildcats *b b*, by which means the wildcats 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, etc. (See plate XII.)

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

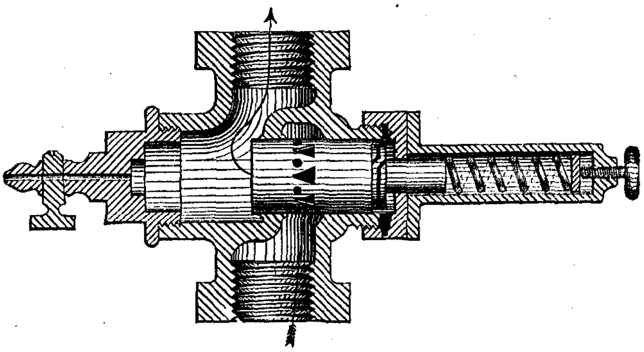


STEAM WINDLASS AND CAPSTAN.

Diameter of windlass shaft	inches	$3\frac{3}{4}$
Smallest diameter of gypsy heads	do	$10\frac{1}{2}$
Largest (inboard) diameter of gypsy heads	do	15
End (outboard) diameter of gypsy heads	do	$13\frac{1}{2}$
Length of gypsy heads	do	$13\frac{1}{2}$
Number of whelps on wild cats		5
Size of starboard chain (diameter of iron)	inches	$1\frac{5}{8}$
Size of port chain (diameter of iron	do	$1\frac{3}{16}$
Chain per revolution of starboard wild cat	fathoms	$\frac{3}{8}$
Chain per revolution of port wildcat	do	$\frac{19}{17}$
Di meter of friction-brakes	inches	23
Width of face of friction-brakes	do	$2\frac{1}{2}$
Total length of windlass shaft	do	92
Number of teeth in bevel spur-wheel		49
Number of teeth in bevel pinion		12
Number of teeth in spiral gear-w eel		52
Number of convolutions of "worm" screw thread		4
Outer diameter of worm screw	inches	8
Radial length of worm-screw threads	do	$1\frac{1}{4}$
Pitch of spiral gear	do	$1\frac{3}{4}$
Diameter of capstan spindle	do	$3\frac{7}{16}$
Smallest diameter over capstan whelps	do	$10\frac{3}{4}$
Projected height of capstan drum	do	14
Number of steam cylinders		2
Diameter of steam cylinders	inches	8
Stroke of pistons	do	8
Diameter of piston rods	do	$1\frac{3}{8}$
Diameter of connecting rods at neck	do	$1\frac{1}{2}$
Diameter of crank pin	do	$2\frac{3}{4}$
Length of crank-pin journal	do	6
Diameter of cross-head pins	do	2
Length of cross-head pin journals	do	2
Ordinary speed of eng ne, in revolutions, per minute		300
Rate of heaving in starboard anchor, in fathoms, per minute		4
Rate of heaving in port anchor, in fathoms, per minute		$3\frac{4}{16}$
Length of starboard chain	fathoms	120
Length of port chain	do	120
Weight of starboard chain	pounds	14,745
Weight of port chain	do	9,283
Weight of starboard anchor and stock	do	2,760
Weight of port anchor and stock	do	1,950
Total weight of both anchors and chains	do	28,737
Weight of steam capstan windlass, complete	do	9,000

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 a pressure-regulating valve (cut 24) is placed in the steam-pipe; by tightening or slacking the screw the steam is adjusted in the cylinders to any pressure inside the limit of the boiler pressure.

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



CUT 24.—Pressure-regulating valve.

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 3.4 fathoms per minute.

LIGHTING.

The *Albatross* has an electric plant for both internal and external lighting; also a complete outfit of oil lamps for burning mineral sperm. She was the first United States Government vessel to receive an electric installation for internal illumination. The original Edison electric plant furnished the vessel in 1882 consisted of a Z dynamo having a B circuit of 51 volts, driven by an Armington & Sims 8½ by 10 inch engine, which, at 350 revolutions, drove the dynamo 1,700 turns per minute and furnished ample power and uniform speed.

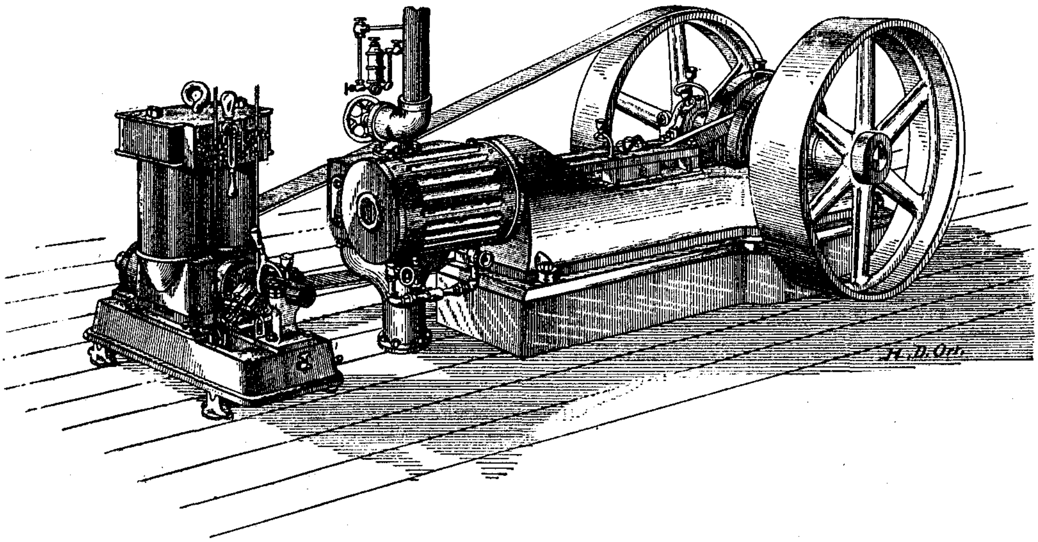
There were 120 8-candle incandescent lamps in circuit, also a powerful arc lamp, which was run on the same circuit and used when a concentration of light was required at the table sieve to facilitate the work of the naturalists. The dynamo was rated at 1,200 candles by the makers, but was capable of developing much greater power. A new electric plant was installed in 1887, which represented the improvements of five years. It consists of a No. 3 dynamo, with an A circuit of 110 volts, driven by an Armington & Sims 6½ by 8 inch engine (cut 25), which at 300 revolutions drives the dynamo 1,200 turns per minute.

The dynamo was rated by the makers at 1,200 candles, yet it develops nearly twice that power without visible evidences of distress. There are at the present time 152 16-candle incandescent lamps in circuit, besides several portable hand lamps, which are connected as occasion requires. Of course, the lamps are never all in use at the same time, seldom more than half of them, the installation furnishing all the current needed.

The governor of this engine is fixed to the fly wheel, which is keyed to the shaft, and consists of two eccentrics, one within the other, each moving independently upon its axis, two weights pivoted to the arms of the fly wheel with their centers of motion opposite, and two spiral springs. The weights are each connected to one of the eccentrics by an arm or rod, their centrifugal force being controlled by the spiral springs in such a manner that the motion imparted to them by the revolution of the fly wheel throws one eccentric ahead and the other back, thus diminishing their throw and effecting a shorter cut-off without changing the lead of the valve.

The governor maintains a uniform speed under all the varying conditions of service, and the uniformity of current supplied to lamps in use is preserved by an adjustable resistance box and switch placed in the field circuit.

Wiring: The original wires, all copper between Nos. 10 and 20, were insulated with woven cotton and white lead, extra covering of rubber being used where they passed through damp places; hard rubber tubes encased them where they led through bulkheads, and in hot places, such as the engine and fire rooms, they were drawn



CUT 25.—Edison No. 3 dynamo and Armington & Sims engine.

through lead pipes; the wires were covered by battens in exposed places but they were led out of sight wherever possible, a practice which was soon abandoned. There were two main circuits.

The vessel was rewired in 1893 by the Pacific Electric Storage Company, of San Francisco, Cal. The highest grade rubber-covered, moisture-proof B. & S. wire of Nos. 4, 6, 8, 10, 12, and 14 was used, all run in water-tight white-pine moldings, painted before and after the wires were run. The moldings are all in plain view and easy to get at. Extra protection is given to wires passing through bulkheads.

Circuits: There are eight circuits, as follows, all controlled by a switch board placed near the dynamo:

No. 1. Cabin and ward-room, port side.
No. 2. Cabin and ward-room, starboard side.
No. 3. Deck-house, outside.
No. 4. Drum-room, galley, deck-house rooms.
No. 5. Laboratory and chart-room, starboard side.
No. 6. Laboratory and chart-room, port side.
No. 7. Steerage, main deck, forecastle starboard side.
No. 8. Steerage, main deck, forecastle port side.

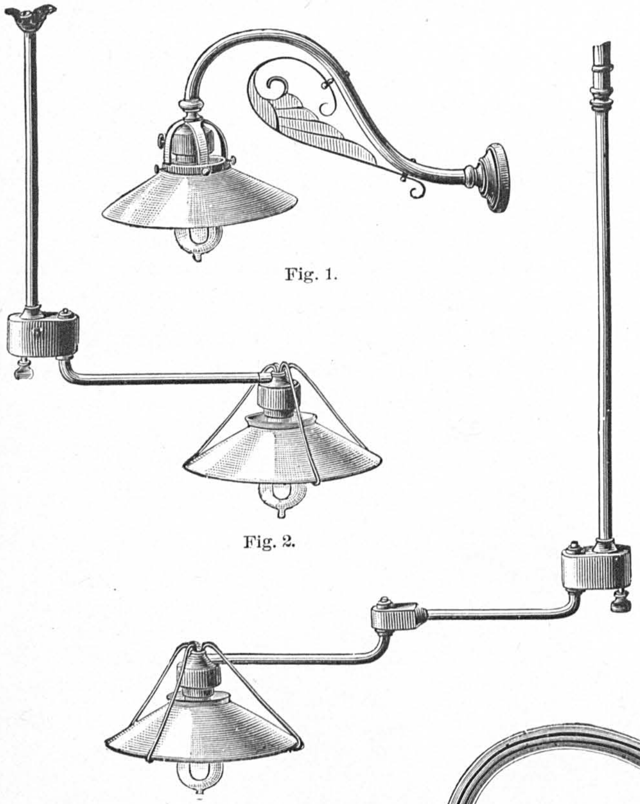


Fig. 1.

Fig. 2.

Fig. 3.

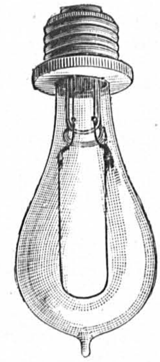


Fig. 6.

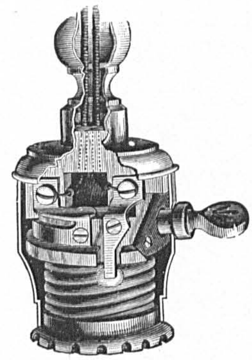
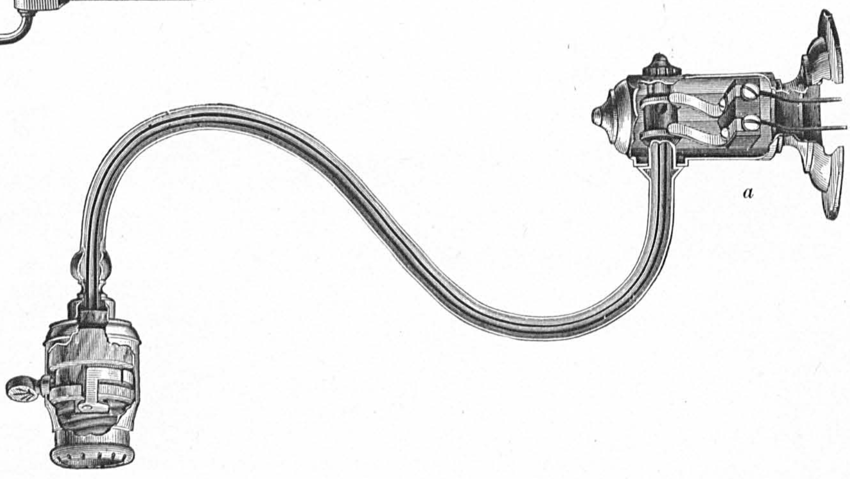


Fig. 5.



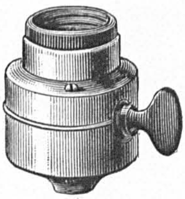


Fig. 7.

Fig. 4.

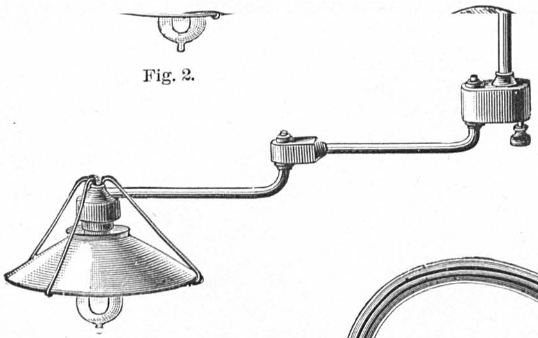
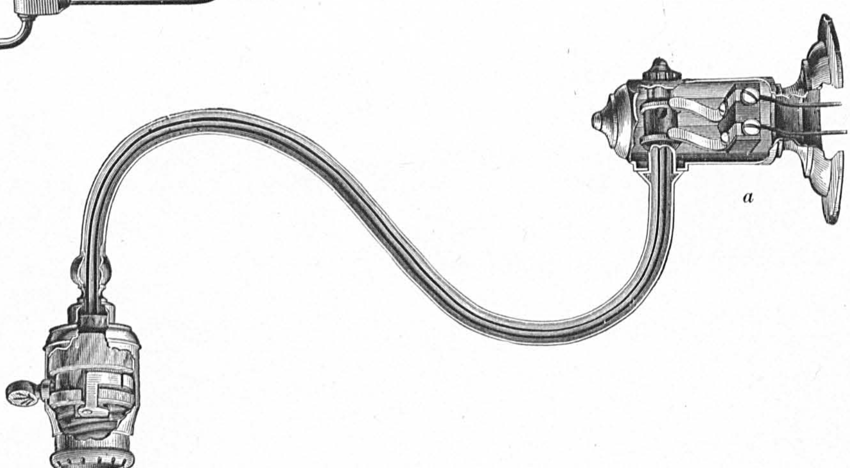


Fig. 2.

Fig. 3.



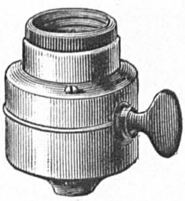


Fig. 7.

Portable electric lights: There are two small reels carrying 50 feet each of insulated flexible cable, to which 50-candle incandescent lamps are attached; one reel is in the pilot-house, the other under the forecastle, and both can be concentrated upon the table sieve, where a bright light is required for collecting and assorting specimens at night. These lamps have replaced the arc lights used for the same purpose during the first cruise of the *Albatross*. They are more easily managed and answer the purpose equally well.

Submarine electric lamps are improvised on board the *Albatross* by connecting an ordinary 16 or 50-candle lamp to one end of an insulated cable, carefully wrapping the joint to make it water-tight; a plug on the other end forms a convenient connection wherever a lamp socket is found. They are especially useful in collecting at or near the surface, lighting up the sounding machine, dredging gear, or any part of the deck remote from fixed lamps.

LAMP FIXTURES.

There are combination electroliers in the cabin and ward-room arranged to burn either mineral sperm oil or electricity or both. The bracket fixtures are designed to be suspended above and cast unobstructed rays of light downward; they are handsomely made of brass with porcelain shades, three kinds being used, called brackets, swing brackets, and double swing brackets, as shown in figs. 1, 2, and 3 (plate XIII).

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. 4, 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. 5, 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 lamps are of thin glass, pear-shaped, containing a thread of bamboo carbon about as thick as a horsehair. The small end of the lamp (fig. 6) 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. 6), 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. 7) the circuit is completed or broken by the switch or key already described.

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. 8 shows a lamp screwed into its socket.

By varying the length, and also the sectional area of the carbon thread, keeping the electro-motive force constant, Edison has varied the candlepower of his lamps.

Sixteen candlepower lamps are in general use on board the *Albatross.* The copper 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.

Let R = the resistance of a conductor; S = its sectional area; L = its length; 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 "lifetime" of these lamps is warranted to be 600 burning hours.

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. 9 and 10 (plate XIII). 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.

VENTILATING.

Natural ventilation is provided by large air-ports and skylights which, under ordinary conditions, afford sufficient circulation to insure normal hygienic conditions, but, to guard against the discomforts of closed ports and skylights in stormy weather, and to insure the safety of the laboratories where large quantities of inflammable material and volatile liquids are carried, the vessel is provided with a simple system of artificial ventilation capable of supplying over 7,000 cubic feet of air per minute.

The plant consists of a pair of Sturtevant No. 5 Monogram exhaust fans, driven by an upright engine belted to them. The conduits are of Root's spiral galvanized-iron pipe. Those leading forward are 9 inches and those leading aft 7 inches in diameter, both diminishing in size to 3 inches in diameter at the extremities of the ship. They run fore and aft on both sides just under the lodger plates of the berth deck, and branch pipes 3 inches in diameter are carried up through the deck to the apartments to be ventilated.

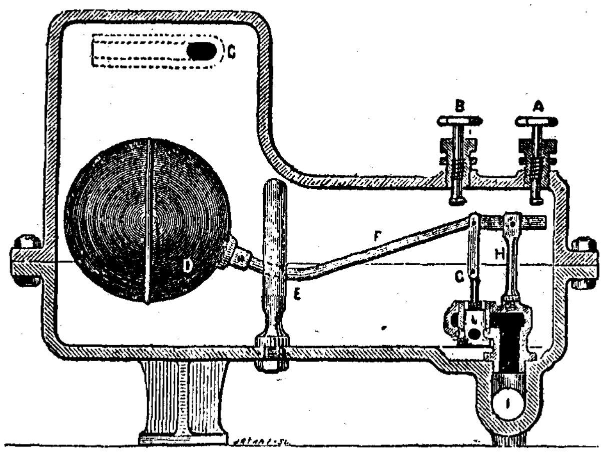
Each pipe terminates in a polished brass register, easily worked by hand, and air and water tight when closed; sliding gates in the conduits control the volume of air exhausted from different compartments and shut off communication in case of fire. The air is rapidly changed by running the fans even at a moderate speed, when there follows a notable absence of odors peculiar to ships, of stuffiness in the sleeping apartments, of headache and nausea on waking in the morning, and of dangerous accumulations of gas in the laboratories.

WARMING.

The *Albatross* is warmed by the simplest form of steam radiators, 1 square foot of radiator surface being allowed for every cubic foot of space to be heated. The discharge is trapped and the water conveyed to the hot well. Much trouble was experienced with the traps from lack of sufficient head until Chief Engineer Baird devised one (cut 26) which performed its work satisfactorily.

The wheels A and B are used only when the valve J becomes clogged or sticks.

The operation of the trap is as follows: When the steam and water enter it at C and rise to the floating points of the ball the water lifts it and opens the valve J enough to bring the port holes in it opposite the holes in the cylindrical case in which it works, and discharges the water at I into the hot well.



Cut 26.—Baird's Automatic Steam Trap.

A. Valve wheel by which the lever F is raised, thus opening the trap by hand.
B. Valve wheel by which the lever F is lowered, closing the valve by hand.
C. Inlet to receive the discharge from the radiators.
D. Copper ball, or float, heavy, and brazed at the joints so that it can not collapse or leak.
E. Guide in which the lever works.
F. Lever operating the float and valve.
G. Connecting rod between the lever F and piston valve J.
H. Stud supporting lever F and float D.
I. Outlet or discharge.
J. Piston valve.

Baird's trap has the following advantages:

1. It has a perfectly balanced valve, which operates equally well with high or low pressures.

2. The area of the openings in the valve are equal to the inlet and discharge pipes, which prevents the trap from being flooded.

3. It has a drain pipe through which all water or sediment can be blown out from the bottom, or, being left open, keeps the trap dry when the radiators are not in use.

THE DEVELOPMENT OF DEEP-SEA SOUNDING.

The ordinary lead and line sufficed for navigational and other purposes until near the middle of the present century, when the needs of deep sea investigation and submarine cable surveys called for improved methods. A device for detaching the weight was recorded in the seventeenth century, showing that attention was attracted in that direction at an early day. Among the earliest recorded soundings of considerable depth may be mentioned that of Ellis, in 1749, off the west coast of Africa, where he reached bottom in 891 fathoms.

In 1819 Sir John Ross sounded in 1,000 fathoms, bringing up a satisfactory bottom specimen in the "deep-sea clamm" designed by him the previous year, and described as follows:

> A large pair of forceps, kept apart by a bolt, and the instrument was so contrived that on the bolt striking the ground a heavy iron weight slipped down a spindle and closed the forceps, which retained within them a considerable quantity of the bottom, whether sand, mud, or small stones.

Officers of the United States Navy and Coast Survey were particularly active in their intelligent and systematic efforts to reach a reliable and accurate method of deep-sea sounding, but the results were meager so long as they retained the rope of large cross-section and nondetachable sinkers of insufficient weight.

The causes for the many failures are made sufficiently obvious by reference to Professor Trowbridge's remarks regarding the resistance of rope in sounding:

> The resistance of the line varies, first, as the square of the velocity; second, as the diameter of the line; third, as the length of the line immersed.

With the above rule in mind, and the fact that a hemp line in sea water is only one-fourth its weight in air, and that its naturally large cross-section is increased by saturation, it will be seen that even in moderate depths the continued action of resistance and the deflective force of currents may approximate to the weight of the lead, and the line, left to sink slowly by its own weight, will continue to run out indefinitely, giving no warning when bottom is reached.

The following reports of soundings made in the Atlantic Ocean and Gulf of Mexico by United States and British naval officers serve to illustrate the primitive appliances and methods of the time and accentuate the great importance of later experience and inventive genius.

Lieut. M. F. Maury, United States Navy, who was always foremost in every effort at advancement, advocated the use of a small line of great strength, made of the finest flax, and a largely increased weight of sinker. The new line weighed less than 10 pounds to the nautical mile, and was measured, waxed, and carefully wound on reels of convenient size when issued for use. Naval vessels were furnished with it about 1850, and some notable successes were achieved by its use, showing that it was a move in the right direction; yet frequent failures and discouragements were encountered.

Lieut. William Rogers Taylor, of the U. S. S. *Albany*, introduced the systematic use of the time interval, which was an important improvement and continued to be a marked feature in deep-sea sounding until the successful introduction of wire, when its importance greatly diminished; indeed, it was of no service as far as the sounding

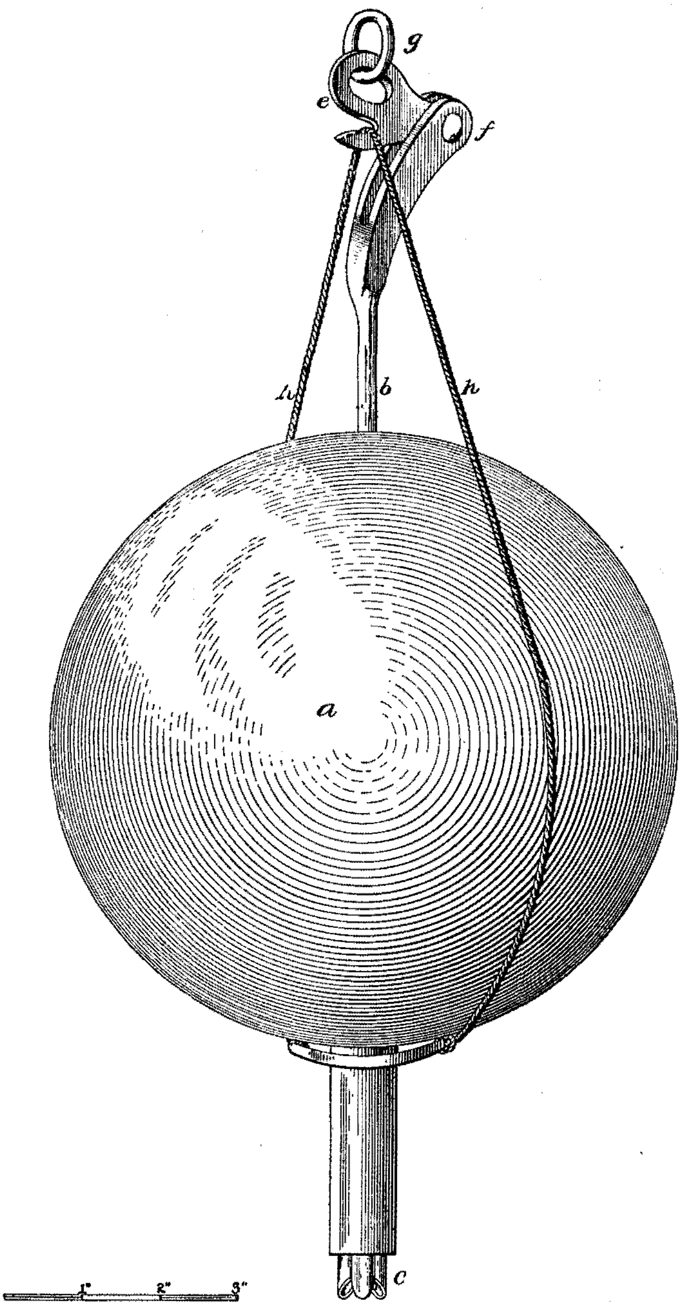


Fig. 1.

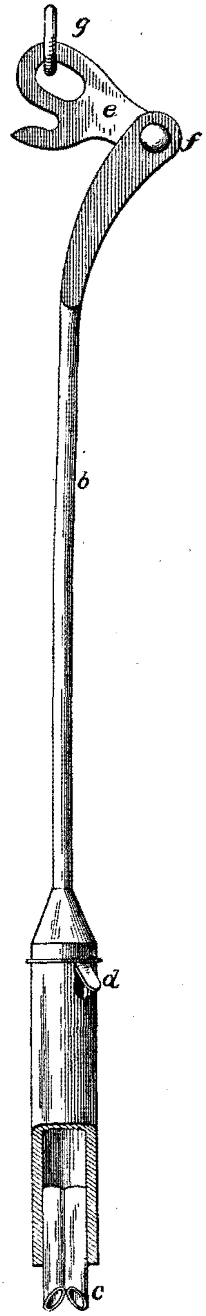


Fig. 2.

Nomenclature.

a. Sinker.
b. Sounding rod.
c. Quills.
d. Circulating valve.
e. Detacher.
f. Pin.
g. Link.
h. Slings.

THE BROOKE DEEP-SEA SOUNDING APPARATUS.

FIG. 1. Rod inserted in the sinker and the latter suspended to the detacher ready for sounding.

FIG. 2. Sectional view of the detacher in position for releasing the slings; it shows also the lower part of the specimen cup in section.

itself was concerned, but was and is still recorded to show comparative results under the varying conditions of actual practice.

The explorations of the U. S. S. *Dolphin* from 1851 to 1853, under Lieutenants Lee and Berryman, were accorded a prominent place among the notable achievements of the day. They used the apparatus just described, introducing from time to time such improvements as experience suggested, and under their hands the science of deep-sea sounding rapidly approached a practical basis. They sounded from boats, which were held in position by the use of the oars, operations being confined to smooth or moderate weather. They used waxed twine, observed time intervals, and, the sinker having reached the bottom, the sounding line was cut, no effort being made to recover the weight. Submarine telegraphy was assuming great importance in the public mind at that time, stimulating invention in everything pertaining to the development of ocean depths.

BROOKE'S DEEP-SEA SOUNDING APPARATUS.

In 1854 Passed Midshipman John M. Brooke, United States Navy, devised a simple and effective method of detaching the sinker and bringing up a specimen of bottom soil. This timely invention (plate XIV) marked the beginning of an entire revolution in the appliances and methods of deep-sea sounding and remains the acknowledged progenitor of all the various forms of sounding rods and detachers that have been introduced to the present time. It is no longer used in its original form, yet a brief description will be given to show how completely the principle of his apparatus is retained in all subsequent modifications, which are little more than successive refinements of his simple mechanism.

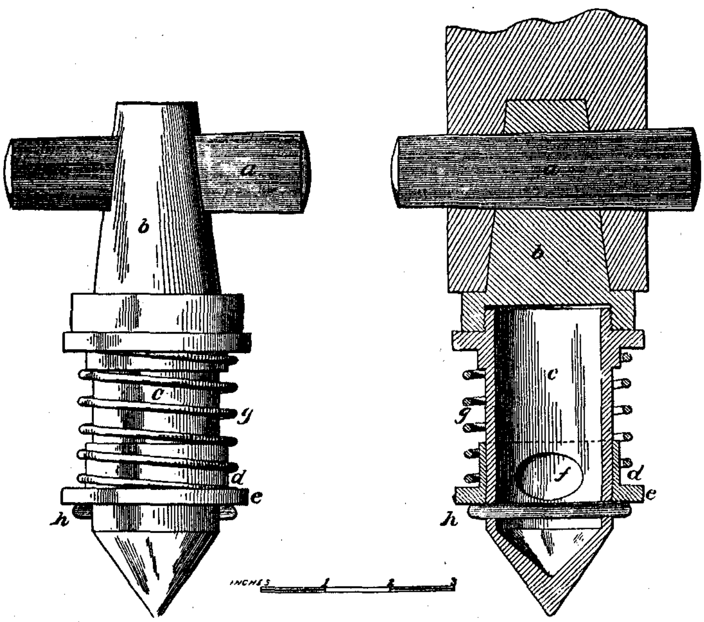
The sinker is a spherical shot cast with a hole through it and shallow grooves on opposite sides to guide and steady the slings. A number of goose quills are shown in the lower end of the specimen cup, held in place by their own elasticity, intended to act as collectors and foot valve. A leather circulating valve opens outward from the upper end of the cup, which allows free circulation of water through it during its descent, but closes and protects the contents while it is going up.

The rod and detacher are so designed that the former retains a vertical position during the descent of the sinker. When it reaches the bottom its weight is removed from the detacher and the latter falls by its own gravity, thus releasing the slings and freeing the sinker from the rod after it has performed its function of carrying the latter rapidly to its destination and pressing it into the bottom soil to secure the desired specimen.

In 1856 the U. S. S. *Arctic*, Lieutenant Berryman, made a cable survey from Newfoundland to the coast of Ireland, which may be considered the first deep-sea sounding expedition in which an approach to modern appliances and methods was successfully used. The line was of flax, 1 inch in circumference, wound on a steam reel arranged to work from the bow of the vessel. The Brooks apparatus was used with sinkers about 150 pounds in weight, and the depths were checked by a Massey self-registering sounding machine.

The results of the survey, although accurate for the time, were at first somewhat discredited from their having discarded the time interval, but in the light of modern experience it is evident that the officers of the *Arctic*, who were certainly the best judges, considered their methods and results reliable without its use. The secret of their success is attributable to the Massey machine combined with a comparatively heavy detachable sinker, controlled in its descent by an intelligent application of the friction brake, which stopped the reel promptly when bottom was reached. The line weighed about 200 pounds to the nautical mile and would have carried a sinker of 500 pounds with safety, thus materially increasing the rapidity and accuracy of the work.

The Stellwagen and the Sands cup leads, with nondetachable weights, were among the many devices brought forward for sounding. They were both excellent for use in shallow water, or moderate depths where the lead can be recovered.



CUT 27.—Sands cup, side and sectional views.

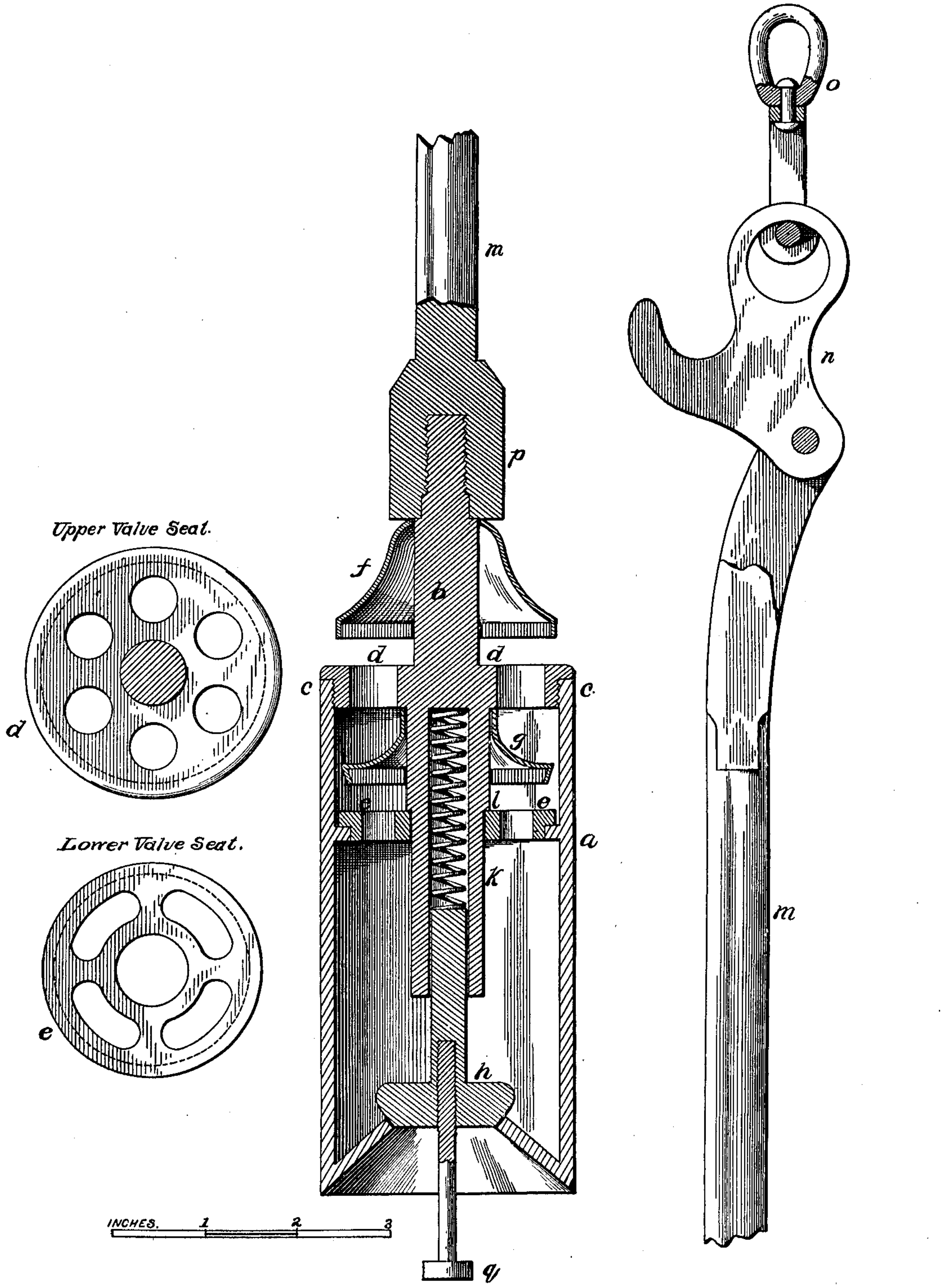
Belknap describes the Sands cup as follows:

A key, *a*, holds the tenon *b* into the bottom of the deep-sea lead, into which tenon is screwed the tube *c* (which is conical at the lower end for penetrating the bottom), over which moves a cylindrical sliding valve *d*, with flange *e*, which, resting on the bottom when the lead reaches it, is pushed up above the elliptical hole *f*, in the side of the tube for the admission of the specimen, and closed by the spiral spring *g* (when the lead is free from the bottom), which keeps it firmly down on the rest-pin *h*, preventing the washing out of the specimen in the jerking motion of hauling in the line by hand. The tube is unscrewed from the tenon, and the specimen emptied out at the upper end.

The material of the specimen cup is brass; it is easily attached to an ordinary deep-sea lead, and may be used to advantage in moderate depths. Sands subsequently added to his cup a detachable sinker composed of two hemispheres of cast iron with suitable grooves on their flat surfaces to take the rod where they were held in place by appropriate studs and springs, which also released them on contact with the bottom.

British naval officers were also active in deep-sea sounding and did much toward its advancement; the "bull dog" apparatus, a modification of Ross's "deep-sea clamm," was introduced in 1860. The forceps are retained but the weight is detachable. The Fitzgerald and Hydra, both having detachable weights, were brought out in 1868, and the latter was successfully used on the *Porcupine* during her scientific cruise, where with a line 0.8 inch in circumference, weighing 125 pounds to the nautical mile, and detachable sinker of 336 pounds, they reached bottom at a depth of 2,435 fathoms at the mean rate of 72 fathoms per minute, about seven-tenths of the best modern practice with wire.

This was evidently an exceptional sounding, made under the most favorable conditions, and can not be accepted as average work, yet it shows marked improvement, the result of increased weight of sinker.



THE BELKNAP SOUNDING CYLINDER, NO. 2.

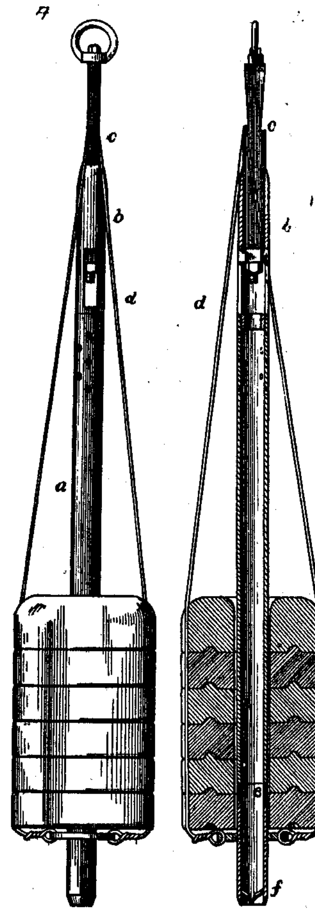
a. Cylinder, brass.
b. Castings, brass.
k. Spiral spring.
l. Shoulder holding lower valve seat down.

H. B. M. S. *Challenger* sailed on her celebrated scientific voyage around the world in December, 1872, six months after the introduction of Sir William Thomson's machine for sounding with wire, and at the instance of the inventor one of his machines was placed on board, but was relegated to the storeroom, where it remained during the entire cruise notwithstanding the remarkable success attending its introduction into the United States Navy and Coast Survey.

The successful operations of the *Porcupine* in sounding with rope naturally influenced its retention on the *Challenger*, which was amply supplied with the best Italian hemp No. 1 line, 1 inch in circumference, weighing about 200 pounds per nautical mile. The Baillie sounding machine, a modification of the Hydra, was adopted, and it was unquestionably the best device yet introduced for sounding with rope. It differed from the Hydra principally in the detacher, which was much improved; the rod remained practically the same, and the disk weights were retained. A further increase in the weight of sinkers to 400 pounds and upward in deep water, enabled them to obtain good results, although at the expense of much time and labor.

The Baillie sounding machine is described as follows by Sir C. Wyville Thomson:

It is represented in perfection in the position in which it is let go in A, and in section in same position at B. The tube A is about 5 feet 6 inches in length by 2½ inches in diameter. The bore is 2 inches, so that the wall is one-fourth inch thick. The principal part of the tube is of iron. It is bored near its upper end with a number of holes to let out the water; it unscrews into two at *e*, and at its lower end, *f*, there is a pair of butterfly-valves working inward. A strong brass cylinder, *b*, with a diameter equal to that of the tube, is firmly attached to the upper end; a heavy piece of iron, *c*, works in the brass cylinder like a piston to the extent of the length of the slots, *d*, in the sides of the cylinder, in which it is retained by a strong square bolt. The piston iron is flattened, and it is provided at *c* with a projecting shoulder, which, when the piston is drawn out—the bolt being at the top of the slot as in the figure—is well above the top of the cylinder; but when the piston is drawn down, and the bolt at the bottom of the slot, the shoulder is just within the upper part of the cylinder. The wall of the upper part of the cylinder is beveled away to a long rounded slope.



CUT 28.—Baillie sounding machine.

When to be used, the instrument is hung by the ring to the sounding line, a sufficient number of weights are suspended on an iron wire sling, as in the Hydra machine, the tube passing through the middle of them, and the sling hooking upon the shoulder of the piston iron. When the tube and weights touch the bottom, the brass cylinder is pushed upward the length of the slots, and the sling is slipped off the shoulder of the piston iron by the upper rim of the cylinder and allowed to slide down over its beveled upper end. This is a very simple plan, and the doing away with the steel spring of the Hydra is an advantage. The larger tube also brings up a better and fuller sample of the bottom.

In the spring of 1873, a few months after the departure of the *Challenger*, the U. S. S. *Tuscarora*, Capt. George E. Belknap, United States Navy, was fitted out for the purpose of sounding a submarine cable route from California to Japan. She was supplied with a large quantity of rope, steam reel, and other appurtenances, and, in addition, one of Sir William Thomson's machines for sounding with wire. It was furnished by order of Commodore Ammen, chief of the Bureau of Navigation, who rightly appreciated the great value of Sir William's invention, in spite of the crude and imperfect form of the original machine and the cold reception given it by the *Challenger*. He was familiar with Thomson's experiments, thoroughly understood the preeminent qualities of pianoforte wire for deep-sea sounding, and wisely trusted to Belknap's enterprise and inventive genius to supply any deficiencies that experience might develop in existing appliances.

Brooke's apparatus was designed for use with rope, as were all devices known at the time, and the production of a simple form of sounding rod and detacher fulfilling modern requirements was one of the first and most important problems Belknap had to solve. He retained the Brooke principle, modified the detacher very slightly to better adapt it for use with wire, increased the capacity of the cup or cylinder in order to bring up a larger bottom specimen, substituted a metal poppet-valve in place of the goose quills, provided for a free circulation of water through the cylinder during its descent, and protected the bottom specimen from wash during the ascent. It was introduced by the inventor as the Belknap deep-sea sounding cylinder No. 2, was successfully used throughout the extended cruise of the *Tuscarora*, and became the standard sounding cylinder for deep-sea work in the United States Navy and the Coast Survey.

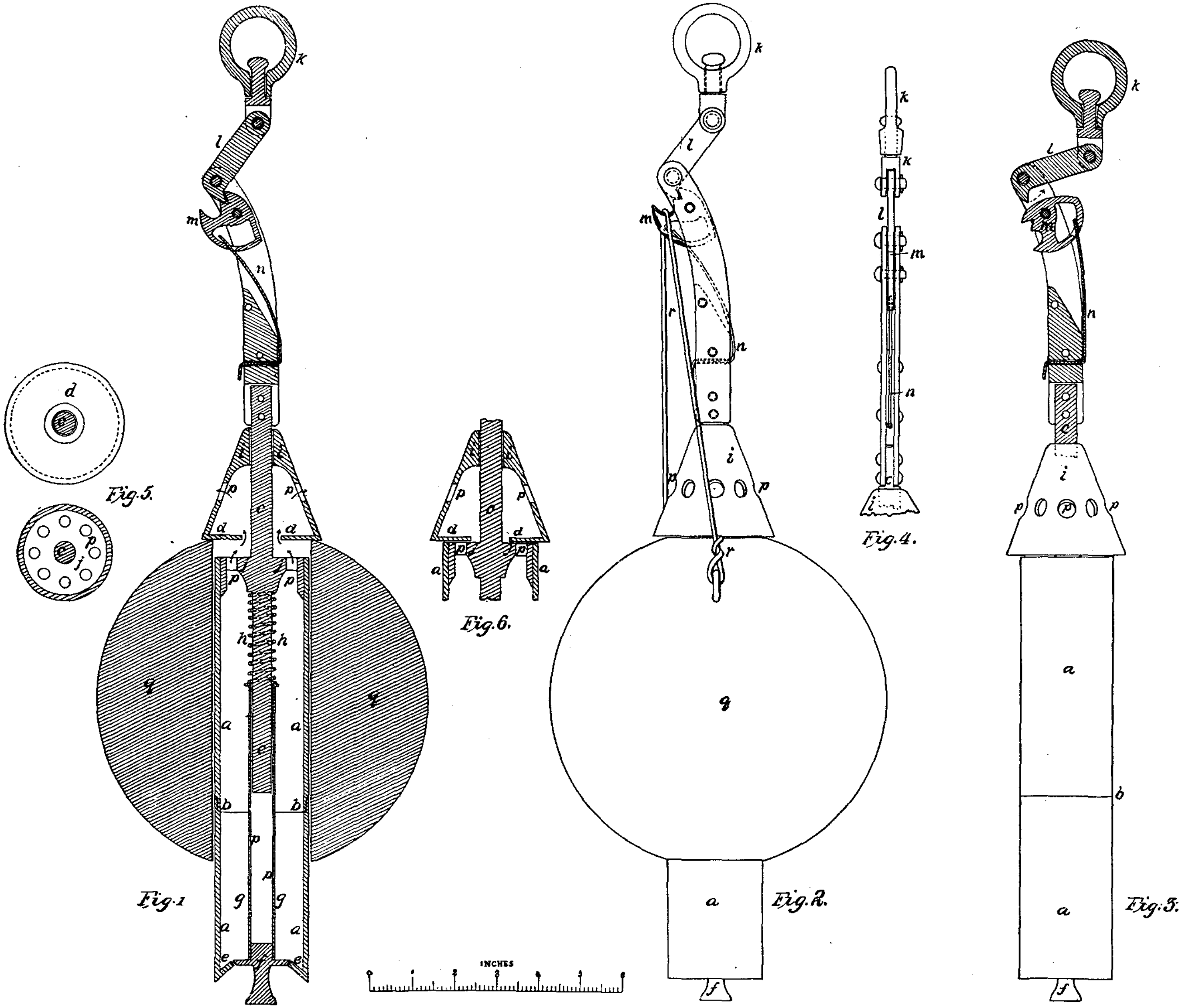
THE BELKNAP DEEP-SEA SOUNDING CYLINDER NO. 2.

The cylinder, casting, valves, and valve seats are brass, the rod and detacher of wrought iron or steel (plate XV). The detacher is so proportioned that the lip receives the wire bail and carries the weight of the sinker in exact prolongation of the axis of the cylinder, thereby maintaining it in a vertical position until the tension is removed by the sinker resting on the bottom; the wire is then slackened, allowing the detacher to fall by its own gravity, slipping the wire bail and releasing the weight, which has carried the cylinder swiftly down and pressed it into the bottom soil to receive its specimen.

The cylindrical casting has a screw at its upper extremity by which the rod is attached. The upper cylinder head and valve seat are formed by an expansion of the casting near its center, and a small shoulder a few inches beneath it holds the lower valve seat in place. The spiral spring and poppet-valve stem are contained within a cylindrical chamber which serves as guide for both.

The upper and lower valves have free vertical movement; they are faced with leather to insure their being tight, and the valve seats are provided with apertures for the free circulation of water during the descent, when the valves are all kept open by the upward rush of water through the cylinder, and promptly closed by reverse action when the upward movement begins, thereby preventing the wash of the bottom specimen in the barrel of the cylinder.

The spiral spring is delicately adjusted to retain the poppet valve on its seat without undue resistance to external pressure, and the adjustable screw stud projecting below the cylinder is intended to facilitate the opening of the poppet valve, and is of service only on hard, sandy bottom. The bottom specimen is removed by unscrewing the cylinder from the casting at *c*.



Nomenclature.

a. Cylinder.
b. Screw joint.
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.

THE SIGSBEE SOUNDING ROD.

FIG. 1. Longitudinal sectional elevation of the Sigsbee sounding rod.
FIG. 2. Side view, with the sinker suspended from the detacher by the wire bail.
FIG. 3. Plan view of the cylinder and a longitudinal sectional elevation of the detacher.
FIG. 4. Back view of the detacher.
FIG. 5. The perforated plate *j* and cylindrical ring *d*.
FIG. 6. Enlarged view of the hollow cone *i*, cylindrical ring *d*, apertures *p*, and the upper end of the cylinder *a*.

PLATE XVI.

THE SIGSBEE SOUNDING-ROD.

The next marked improvement was made by Lieut. Commander C. D. Sigsbee, U. S. N., while in command of the United States Coast Survey steamer *Blake* from 1874 to 1879. Following in the footsteps of Belknap and conversant with his work on the *Tuscarora*, he was in a particularly favorable position to take up the general subject of improved appliances and methods in deep-sea sounding.

The *Blake* had a Thomson machine for sounding with wire, which Sigsbee used with great success in his extended examination of the Gulf of Mexico. The first of his many improvements in deep-sea apparatus was a detacher which he used in connection with Belknap's cylinder No. 3, followed by a design of his own, a modification of Belknap's No. 2, which after much experience he considered superior to the former for deep-sea work. Regarding this, Sigsbee says (Deep-Sea Sounding and Dredging):

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

He enumerates the requirements for a perfect sounding-rod, as follows:

1. Certainty of not detaching the sinker during the descent.
2. Certainty of detaching on striking any character of bottom.
3. Certainty of not rehooking or of fouling with the sinker, in any way, after the same has once been tripped.
4. Adaptability to getting a specimen from the various kinds of bottom material.
5. Certainty of not grappling irretrievably with the bottom.
6. Certainty of retaining the specimen against the wash of water in the ascent.
7. Handiness for extracting the specimen and for cleaning the parts.
8. Freedom from changing its form under the severe pressure in deep water.
9. Strength, simplicity, cheapness, light weight, and freedom from corrosion.

In general there are two ways of detaching a sinker from its rod: (1) By actual or partial slacking of the sounding wire or rope. (2) Directly by the impact of the rod against the bottom. The former method is regarded as safer, but sometimes both are involved in one detaching apparatus. The detacher which depends for tripping solely on the resistance of the bottom material is usually more sensitive on hard than on soft bottom; also, should the sinker glance on the side of a rock or ledge the trigger or other appliance might not be presented fairly to the blow necessary to upset the connection which holds the sinker in place.

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

Remarking upon the construction of the sounding-rod, he says:

> 1. The pawl and tumbler are made to fit each other in such a manner that, when connected and under strain, they are held undeviatingly as shown in figs. 1 and 2—that is, the wire is in the prolongation of the axis of the rod. If this be not observed the relation of the leverages of the pawl and tumbler will be destroyed and the detacher may be too sensitive, besides which the rod may incline to a degree that will act somewhat against a vertical descent.

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

3. All parts should work freely.

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

5. The spiral spring *h* should not be so strong as to prevent soft bottom material entering the cup; its strength should be sufficient, when the rod is lying flat, to force the valve smartly to its seat when the valve is pushed inward and released, and yet not strong enough to seat it by about 1 inch, when the rod is held bottom upwards. The springs for the *Blake's* rods are of No. 17 American, or No. 18 Stubb's gauge spring-brass wire; they are 3 inches in length when not under compression, and have twelve coils each. Any spring thus made could easily be adapted to the requirements.

6. If desired, the rod might be made considerably lighter for very deep work, the present size of the detacher being retained. On the scale of plate XVI, the rod and detacher are strong and handy, weighing 5¼ pounds. The size of the specimen sought should have much influence in determining the size of the rod. If only an indication of the bottom material were wanted, no specimen for careful examination being needed, a rod weighing only 2 or 3 pounds would suffice.

DETAILS OF CONSTRUCTION.

The cylinder *a*, fig. 1, plate XVI, is a brass tube of commercial pattern, 2¼ inches outside diameter and 10 inches in length, rigidly secured to the perforated plate *j* by small brass screws, and the valve seat *e* is soldered to the other extremity of the cylinder which has its cutting edge sharply beveled as shown in fig. 1. The poppet-valve *f* is of cast brass secured by a drift-pin to its hollow stem, a thin brass tube, which impinges on the spiral spring *h*, both traversing the stem freely. The upper and lower guide stem is a brass casting enlarged near its center to form the perforated plate *j*. The hollow cone *i* is a brass casting having apertures, *p*, for the escape of water; the cylindrical ring *d* is soldered to its base.

The detacher is composed of the tumbler *m*, pawl *l*, swivel *k*, and spring *n*; all movable parts working on loose brass pins which are held in place by small split keys of spring brass. The spring is of No. 14 American gauge brass spring wire. The detacher frame is riveted to the flattened end of the guide stem, in prolongation of it, and there is a screw joint at *b*, on the cylinder, by which the two parts are separated for convenience in securing its contents.

TO USE THE SOUNDING-ROD.

To sound and bring up a specimen of the bottom, attach the stray line, which should always intervene between the wire and sounding rod, to the swivel ring *k*, pass the rod through the hole in the sinker, hook the wire bail *r* over the lip of the tumbler *m*, lock the pawl and tumbler and suspend the rod from the swivel ring *k*, when it will promptly assume a vertical position. The cone *i* remains unseated during its descent by contact with the shot (fig. 1), and the valve *f* is raised by the upward pressure of the water, which then circulates freely through the cylinder, reducing its resistance and increasing its rate of descent.

When the sinker strikes the bottom the tension on the line is relieved and it becomes more or less slackened, the pawl assumes a horizontal position by its own weight, releasing the tumbler, which is thrown out of action by the spring *n*, assisted by excess of weight at the lip, and thus the sinker is released.

The combined weight of shot, sounding-rod, small lead, and thermometer, altogether about 70 pounds, descending at the rate of 8 to 10 feet per second, forces the rod well into ordinary soils, lifts the valve *f*, and fills the cylinder to a greater or less extent with a bottom specimen. The reverse motion, when the ascent begins, promptly closes the valves and protects the contents from wash, to which it would otherwise be subjected. The specimen is readily removed by disconnecting the cylinder at the screw joint *b*, which also facilitates the cleansing of the cup.

Failure to detach the sinker.—The Sigsbee sounding-rod has been used exclusively on the *Albatross* since 1882, except during the cable survey between California and the Hawaiian Islands, when a few No. 2 Belknap cylinders were received and successfully used from time to time, although the Sigsbee rod was preferred in deep water.

Several thousand soundings have been made with the latter on board the *Albatross* without a single failure to detach the shot and bring up a bottom specimen through any fault of the instrument itself. Failures from the following causes have occurred, however, at rare intervals:

1. The wire bail was too short and brought sufficient tension on the lip of the tumbler to sustain the weight of the pawl by friction of the latch surfaces, a rare occurrence, possible only through the determined effort of a muscular man.
2. It has failed to detach in deep water and very soft bottom, from the rod having been carelessly sent down with the spring *n* out of action.
3. The rod jammed in the shot by a pebble becoming detached from the scale in the hole, which had not been properly cleaned. The bail was free.
4. Partially disintegrated volcanic rock was driven into the space between rod and sinker so firmly that the shot was brought back although the bail was free.
5. The rod struck hard rock with sufficient force to bruise and distort the bottom to such an extent that it would not go through the hole in the sinker although the bail was free.
6. Once during a gale of wind, with heavy breaking sea, the descent of the stern of the vessel from crest to trough was so violent that it slackened the wire and detached the shot. It is remarkable that this should have been the only instance of the kind, for the *Albatross* sounded from the stern in all conditions of wind and weather.
7. An officer unaccustomed to sounding with wire allowed the reel to "run wild" until slack turns of wire were seen, and, supposing bottom had been reached, hove in the wire, bringing the sinker back from the few hundred fathoms that had run out.

Failures of the rod from any cause were so rare as to provoke comment when they did occur, and it was seldom those mentioned above happened more than once.

The Belknap cylinder No. 2 failed to detach its shot on a few occasions:

1. In deep water and very soft bottom it sometimes failed to detach promptly, but it was usually accomplished after repeated efforts, although on a few occasions the shot was brought back.
2. The rod and detacher unscrewed from the cylinder on one occasion and the latter was lost.
3. The shot was brought back with the bail over the detacher, which had fallen the wrong way when the wire slackened. It was caused doubtless by the shot landing on rough bottom and capsizing before it was detached.

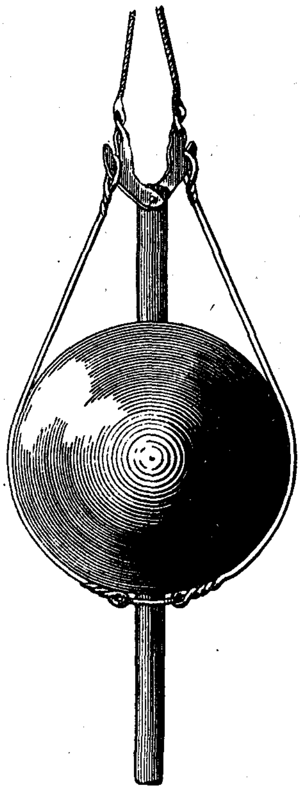
The failures mentioned in connection with the Belknap cylinder No. 2 did not happen with the Sigsbee rod, but such as occurred with the latter are equally liable to happen with either.

IMPROVISED SOUNDING-RODS.

It may be desirable at times to have a cheaper and lighter sounding-rod, in very deep water for instance, where small specimens are required, sufficient only to indicate that bottom has been reached, or the supply of rods may be exhausted by unexpected losses while at sea engaged in important work which would suffer from the delay incident to an immediate return to port. Hence any device, however crude, would be of great value providing it insured uninterrupted continuance of operations, and it is hardly reasonable to suppose that a vessel conducting extensive deep-sea sounding would be without the necessary materials with which to construct some simple and fairly effective form of rod.

THE SIGSBEE GAS-PIPE SOUNDING-ROD.

In the deep waters of the Gulf of Mexico, where large bottom specimens were not required, Sigsbee used a sounding-rod of one-half-inch to three-fourths-inch gas pipe, 20 inches in length, with a Sigsbee detacher screwed into one end, and in the other a metal ball valve to retain a small bottom specimen; an arming of tallow may be used, but the valve is preferable. Additional length is given the cylinder to insure prompt action of the detacher when the shot reaches the bottom. A ball of lead or other metal inserted in the pipe with one-eighth-inch clearance and the lower end of the latter upset sufficiently to form a valve seat will answer the purpose; there should be a couple of small holes in the pipe near the upper end for the escape of air and water. This rod being inexpensive, light, and offering little resistance when reeling in, may be used to advantage under the exceptional circumstances before mentioned.


CUT 29.—The Brooke double-arm detacher.

EMERGENCY SOUNDING-RODS.

Sounding-rods of this description would be used only when the regular supply became exhausted, and, being hurriedly improvised, perfect action or thorough reliability could not be expected. They may be made of iron or brass pipes, spare condenser tubes, iron rods, or flat bars, providing they have the necessary rigidity. The gas-pipe rod has been described, and if the facilities are at hand for making the Sigsbee detacher an effective sounding-rod is assured, otherwise there is left a choice between the two forms of Brooke apparatus, the double and single arm detachers.

THE BROOKE DOUBLE-ARMED DETACHER.

While this form is not as readily operated or as reliable as the single arm subsequently introduced by Brooke and generally adopted, it is the most readily improvised with the facilities usually found on shipboard, and deserves a short description.

It is composed of two flat arms, alike in every respect, each having a hole through its lower end for a pin upon which they work, a hole through their upper extremities to which the bridle is attached, and lips on their outer edges from which to suspend the sinker during its descent and release it when it strikes bottom.

The single arm detacher has already been described with the Brooke deep-sea sounding apparatus. Belknap adopted it, and next to the Sigsbee it is the most reliable. Its construction is comparatively simple, providing the points of suspension are maintained in prolongation of the axis of the rod, as shown in the description of the Brooke apparatus, and it would probably be the form usually adopted. To insure proper action the relative proportions of the detacher would be determined by experiment, and if it be made to release the weight at a tension of 10 pounds and hold on to it under greater strain it can not be far wrong. The Sigsbee detacher trips at 8 pounds, but it would not be advisable to give an improvised tumbler so small a margin of safety.

IMPROVISED BROOKE SOUNDING-ROD.

Sigsbee's gas-pipe rod with Brooke's single detacher is the simplest and most effective, providing suitable pipe is at hand; if not, an iron rod may be substituted, the upper end split to admit the detacher, and a short piece of pipe attached to the lower end for a specimen cup, substituting the ball valve for the goose quills of Brooke's rod. If pipe can not be had, a small chamber can be formed by drilling, in which an indication of bottom may be obtained by coating the interior with white paint.

THE BAR SOUNDING-ROD.

In the absence of other material a serviceable sounding-rod may be improvised by taking two pieces of flat bar-iron, from 1 inch to 1½ inches wide and 2 feet long, and inserting between them three filling pieces cut from the same bar, placed at irregular intervals as follows: One at the bottom, one 4 inches above it, and the other 6 inches below the detacher; drill or punch corresponding holes through bars and filling pieces and rivet them together; smooth the outer surfaces to insure free passage through the hole in the sinker and adjust the detacher, the bars having been shaped for the purpose. The interior space between the lower filling pieces, being coated with thick white paint, will serve as a specimen cup.

LEADS AND OTHER WEIGHTS FOR SOUNDING.

The time-honored lead, so familiar to all mariners as the medium of communication between the surface and bottom by sounding, retains its place to a great extent in shoal water, and even in moderate depths, but has been superseded for deep-sea work by modern appliances.

Hand leads, weighing 7 to 14 pounds, are used in shoal water and cast by one man.

Coasting leads vary in weight from 25 to 50 pounds. They are used in depths beyond the reach of the lighter hand lead, and usually when the vessel is under way; they are now frequently used in combination with wire and pneumatic sounders for navigational purposes, and depths of 50 to 100 fathoms are readily reached while the vessel is at full speed. The general introduction of wire for deep-sea sounding has increased its range and it is common practice to use it in depths not exceeding 1,000 fathoms where large bottom specimens are not required. A 35-pound lead is used for this purpose on board the *Albatross*.

Deep-sea leads range from 75 to 120 pounds in weight and are used for sounding in moderate depths, with rope; they are no longer in use on board vessels provided with wire for sounding.

The auxiliary lead, weighing about 4 pounds, is attached to the stray line whenever wire is used in sounding to prevent its kinking when the weight of sinker is suddenly removed by its striking the bottom.

The shape of leads is practically the same for all sizes; they are octagonal in cross-section, largest at the base, tapering gradually to the upper end, which is flattened and pierced with a hole through which the lead line is secured; and a roughened, irregular cup-shaped cavity is formed in the base for the reception of arming, which is usually of tallow, or a mixture of tallow and white lead.

Mechanical attachments, such as the Stellwagen and Sands cups, have been applied to coasting and deep-sea leads, and under favorable conditions bring up satisfactory bottom specimens, but their range being confined to depths within 1,000 fathoms, where liability to injury from contact with rocky or coral bottom is greatest, they have not come into general use.

DETACHABLE SINKERS.

The 60-pound spherical shot is the standard sinker in general use on board United States vessels for deep-sea work. It is about 8 inches in diameter, has a 2½-inch hole through its center, and small eyes or lugs of No. 5 American gauge iron wire are cast upon opposite sides of its upper exterior surface, to which the ends of the bail are secured. Sinkers of greater weight have been recommended, and, while the necessity for increased weights has not been felt on board the *Albatross*, where the 60-pound shot has been in constant use, under all conditions of service, up to depths exceeding 4,000 fathoms, it is possible that in exceptionally deep water, where the weight of wire largely exceeds that of the standard sinker, or when from any cause the wire can not be maintained in a vertical position, a 75 or even an 80 pound weight may be used to advantage. It must be considered, however, that the wear and tear and liability to accident increases with the size of the sinker.

In sounding with rope of large cross-section, which is peculiarly susceptible to the deflective force of currents, the preponderance of weight should be largely on the side of the sinker, while the expert sounder with wire cares little on which side it is.

Experience on the *Albatross* led to the adoption of a lighter detachable sinker, which has been used to advantage between 1,000 and 2,000 fathoms, and occasionally in still greater depths; once, at least, a sounding was taken with it in over 3,000 fathoms.

The 35-pound sinker is of cast iron, elliptical in form, 8 inches in length, 5¾ inches in diameter, with a 2½-inch hole through the center; the wire lugs described in connection with the 60-pound shot are common to both.

The advantages attending the use of the lighter sinker within prescribed limits are the facility of manipulation, the minimum of wear and tear on sounding machine and wire, and economy of material. The disadvantages are nominal when operating in smooth water, but in a heavy sea the loss of time becomes apparent and frequently of sufficient moment to warrant the use of the heavy weight.

Sinkers are usually made of scrap iron, and cost from 2½ to 3 cents per pound.

IMPROVISED DETACHABLE SINKERS.

Sinkers of the ordinary type are comparatively inexpensive and easily stowed on board ship, hence a sufficient supply is usually carried to meet all possible contingencies; yet it has been found necessary to resort to makeshifts rather than suffer the loss of time and extra expense of an immediate return to port. Sigsbee sounded successfully in the Gulf of Mexico with a gas-pipe sounding rod and old grate bars, an old ash bucket filled with fire brick, etc., and the list of available material may be largely extended.

If old lead can be had, it would be very easy to cast disks weighing from 10 to 20 pounds, which may be used in series, as on the Baillie machine. In the absence of better facilities they may be cast in open molds of ordinary deck sand; a little molasses and flour should be added to give greater consistency, wood or metal being used for a core.

Cast-iron ballast is readily transformed into sinkers; shot, shell, and canister are equally available; and small chain or wire rigging made up in suitable coils, chain shackles, and pins, links of chain cable, pieces of condemned machinery, and even sand in tin cans or canvas bags may be utilized. Wire is preferable to hemp or manila for binding fragments together to form a well-balanced sinker, and it is best for bails also.

LUGS AND OTHER DEVICES FOR SUSPENDING DETACHABLE SINKERS.

The lugs on detachable sinkers reached their present form through a process of evolution. Brooke suspended the shot by slings and washer, as shown with his apparatus, and Belknap used the same until repeated fouling of washer and cylinder induced him to substitute wire slings, which consisted of two rings surrounding the upper and lower quarters of the shot held in place by cross-seizings and two wire lanyards, one end secured to the lower ring on the sinker, and on the other end small iron rings to receive the lip of the tumbler and insure prompt clearance when it tripped. This arrangement prevented fouling, but was found to be rather cumbersome and required too much time to prepare the sinker for use.

Cast-iron lugs on the upper exterior surface of the shot were soon adopted, and proved to be a long stride in the direction of simplicity, certainty of action, and immunity from fouling. A single wire bail was used, the ends being secured to the lugs with large eyes, which permitted it to move freely and even fall away from the disengaged tumbler by its own weight. The sole disadvantage attending the introduction of cast-iron lugs was the frequent breakages caused by the brittleness of the material.

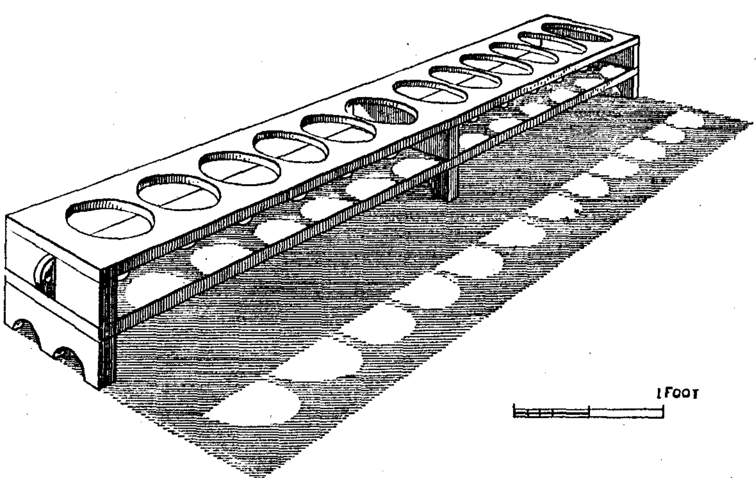
Bail holes were introduced by Sigsbee, who found cast-iron lugs too unreliable. They were cast in the same relative positions on the surface of the sinker, which insured convenient and secure attachments for the bail but did not allow the same freedom of movement.

Iron wire lugs, cast with the shot, were subsequently introduced and are still in general use. They are in the form of wire staples, cast into the surface of the sinker parallel with the axis of the central hole, and project above the surface only far enough to afford convenient attachment and free movement of the bail. They are seldom broken by rough handling, as the wire becomes thoroughly annealed in the process of casting and subsequent cooling, and they can be bent flatly to the surface of the shot without injury.

The wire bails now used with detachable sinkers are of annealed iron wire, No. 8, American wire gauge, and may be conveniently fitted by first cutting them from the coil in uniform lengths and bending them over a form to insure a free and uniform seat for the lip of the tumbler.

Sinkers should not be bailed until they are required for use, and when the requisite number have been placed in the racks, proceed first to examine the lugs and see them properly straightened, then pass the sounding rod back and forth through the hole, and when satisfied that it moves freely let it remain in the sinker with its weight resting on the base of the hollow cone; pass the ends of the bail through the lugs, put the bight over the tumbler, which for convenience has been placed in action and secured by a seizing of twine, then bend the ends up and take a couple of turns around their standing parts, leaving sufficient slack to unhook the bail without displacing the tumbler. This will insure the proper length of bail, which should suspend the shot just high enough to lift the hollow cone off its seat without bringing its apex in contact with the shoulder at the upper end of its stem. It is not absolutely necessary to hold the hollow cone off its seat during the descent, but by doing so the sinking of the shot is accelerated in proportion to the power required to lift it by the ascending column of water in the sounding rod.

Caution should be observed when fitting the bails that no projecting scraps of iron are left in or at either end of the hole and that all scale is removed from its walls, for it expands and becomes softened when it is wet; at the same time the material of the



CUT 30.—Rack for holding sinkers.

sinker shrinks under low temperatures near the bottom, both tending to crack and disengage the scale, which is liable to jam the sounding rod irretrievably.

Racks for sinkers are necessary on board of vessels engaged in extensive deep-sea exploration, not only for convenience in bailing and final preparation, but to have a sufficient number at hand for present use, and also to avoid the necessity of bringing them on deck and fitting them at night. They should be placed near the sounding machine and be capable of holding a dozen sinkers at least.

A serviceable rack can be made from two boards 1 inch thick and 12 inches wide, placed one above the other, 4 inches apart, and secured by suitable end and transverse pieces. The upper board has a series of circular holes that receive the sinkers and allow them to rest on the lower board, which is pierced with 3-inch holes, directly under the larger ones, to allow for the passage of the sounding rods, and, in order that they may be passed their whole length through the sinker, the rack should be 10 inches in height.

THE USE OF WIRE FOR SOUNDING.

The first recorded instance of wire having been used for deep-sea sounding was by the Wilkes Exploring Expedition, 1838–42. In 1849, Captain Barnett, H. B. M. S. *Thunderer*, experimented with it, and during the same year Lieut. J. C. Walsh, United States schooner *Taney*, attempted to sound with it in the vicinity of the Bermudas. It failed in every instance from practically the same causes, although Wilkes was unfortunate in the selection of copper wire which was of such low tensile strength that little margin of safety remained. Barnett used iron wire of large size and sufficient strength, while Walsh was supplied with three sizes of steel wire, either of which would have proved successful under proper treatment.

The principal causes of failure were due to insufficient weight of sinkers and lack of proper control over the reel when paying out, as evidenced by such time intervals as were recorded, which show a more rapid rate of descent than obtains in the best modern practice with perfected appliances and a proper relation of weight between the sinker and submerged wire. These repeated failures brought wire into such disrepute that no further attempts were made to sound with it until Sir William Thomson commenced his experiments in June, 1872, which resulted in totally revolutionizing the art of deep-sea sounding. Commander (now Rear-Admiral) George E. Belknap, U. S. S. *Tuscarora*, used pianoforte wire successfully in 1873–74. Commander (now Commodore) J. C. Howell, United States Coast and Geodetic Survey Steamer *Blake*, adopted it later in the same year, and Lieut. Commander (now Commander) C. D. Sigsbee, succeeding to the command, used it with great success from 1874 to 1878, by which time it had passed the experimental stage and been generally adopted for deep-sea work.

Wire was first used by the United States Fish Commission on board the *Fish Hawk*, Lieut. Z. L. Tanner, U. S. N., on the 6th of August, 1880; then on board the *Albatross*, Lieut. Commander Z. L. Tanner, which made her first sounding with wire on March 22, 1883, and it has since been in constant and successful use on board vessels of the Fish Commission.

Sir William Thomson used pianoforte wire of No. 22 Birmingham wire gauge in his experiments and that size, or sizes closely approximating to it, have been universally adopted for deep-sea sounding.

The wire in general use for that purpose on board the *Albatross* is made by the Washburn & Moen Manufacturing Company, of Worcester, Mass., and called by them No. 11 music. It is 0.028 of an inch in diameter, weighs 13 pounds per nautical mile of 1,000 fathoms in air, 11.3 pounds in sea water, and approximates to No. 21 American gauge and No. 22 Birmingham wire gauge. Its tensile strength is remarkably uniform, the mean of many tests giving 207 pounds as the breaking strain; it is highly polished and resists rust unusually well when in use. It is furnished by the manufacturers in sealed tin cans, containing 50 pounds, or about 3,850 fathoms, in six coils 8½ inches in diameter, each coil being composed of two pieces of wire. It will be furnished in any desired length, however, on special order.

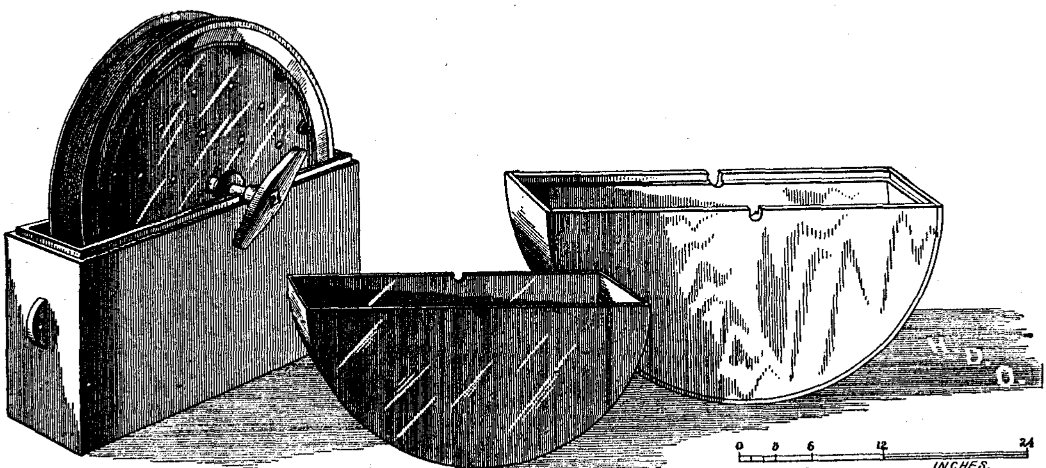
The coils are doubled for packing, one being laid on top of the other and carefully wrapped with the best oiled paper, a liberal sprinkling of whiting, slacked lime, or other absorbent being inclosed with the wire as a preservative against oxidation. The packages are placed one above the other in the can, a quantity of whiting between them, and sealed air-tight; the wire is practically indestructible so long as it remains in the sealed can, and, if stored in a dry place, will keep quite well in its paper wrappings after the can has been opened.

The *Albatross* has never lost a fathom of American wire from rust in the coil. English wire, No. 22 Birmingham gauge, has been used occasionally. Its tensile strength was 214 pounds, practically the same as No. 11 music, but it was not as highly polished as the American wire, and its only protection was an insufficient wrapping of oiled paper, which was liable to be torn in handling, thus exposing it to the action of sea air or other moisture, which soon caused it to rust. Losses from this cause were quite serious and tended to counteract the advantages derived from its cheapness at first cost. It was received from the makers, Messrs. Webster & Horsfall, Birmingham, England, in 18-inch coils, made up of pieces from 100 to 400 fathoms in length, the coils weighing about 60 pounds each.

An excellent quality of American wire, No. 21 gauge, was furnished to the United States Navy in 1892 by the John S. Roebling's Sons Co., of Trenton, New Jersey. Its tensile strength ranged from 245 to 255 pounds, and it was fairly well polished. It was slightly larger in cross-section than No. 11 music, which accounts in part for its greater strength.

PRESERVATION OF SOUNDING WIRE.

It should be received on board in sealed tin cans, which may be advantageously coated with paint before they are placed in the storeroom. Broken packages are liable



CUT 31.—Spare sounding wire, reel box, and copper tank.

to rust, hence as few as possible should be kept on hand. They may be stored for a short time with comparative safety, providing the wrapping is intact and the store-room perfectly dry. A safer plan is to submerge all broken packages in sperm oil.

The following method was finally adopted on board the *Albatross:* There were available two service reels, one temperature reel, and one storage reel, each holding nearly 6,000 fathoms of wire. Both service reels were kept ready for use, with about 5,000 fathoms of wire and stray lines attached. When unmounted they were submerged in sperm oil in suitable galvanized-iron tanks with tight covers. When mounted, but not actually employed in sounding, the lower part of the reel was submerged in sperm oil contained in a semicircular copper tank (cut 31) placed temporarily beneath it, and the oil was distributed over the surface of the wire by slowly revolving the reel a few turns once a day.

When actually engaged in sounding, the surface of the wire on the reel was constantly oiled with rag or sponge while reeling in, and it was wiped with an oily rag when the intervals between casts exceeded twelve hours.

The temperature reel, with its special wire of large size, and the storage reel, filled with its sounding wire in readiness to be transferred to the service drums, were suspended upon their bearings in wooden reel boxes (cut 31) containing semicircular copper tanks, like that above described, with sufficient oil to submerge the lower portion of the reels, distribution of oil over the surface of the wire being effected by a few turns of the reels daily as before. The boxes have semicircular covers for the further protection of reels and wire.

Lime water has been successfully used as a preservative, but it is inferior to sperm oil for the purpose, and has the further disadvantage of irritating the eyes and aggravating any sores the sounding crew may have on their hands or faces, although this objection is hardly worthy of serious consideration except when sounding continuously.

Large, strong wire, No. 21 music, approximating to No. 18½ Birmingham gauge or No. 17 American gauge, is used on the Tanner machine, and little or no attention is given to its protection, except that new wire is imbedded in melted tallow when it is wound on the reel, and once or twice a year it is reeled off, cleaned with emery paper, replaced upon the reel, and again imbedded in melted tallow. The life of the wire under this treatment is about two years.

METHODS OF SPLICING WIRE.

Sir William Thomson describes his method in 1872 as follows:

A splice 2 feet long I have found quite sufficient, but 3 feet may be safer. The two pieces of wire are first prepared by warming them slightly and melting on a coating of marine glue to promote surface friction. About 3 feet of the ends so prepared are laid together and held between the finger and thumb at the middle of the portions thus overlapping. Then the free foot and a half of wire on one side is bent close around the other in a long spiral, with a lay of about one turn per inch, and the same is done for the free foot and a half on the other side. The ends are then served round firmly with twine, and the splice is complete.

This splice is no longer used, and is given here simply as a matter of interest in connection with Sir William's successful experiments in sounding with wire.

BELKNAP'S SPLICE.

Commander George E. Belknap, U. S. N., adopted the following splice in 1873:

A long-jawed twist, 2 feet in length, soldered at the ends and at two or three intermediate places, and served with fine waxed twine.

HOWELL'S SPLICE.

Commander J. C. Howell, U. S. N., used the following splice in 1874:

A short-jawed twist, total length of splice 3 inches. After the first cross the turns are close together around standing part, the whole covered with solder, surface smoothed, and ends tapered.

This splice was successfully used by Sigsbee during his extended exploration of the Gulf of Mexico from 1874 to 1878.

THE ALBATROSS SPLICE.

This splice was reliable when new, but was liable to strip after extended wear. It was named from its having been the one adopted on board the *Albatross* in 1883, and is as follows:

The ends of the wire, being first cleaned for 3 feet or more, are lapped and twisted together with eight long-jawed turns. The ends and two intermediate points are wound with a few turns of fine annealed iron wire, the whole covered with solder, ends tapered, and surface carefully smoothed.

MAY'S SPLICE.

Lieut. Sidney H. May, U. S. N., had charge of the *Albatross's* sounding apparatus during the first year of the cruise, and among many useful suggestions was the following wire splice (plate XVII), which proved so simple and effective that it was finally adopted in preference to all others. It is from 6 to 7 inches in length, will not strip, is quite flexible, and practically indestructible. The following describes the process:

Grasp the wire in a hand vice, lay the end on the soldering board or other convenient place, and taper it to a fine point with a three-cornered saw file; prepare the other end in the same way, lap them, put on the first annealed wire seizing, leaving the tapered end free; then take four turns with the free end and clap on the other seizing; pass the tapered ends snugly around their respective standing parts, using the pliers for the purpose.

Now apply the soldering fluid and cover the splice with solder by drawing it back and forth through molten solder contained in the grooved soldering board; then taper the ends and trim the surface with knife, file, and sandpaper.

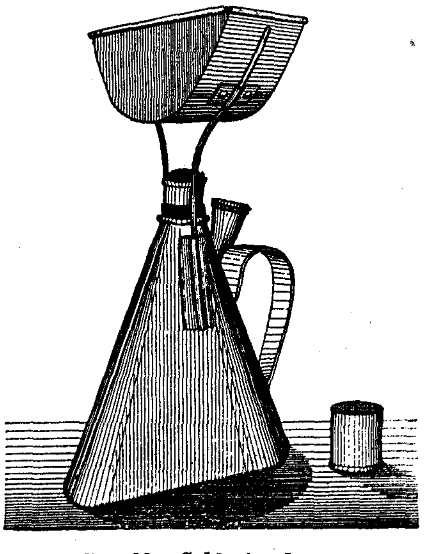
IMPLEMENTS REQUIRED.

The following implements are required for splicing wire:

- 1 tinman's furnace.
- 2 soldering irons.
- 1 pair cutting pliers.
- 1 pair small flat pliers.
- 1 small hand vise for holding wire.
- 1 spool of fine annealed iron wire.
- 1 box of soft solder.
- 1 bottle soldering fluid.
- 1 soldering board.
- 1 small bottle of oil.
- 1 small box of tallow.
- 1 canvas pocket.
- 1 soldering lamp.

The splicing board is of hard wood, 1 inch thick, 6 inches wide, and 2 feet in length; a groove is cut across its surface, near one end, large enough to hold sufficient molten solder for one splice.

The canvas pocket is the most convenient receptacle for the splicing tools; it is provided with suitable compartments for each article, and is rolled up snugly and lashed when not in use.



CUT 32.—Soldering lamp.

The soldering lamp will be found convenient in calm, smooth weather; it is an ordinary alcohol lamp, with a large, round wick and an adjustable semicircular cup supported above the flame, in which the solder is placed and kept in a molten state as long as required. The wire, having been prepared as directed, is drawn back and forth through the solder until a sufficient quantity adheres to the splice, when it is trimmed and smoothed in the usual manner.

The soldering irons may be heated in the fire room or galley range in case a single splice is to be made, and one iron will suffice in the hands of an expert, yet any delay, however small, will make it necessary to use a second one. Almost any form of soldering iron will answer equally well when used with the soldering board, and it is not necessary that the points of the iron should be tinned.

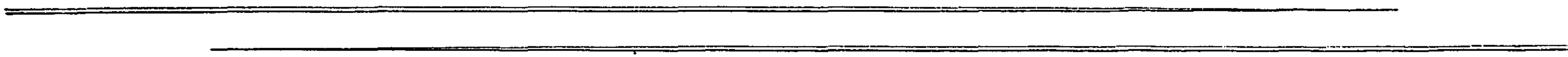


Fig. 1.

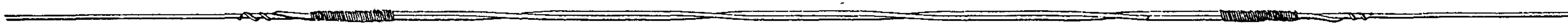


Fig. 2.

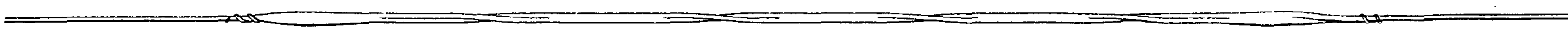


Fig. 3.

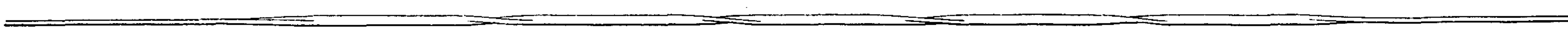


Fig. 4.

Fig. 5.

MAY'S SPLICE.

FIG. 1. Tapered ends of the wire, full size.
FIG. 2. Ends laid together and seizings on.
FIG. 3. Splice partially covered with solder.
FIG. 4. The completed splice.
FIG. 5. Splice of sounding wire to stray line.

Soldering fluid, for use with soft solder, after Haswell's receipt, has been successfully used on board the *Albatross*, and is considered the best preparation for wire soldering. It is as follows:

To two fluid ounces of muriatic acid, add small pieces of zinc until bubbles cease to rise. Add half a teaspoonfull of sal ammoniac and two fluid ounces of water.

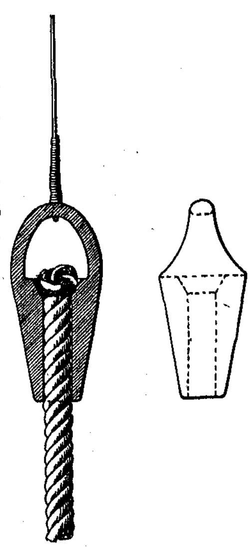
Pulverized resin may be used in the absence of soldering fluid, but greater care will be required in making the splice, and the results are liable to be unsatisfactory, particularly when splicing old wire.

METHOD OF SPLICING WIRE TO STRAY LINE.

In sounding with wire it is customary to splice about 5 fathoms of slack-laid codline to its working end to take up the slack that occurs when the sinker strikes bottom, and as a convenience for attaching the sounding rod, deep-sea thermometers, and auxiliary lead. This cord is known as the stray line and is attached to the wire in the following manner:

At a point about 5 inches from one end of the stray line stick the wire twice against the lay, fig. 5, then pass it with the lay from 4 to 6 inches, and again stick it twice against the lay. Cut the wire to the proper length, clap a seizing of waxed twine over the places where it was stuck against the lay, carefully covering the end of the wire to prevent its catching when reeling in. It now remains to complete the end of the splice: Put wire and stray line under moderate tension, lay the wire in the center of the line by passing the free end of the latter around it, put on a temporary seizing, trim the strands down to a point and serve over the taper with waxed twine. This makes a neat and secure splice which outlasts the stray line and reels in without danger of catching on guards or fairleader.

Tanner's link was devised by the writer as a simple method of quickly attaching wire and stray line in case either should break while sounding, thereby saving the time required to make the regular splice. It consists of a small brass link, through the socket of which the stray line is drawn and is held in place by a single wall knot, leaving the opposite end free for attaching the wire. A stray line fitted in this manner is adjusted in a moment by taking three turns of the wire around the link, and passing the end closely around its standing part half a dozen times. Attention will be required in reeling in to guard against the link fouling when it reaches the machine, but with ordinary care it may be used until such time as a regular splice can be made without loss of time.



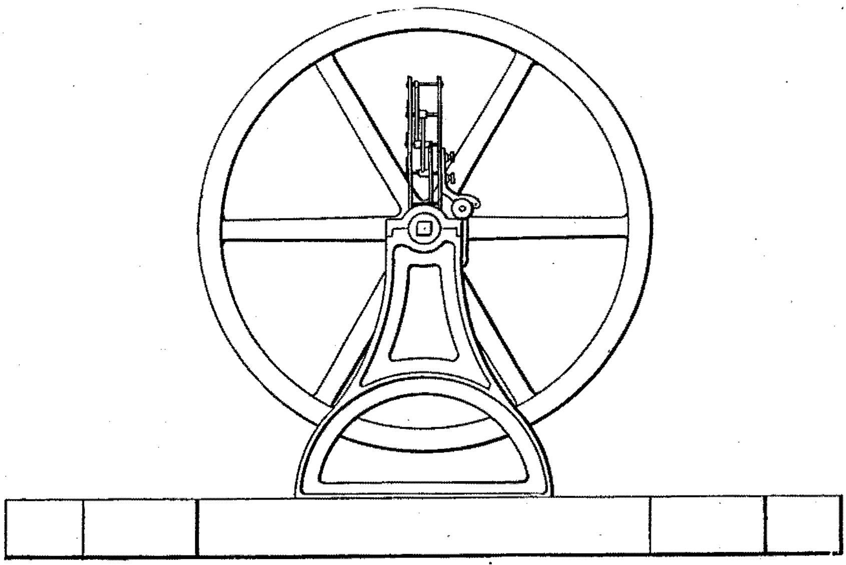
CUT 33.—The Tanner link.

THE MEASURING REEL.

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 (cut 34), 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.

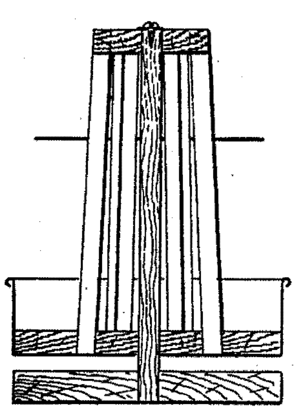
THE BLADE.

The blade is used in connection with the measuring reel for transferring wire from

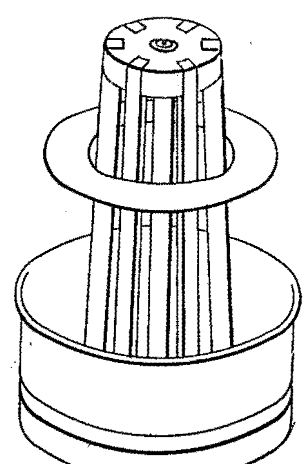


CUT 34.—Measuring reel.

the commercial coil to the service reel of the sounding machine. Cut 35 is a sectional elevation, and Cut 36 a general view of the blade used with American wire. It is



CUT 35.



CUT 36.

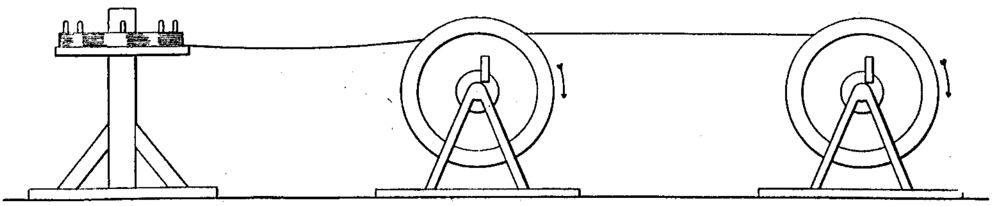
made of oak, has an iron screw and washer at the top of the spindle to hold the reel in place, a galvanized-iron disk that slips over the reel above the coil of wire to prevent slack turns from flying off, and a galvanized-iron base rim around the reel to retain slack turns that slip down from the coil.

Cut 37 is a general view of the blade used with English wire, which is put up in larger coils than the American. It is constructed entirely of oak or other hard wood, and is adjustable by means of a series of holes through the disk into which pegs are set. The transfer of wire will be greatly facilitated by securing the blade to the deck during the operation by the means of screws, socket bolts, or other convenient method.

TRANSFERRING AND MEASURING WIRE.

The service reel is mounted on its machine, its face cleaned and oiled, hand cranks and register are shipped, and the latter carefully oiled and examined to see that it works properly.

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



Adjustable blade. Measuring reel. Working reel.

CUT 37.—Measuring and transferring wire.

the hole provided for this purpose. The two men at the blade reel back the slack wire, the recorder 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 tension on the wire by pressing his hand against the side of the blade.

The recorder 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 is always available for the same reel or any other of like dimensions, provided the wire is the same size and the amount does not exceed that for which the table was constructed.

The necessary data having been obtained as above described, it is advisable to construct a correction curve, frame it under glass, and hang it in some convenient place to serve as a check on the table that is usually copied into the record book for daily use at the sounding machine; it will also furnish a graphic method of detecting errors in the computation and application of corrections taken from the table. The following figures are taken from the original record of the measuring and transfer of 4,577 fathoms of wire from the commercial coil to the service reel of the Sigsbee sounding machine on board the *Albatross*, and demonstrates, through the regular increase in the column of differences, the remarkable accuracy attainable by an expert in guiding wire evenly upon the reel, besides furnishing complete data for the construction of correction curve or table.

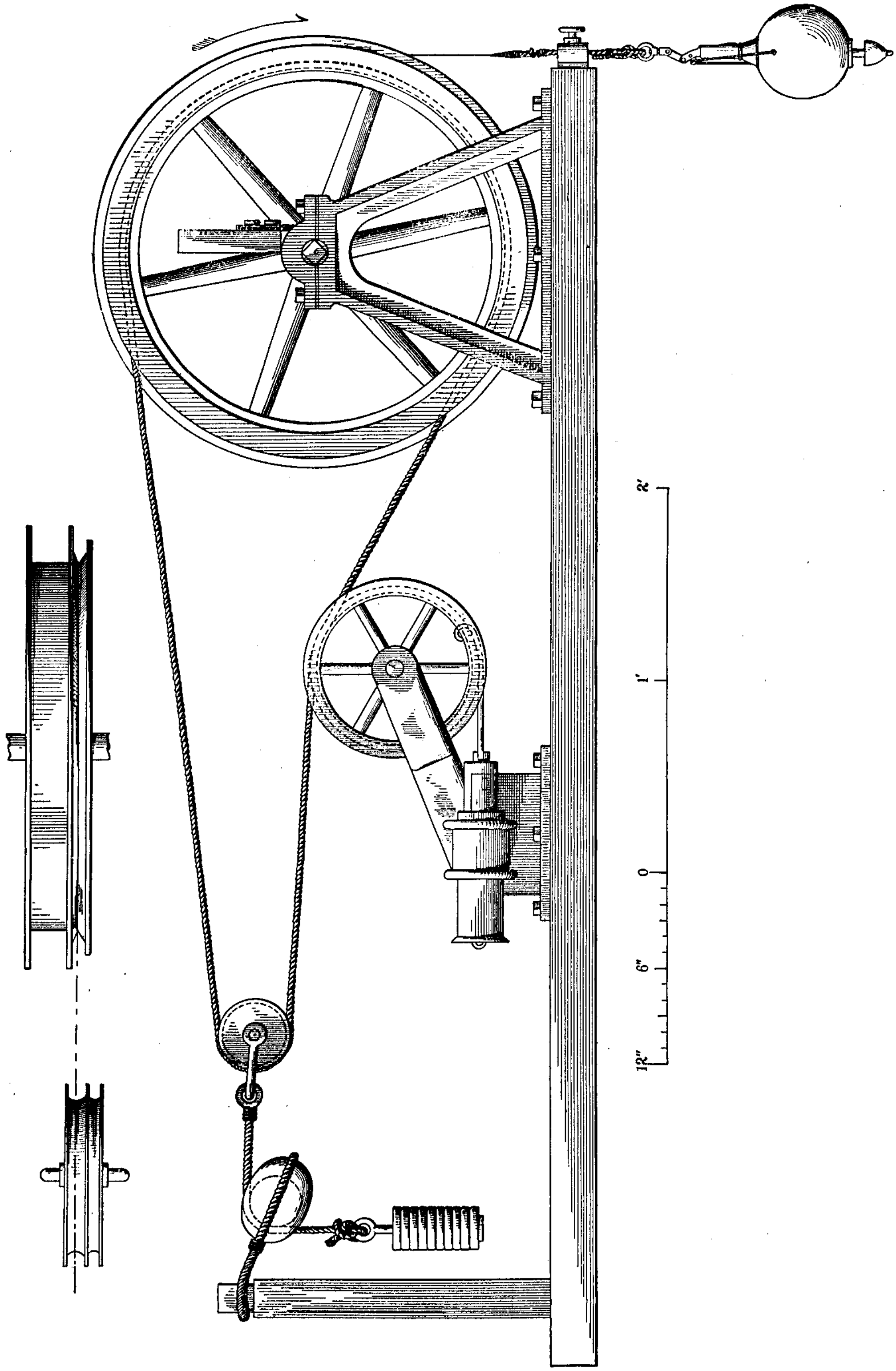
[Correction table, Navy steel reel, No. 2. Wire, No. 11 music.]

Number of turns on service reel.	Number of fathoms by measuring reel.	Fathoms diff. +	Number of turns on service reel.	Number of fathoms by measuring reel.	Fathoms diff. +	Number of turns on service reel.	Number of fathoms by measuring reel.	Fathoms diff. +	Number of turns on service reel.	Number of fathoms by measuring reel.	Fathoms diff. +
50	50	0	50	1,160	10	50	2,295	45	50	3,452	102
100	100	0	1,200	1,211	11	2,300	2,347	47	3,400	3,505	105
50	50	0	50	1,262	12	50	2,399	49	50	3,558	108
200	200	0	1,300	1,313	13	2,400	2,451	51	3,500	3,611	111
50	50	0	50	1,364	14	50	2,503	53	50	3,664	114
300	301	1	1,400	1,415	15	2,500	2,555	55	3,600	3,717	117
50	351	1	50	1,466	16	50	2,607	57	50	3,770	120
400	401	1	1,500	1,517	17	2,600	2,659	59	3,700	3,823	123
50	451	1	50	1,568	18	50	2,711	61	50	3,876	126
500	502	2	1,600	1,619	19	2,700	2,763	63	3,800	3,929	129
50	552	2	50	1,671	21	50	2,816	66	50	3,983	133
600	602	2	1,700	1,723	23	2,800	2,869	69	3,900	4,037	137
50	652	2	50	1,775	25	50	2,922	72	50	4,091	141
700	703	3	1,800	1,827	27	2,900	2,975	75	4,000	4,145	145
50	753	3	50	1,879	29	50	3,028	78	50	4,199	149
800	804	4	1,900	1,931	31	3,006	3,081	81	4,100	4,253	153
50	854	4	50	1,983	33	50	3,134	84	50	4,307	157
900	905	5	2,000	2,035	35	3,100	3,187	87	4,200	4,361	161
50	956	6	50	2,087	37	50	3,240	90	50	4,415	165
1,000	1,007	7	2,100	2,139	39	3,200	3,293	93	4,300	4,469	169
50	1,058	8	50	2,191	41	50	3,346	96	50	4,523	173
1,100	1,109	9	2,200	2,243	43	3,300	3,399	99	4,400	4,577	177

Splices occur at the following intervals, in fathoms: 100 295 630 880 1210 1625 1970 2170 2475 2970 3275 3560 3670 3770 4230.

Example: A sounding is made, the register reading 3,050 turns. What is the depth in fathoms?

Number of turns on the reel	4,400	cor. + 177
Number of turns registered	3,050	
Turns remaining on reel	1,350	cor. — 14
Correction for 3,050 turns		+ 163
Number of turns registered		3,050
Depth in fathoms		3,213



THE SIR WILLIAM THOMSON SOUNDING MACHINE, ORIGINAL FORM, FURNISHED TO THE BLAKE.

[Correction table. Tanner reel. Wire No. 21. Music No. 17, A. W. G.]

Turns on Tanner reel.	Fathoms by measuring reel.	Correction, in fathoms.	Turns on Tanner reel.	Fathoms by measuring reel.	Correction, in fathoms.	Turns on Tanner reel.	Fathoms by measuring reel.	Correction, in fathoms.
25	25	0	25	227	2	25	432	7
50	50	0	50	252	2	50	458	8
75	75	0	75	278	3	75	484	9
100	101	1	300	303	3	500	510	10
25	126	1	25	329	4	25	536	11
50	151	1	50	354	4	50	562	12
75	176	1	75	380	5			
200	202	2	400	406	6			

The wire is in one piece, without splices, having been made to order by Washburn & Moen.

Example: A sounding is made, the register reading 425 turns. What is the depth in fathoms?

Number of turns on the reel	550	cor. + 12
Number of turns registered	425	
Turns remaining on reel	125	cor. — 1
Correction for 425 turns		+ 11
Number of turns registered		425
Depth in fathoms		436

SIR WILLIAM THOMSON'S MACHINE FOR SOUNDING WITH WIRE.

Plate XVIII showing the Thomson machine as it was used on board the *Blake* for one season and the description of its operation, the latter in the words of the inventor, are taken from Sigsbee's Deep-Sea Sounding and Dredging (page 54). It is shown here not only as the first successful apparatus for sounding with wire, but as a type of the simplest and most easily constructed sounding machine. Sir William describes the machine and its action as follows:

The wire is coiled on a large wheel (of very thin sheet-iron galvanized) which is made as light as possible, so that when the weight reaches the bottom the inertia of the wheel may not shoot the wire out so far as to let it coil on the bottom. The avoidance of such coiling of the wire on the bottom is the chief condition requisite to provide against the possibility of kinks, and for this reason a short piece of hemp line, about five fathoms in length, is interposed between the wire and the sounding weight, so that, although a little of the hemp line may coil on the bottom, the wire may be quite prevented from reaching the bottom.

A galvanized-iron ring of about half a pound weight is attached to the lower end of the wire, so as to form the coupling on the junction between the wire and the hemp line, and to keep the wire tight when the lead is on the bottom and the hemp line is slackened. The art of deep-sea sounding is to put such a resistance on the wheel as shall secure that the moment the weight reaches the bottom the wheel will stop. By the "moment" I mean within one second of time. Lightness of the wheel is necessary for this.

A measured resistance is applied systematically to the wheel, always more than enough to balance the weight of wire out. The only failure in deep-sea soundings with pianoforte wire hitherto made has been owing to neglect of this essential condition. The rule adopted in practice is to apply resistance, always exceeding by 10 pounds the weight of the wire out. Then the sinker being 34 pounds, we have 24 pounds weight left for a moving force. That, I have found, is amply sufficient to give a very rapid descent—a descent so rapid that in the course of half an hour or fifty minutes the bottom will be reached at a depth of 2,000 or 3,000 fathoms. The person in charge watches a counter, and for every 250 fathoms (that is, every 250 turns of the wheel) he adds such weight to the break-cord as shall add 3 pounds to the force with which the sounding wheel resists the egress of the wire. That makes 12 pounds added to the break resistance for every 1,000 fathoms of wire run out. The weight of every 1,000 fathoms of the wire in the air is 14½ pounds. In water, therefore, the weight is about 12 pounds; so that if the weight is added at the rate I have indicated the rule stated will be fulfilled. So it is arranged that when the 34-pound weight reaches the bottom, instead of there being a pull or a moving force of 24 pounds on the wire tending to draw it through the water, there will suddenly come to be a resistance of 10 pounds against its motion. A slight running on of the wheel—one turn at the most—and the motion is stopped.

The sounding was made without a hitch of any kind, but the reel showed signs of weakness soon after he began reeling in the wire and the 34-pound weight of sinker, which is referred to by Sir William as follows:

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

Sir William realized the necessity for improvement and encouraged inventors to take it in hand. Captain Belknap, U. S. N., was the first to use it, practically, and he soon remedied its greatest fault by devising a reel capable of withstanding the enormous crushing strains incident to actual service. He was very careful at first about increasing the weight of reel, lest its greater inertia should destroy its usefulness, but he soon found that a few pounds more or less was a matter of indifference to the practiced marine surveyor. Improvements have been introduced from time to time in this and other countries, but the principle of the Thomson machine is invariably retained.

THE SIGSBEE MACHINE FOR SOUNDING WITH WIRE, AND ITS ACCESSORIES, AS USED ON BOARD THE ALBATROSS.

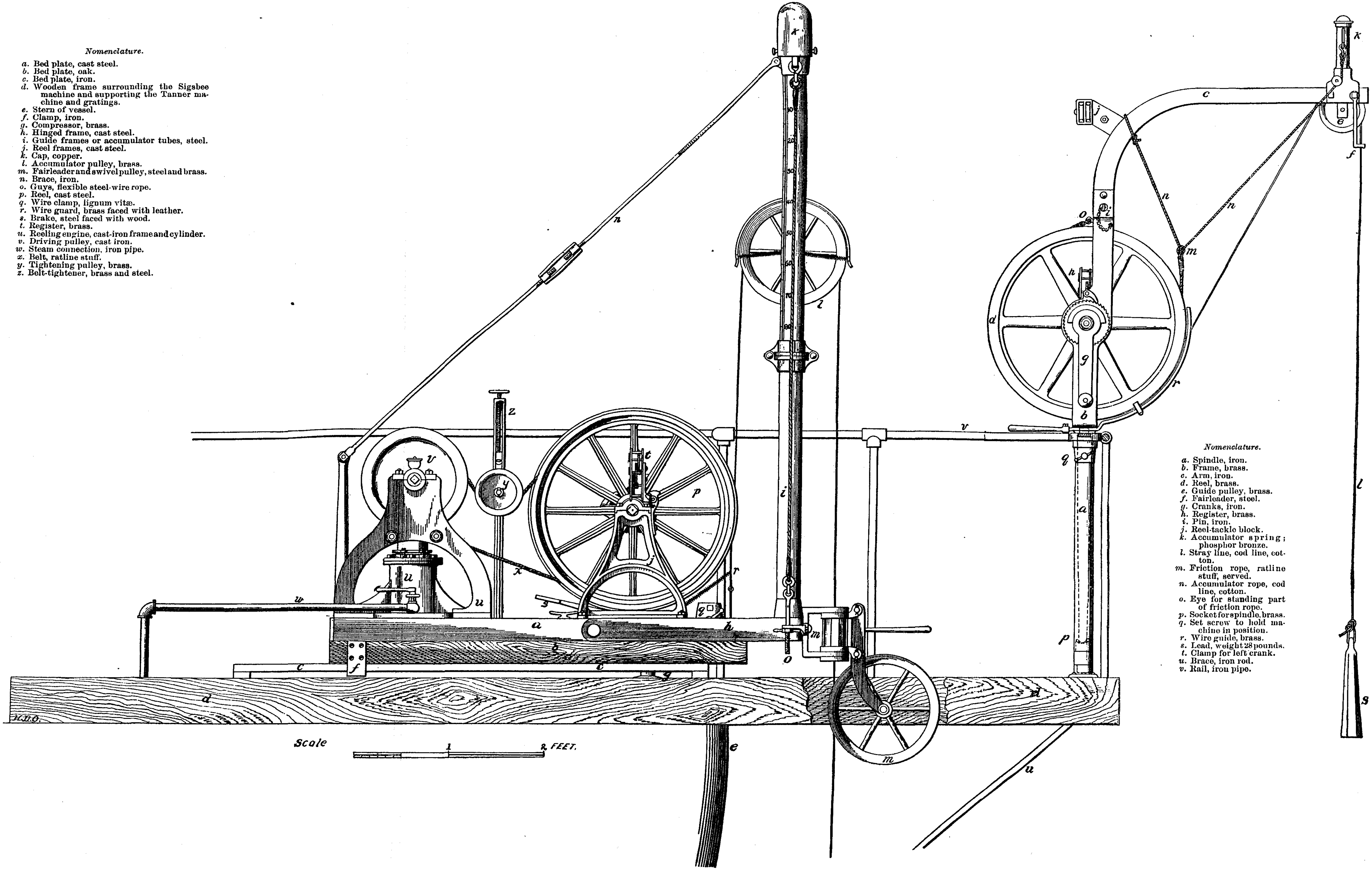
This admirable machine was constructed by Mr. D. Ballauf, Washington, D. C., under the personal supervision of the inventor, Commander C. D. Sigsbee, U. S. N., and is still in good condition after constant service of fourteen years. A few improvements have been added from time to time, yet it remains essentially the same as when received from the hands of the maker.

The aim of the inventor was to design a machine that should be light, strong, simple in structure, easily manipulated, and accessible in all its parts, yet compact and susceptible of snug stowage when not in use; hence steel was used whenever practicable, and brass was utilized for the minor parts where immunity from oxidation was of more importance than great strength.

It is secured to an iron bedplate by the clamps *f* and compressor *g* (plate XIX), and projects over the stern *e* sufficiently to allow the wire a clear passage from the machine to the water when rigged out for service, and is entirely within the line of the stern when rigged in. The wooden frame *d* surrounds the Sigsbee machine and supports the working platform and the Tanner machine. The platform consists of

Nomenclature.

a. Bed plate, cast steel.
b. Bed plate, oak.
c. Bed plate, iron.
d. Wooden frame surrounding the Sigsbee machine and supporting the Tanner machine and gratings.
e. Stern of vessel.
f. Clamp, iron.
g. Compressor, brass.
h. Hinged frame, cast steel.
i. Guide frames or accumulator tubes, steel.
j. Reel frames, cast steel.
k. Cap, copper.
l. Accumulator pulley, brass.
m. Fairleader and swivel pulley, steel and brass.
n. Brace, iron.
o. Guys, flexible steel-wire rope.
p. Reel, cast steel.
q. Wire clamp, lignum vitæ.
r. Wire guard, brass faced with leather.
s. Brake, steel faced with wood.
t. Register, brass.
u. Reeling engine, cast-iron frame and cylinder.
v. Driving pulley, cast iron.
w. Steam connection, iron pipe.
x. Belt, ratline stuff.
y. Tightening pulley, brass.
z. Belt-tightener, brass and steel.



Nomenclature.

a. Spindle, iron.
b. Frame, brass.
c. Arm, iron.
d. Reel, brass.
e. Guide pulley, brass.
f. Fairleader, steel.
g. Cranks, iron.
h. Register, brass.
i. Pin, iron.
j. Reel-tackle block.
k. Accumulator spring; phosphor bronze.
l. Stray line, cod line, cotton.
m. Friction rope, ratline stuff, served.
n. Accumulator rope, cod line, cotton.
o. Eye for standing part of friction rope.
p. Socket for spindle, brass.
q. Set screw to hold machine in position.
r. Wire guide, brass.
s. Lead, weight 28 pounds.
t. Clamp for left crank.
u. Brace, iron rod.
v. Rail, iron pipe.

THE SIGSBEE AND TANNER SOUNDING MACHINES, AS INSTALLED AT THE STERN OF THE ALBATROSS.

gratings on either side and abaft the swivel pulley, the after one hinged to turn up when desired, as in taking serial temperatures.

The cast-steel bedplate a is securely bolted to the oak bedplate *b* for the double purpose of protecting the former from accidental strains and providing a convenient fastening for the machine.

The cast-steel frames j, which carry the reel *p*, are light and strong, and securely bolted to the frame *a*.

The guide frames or accumulator tubes *i* are steel pipes of commercial pattern. They are secured rigidly to the forward end of the hinged frame *h*, their upper ends terminating in a tie frame of cast steel, which carries two grooved pulleys on its upper surface designed to lead the accumulator rope from the springs to the pulley.

Hinged joints of cast steel are introduced near the middle length of the tubes *i* for convenience in attaching or adjusting the accumulator rope and compactness in stowing. They can be turned in either direction by removing a screw-bolt. An adjustable scale of brass, distinctly marked up to 80 pounds, is secured upon the upper after side of the right-hand tube *i*, where it is at all times under the direct observation of the man attending the friction rope and the engineer at the throttle of the reeling engine. The hinged frame *h*, of cast steel, is pivoted at its inboard end to the frame *a*, and extends outboard beyond the frames *a* and *b;* it is supported by the latter in prolongation of the frame *a*, and carries the guide frame *i*, the fair-leader, swivel pulley, and spur buffer. The frame moves freely from its horizontal position when rigged for service, to the vertical when folded for security, economy of space, or for transportation.

The accumulator rope may be of any material at hand, but ordinary coasting lead line has been successfully used on board the *Albatross*. To reeve a new rope, lower the upper section of the frame *i* to a horizontal position over the machine and remove the cap *k*, pull the end of the spring up to the joint with a chain hook or other convenient implement, bend one end of the rope to it, then run the other end up through the tube over its pulley, under the roller on the frame of the accumulator pulley, thence up over its pulley and down through its tube to the joint where it is bent to the spring which has been pulled up with a hook as before. The tension on the springs is determined by experiment in the following manner:

Elevate the frame *i* to a vertical position, reeve the stray line or other cord over the pulley and carry the standing part under the reel and make it fast, suspend a known weight to the hauling part, or, what is better, use an ordinary spring scale graduated to 150 or 200 pounds, which will be found very useful about the machine, putting on any desired strain until, by lengthening or shortening one end of the rope, the weight actually applied corresponds to that shown on the scale, the upper crosshead of the pulley frame being the indicator. Small adjustments may be readily made by easing the screws and moving the scale up or down on the tube.

It is advisable to verify the scale occasionally, especially after renewing the rope.

The accumulator springs are spiral, made of No. 4 steel wire (American gauge). They are 28½ inches in length, 2½ inches outside diameter, and have an elastic limit of about 4 feet, which gives the wire a cushioning of about 8 feet before it can be subjected to a violent jerking strain; and, what is even more important in modern practice, where the machine is located at the stern and the work of sounding carried on under all conditions of weather, the springs absorb an equal amount of slack wire when, the stern being high in the air on the crest of a wave, it suddenly descends to the hollow of the sea with a velocity little inferior at times to the sinking of a sounding shot. This violent motion, under exceptional circumstances, is the only disadvantage of moment in placing the sounding machine at the stern, but with the Sigsbee machine it assumes little importance in comparison with the superior advantages of the location.

The accumulator springs, in connection with the scale, indicate the rapidly varying strains on the sounding wire during the descent of the sinker, and apprise the operator of the instant it strikes the bottom.

The cap k is a neatly fitted, water-tight, copper cover protecting the interior surfaces of the accumulator tubes, springs, rope, and pulleys from the weather. It is held in place by thumbscrews which are readily removed.

The accumulator pulley l is lightly constructed of brass, has a deep groove for the wire, and is mounted in such a manner that it can be readily removed from its bearings without displacing the frame. Guards of sheet brass are hinged to the frame above the pulley and carefully shaped to its surface, where they are held in place by delicate spiral springs to prevent the wire from jumping out of the groove in case it is suddenly slackened from any cause.

The cast-steel frame within which the pulley *l* is suspended is lightly constructed also in order to reduce its inertia to the lowest limit. The cross heads traverse freely on steel guides which are secured to the inner surfaces of the tubes *i*, along their whole length, giving to the pulley a vertical motion equal to the elastic limit of the accumulator springs, which is about 4 feet. Shoulders project from the pulley frame which impinge upon the spur buffer below, or springs above, to guard it from violent shock in case either the sounding wire or accumulator rope should break under heavy strain.

The spur buffer stands in a vertical position on the forward end of the frame *h* directly under the projecting shoulder of the frame which carries the pulley *l*. It consists of a steel tube containing a spiral compression spring, upon which a steel piston rests, its upper end projecting 2 inches above the tube, thus providing a safe cushioning for the accumulator pulley and frame in case the springs or accumulator rope should give way under tension.

The spring buffers are V-shaped steel springs on the middle lower surface of the tie-frame, each side of the accumulator rope. They are intended as a cushioning for the frame and pulley *l* in the event of the sounding wire parting under a heavy strain. The fair-leader and swivel pulley *m* guide the sounding wire to the accumulator pulley, the former when the wire is nearly vertical, and the latter when the angle is great, as would be the case when the vessel was drifting, turning, or steaming ahead.

The fair-leader is a cylinder of tempered steel, with rounded ends, bolted to the outboard end of the frame *i*, with its center directly beneath the outer score of the accumulator pulley. The swivel pulley has a deep groove for the wire, is of brass and very light; its steel frame is bolted to a collar that turns freely on the outer surface of the fair-leader in such a manner that the bottom of the groove on the inner periphery of the pulley *m* retains its position at all times directly beneath the outer score of the pulley *l* and center of the fair-leader.

The swivel pulley is indispensable when reeling in the sounding wire with the vessel under headway, as is customary in modern practice. It is swung to one side out of the way when not required for use, and when taking serial temperatures fair-leader and pulley are removed from the machine. A steel rod, or handle, projects from the frame over the pulley *m* for convenience in swinging it back and forth to the desired angle.

The brace n is an iron rod connected to the head of the tubes *i* and to a strut of cast steel on the inboard end of the frame *a;* it is operated by a turn-buckle, through which its length is increased, thus forcing the head of the tubes forward and pressing the frame *h* down firmly on the oak bedplate *b*, where they are held in position when the machine is rigged for service.

The guys o are of flexible wire rope, with sister hooks in their upper ends which hook into eyes on the tie-frame, and screwbolts at the opposite ends, passing through holes at the outer extremities of a pair of outriggers of cast steel, which pivot on the end of the frame *h*. The guys being properly set up, support the accumulator laterally.

The reel p is of cast steel and known as the "navy reel." It is cast in one piece with 12 light-ribbed spokes; the drum is 22.89 inches in diameter, equal to a fathom in circumference, less 0.028 of an inch, the diameter of sounding wire, hence the initial turns are a fathom each; the face of the drum is 3½ inches wide and the reel will carry about 6,000 fathoms of wire. The weight of the navy reel is about 160 pounds. The V-shaped friction groove, common to all sounding reels, projects from the right flange and is cast with it; the drum, flanges, and friction groove, are lathe-finished.

The shaft, or axle, is of steel; the ends are squared for the reception of cranks and the reel is held in place by a key, which can be readily backed out; there is a ratchet wheel on the left of the reel, and a worm wheel on its right, into which the register *t* is geared. Both the ratchet and worm wheels are keyed on the shaft.

The navy reel is the only one that has been thoroughly reliable under all conditions of service on board United States vessels, and is to be preferred on that account, notwithstanding its great weight, which is really of little moment when used with the carefully adjusted accumulator of the Sigsbee machine. A little closer attention to the friction rope is all that is required on the part of the operator to overcome the effect of increased inertia.

Experiments were made on board the *Albatross* with ingeniously devised and carefully constructed built-up reels, under the impression that it was vitally necessary to keep the weight down; weaknesses were developed when working in great depths and the parts strengthened until the reel increased from 90 to 150 pounds in weight; it failed even then under a crushing strain of about 300 tons.

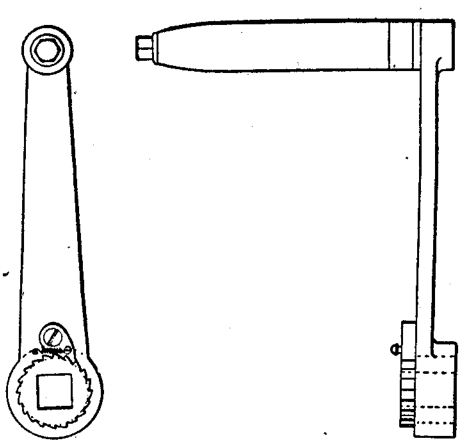
The friction rope is of 18-thread manila, 2 fathoms in length, with an eye spliced in the standing part. To reeve it for sounding, slip the eye over its cleat on the bed-plate *a*, lead the hauling part under the reel, then over it and through the V friction groove; the operator stands forward of the machine, facing it, with the friction line in one hand, and with the other steadying himself in rough weather, which he can do without distracting his attention or interfering with the delicate manipulation of the friction rope, upon which successful sounding so largely depends. He can stop the reel promptly by a moderate pull on the line with one hand, and a further advantage gained by this direct method of running it is that the accumulator is left entirely free to indicate the rapidly varying tension on the sounding wire, which it does with marked precision under all conditions of service; hence the actual resistance imposed upon the reel by the friction line becomes a matter of indifference.

The wire guard r is a T-shaped brass plate hinged to the bedplate *a*. Its head is faced with sole leather and covers the width of the reel between the flanges. The leather rests fairly on the wire when it is in action and a gentle pressure is maintained by a spiral spring attached to the middle of the upright part of the T and to the bed-plate *a* under light tension. The contact of guard and wire takes place at the forward lower quarter of the reel and is intended to supplement the action of the friction line by supporting the slack turns of wire and causing them to be seen more quickly on the upper surface, also to prevent their flying off from the lower part of the reel before they are apparent to the eye of the attendant.

While the relief afforded by the guard is momentary only, it serves to give timely warning to the vigilant operator who is speeding his work by veering wire to the utmost limit of safety.

The brake s is practically indispensable when, from the breaking of a belt or friction line, the reel becomes unmanageable and can not be safely stopped by throwing the pawl into action.

The register t is of brass and has three dials marked for units, hundreds, and thousands; its gearing engages the worm wheel on the axle of the reel, and can be quickly thrown into or out of action, or removed from the machine. It registers the number of turns of wire paid out, the corresponding number of fathoms being found by reference to a correction curve or table prepared for each reel.



CUT 38.—Ratchet crank, front and side views.

The reeling engine *u* is a Copeland & Bacon half trunk, designed for the purpose, 6½-inch cylinder and 6-inch stroke; it has a light-iron frame, cast in one piece, and is bolted securely upon the inboard end of the bedplate *a*. The driving pulley *v* has a V-groove corresponding to that on the reel *p*, over which the belt *x* is run; the steam connection *w* is on the right side of the cylinder, and the exhaust valve and steam chest are on its left side.

Flexible hose, or rigid steam and exhaust pipes, may be used, and where the machine rigs out and in it may be advisable to have a pipe connection on the deck near it and a flexible attachment admitting of the necessary movement.

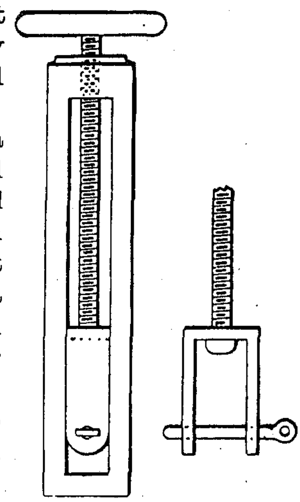
The ratchet crank ships on the squared end of the crank shaft of the reeling engine and is used to work water out of the cylinder, also to assist in starting the engine slowly to avoid sudden and undue strain on the sounding wire; it can be unshipped after the engine has been started or left hanging in place, where it will remain in a vertical position, the ratchet preventing its revolving with the shaft. Cut 38 shows front view and side view of the ratchet crank. It was devised by the writer and constructed by Chief Engineer Baird of the *Albatross*.

The belt x is of 18 or 21 thread ratline stuff, made in the form of a grommet strap, with small sewed seizings covering the ends in the splice, to prevent their working out as the belt becomes stretched. Experiments were made with leather, gutta-percha, manila, etc., for belts, but we found nothing to compare with ratline stuff, which is quickly fitted on board ship, performs its work well, and is fairly durable.

The tightening pulley y, deeply scored to receive the belt, revolves on a stud or axle projecting from the side of a movable collar that traverses freely on a vertical standard erected from the bedplate *a* between the engine and reel.

The belt-tightener z consists of a small steel rod having a screw thread on its whole length, a swivel joint and pin on its lower end, and a small hand wheel on its upper extremity. Its frame is of brass, cylindrical in form, and has a slot running nearly its whole length, in which the rod and swivel joint work. A round hole in the lower end of the frame allows it to slip over the end of the tightening-pulley standard, and there is a screw thread in the other end which engages the thread on the rod.

To operate the belt-tightener, put the belt on the reel and driving pulley, place the tightening pulley on the upper part of the belt, slip the belt-tightener over the end of the standard, and pass the pin through a hole in the swivel joint; then, by revolving the hand-wheel, screw the base of the frame down upon the collar until the desired tension is obtained, which is easily and quickly done with one hand. Should the belt stretch so much that it can not be set taut with the belt-tightener it is only necessary to slip a few washers, or a piece of pipe 3 or 4 inches long, on the standard between the belt-tightener and movable collar.



Cut 39.—Belt-tightener.

It was formerly the practice on the *Albatross* to put a tension on the belt by pressing the pulley down by hand and retaining a uniform strain by the elastic pressure of a spiral spring. It required the united efforts of two or three men to get the belt sufficiently tight. Even then it would slip at times when working in deep water; hence the necessity for a mechanical belt-tightener, which has proved to be simple and effective. Cut 39 shows a general view of the belt-tightener and a side view of the swivel joint and pin.

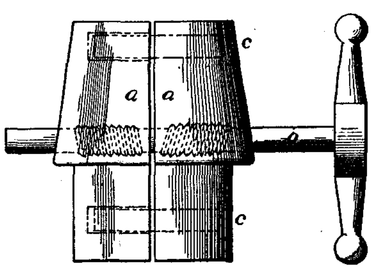
The Sigsbee wire clamp (cut 40) is composed of two pieces of lignum-vitae, semi-circular in form, with right and left hand screws for operating it. It is used for holding the sounding wire in case it becomes necessary to slacken it between the reel and swivel pulley; for instance, if it flies off the reel, or a defective splice, kink, or slack turns are discovered.

To use the clamp, slip the wire between the flat surfaces of the jaws, as shown at *d*, set them firmly against it by means of the right and left hand screws, and lower it into the fair-leader. To suspend the submerged wire and sinker by the accumulator, put the clamp on between the pulley and reel, lashing it well down, below the elastic limit of the springs; but this will seldom be necessary or desirable in practice. The clamp is carried in a socket inside of the bedplate *a*, on the left side, between reel and accumulator frame, where it is available for immediate use. It is held in its socket by expanding the jaws through the reverse action of the right and left hand screws.

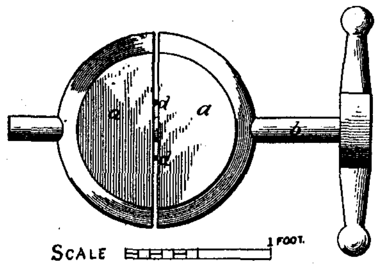
The wire guide is used to lead the sounding wire fairly upon the reel. It is a round piece of wood, 9 inches in length and 1½ inches in diameter, covered with heavy pump leather for half of its length, the leather being nailed on with headless copper tacks, to avoid the possibility of catching the wire. There is a becket through a hole near the end of the handle.

To protect the leather from unnecessary wear, it should be kept well oiled. It will usually receive an ample supply from contact with the wire.

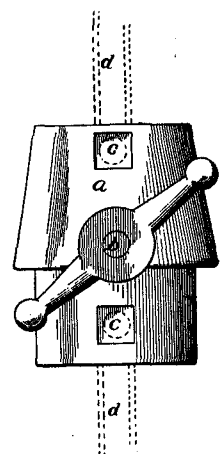
To use the wire guide, take it in the right hand, slip the becket over the wrist, grasp the brace of the sounding machine with the left hand for support, if there is much motion on the vessel, then press the leather-covered surface lightly against the wire with sufficient force to guide it evenly upon the reel. It should be made an invariable rule to use the guide, even though a few fathoms only have been run off, in



CUT 40.



CUT 41.



CUT 42.

a. Lignum-vitae jaws.
b. Spindle, with right and left hand screws.
c. Guide bolts, brass.
d. Sounding wire.

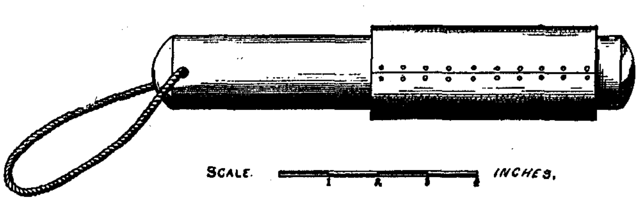
CUT 40.—Side view of the Sigsbee wire clamp, showing jaws *a* and right and left hand screws by which they are opened and closed; also guide bolts *c*, which are rigidly set into right jaw and slide freely in the left.

CUT 41.—Top view, showing ends of jaws *a*, between which are gripped two pieces of sounding wire *d*.

CUT 42.—Front view, showing manner of clamping the wire.

order to guard against the exasperating occurrence of slack turns of wire on the reel. The guide is very useful, also, in the hands of an expert, for detecting kinks or defective splices, which are rarely discernible by sight on rapidly running wire.

The *dynamometer staff and spring* were devised by the writer in 1891 for the purpose of facilitating the guiding of the sounding wire upon the reel with the least possible friction on the splices, reducing the manual exertion required to guide it, and avoiding the danger and annoyance resulting from slack turns.



CUT 43.—The wire guide.

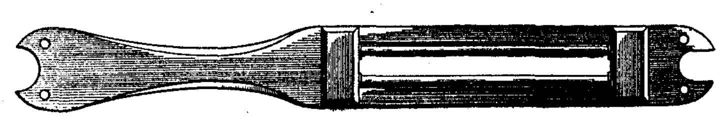
In sounding with the Sigsbee machine, the accumulator pulley, over which the wire leads, has a vertical motion nearly the entire length of the tubes within which its controlling springs are inclosed, and a scale on the right tube indicates the tension on the wire, as well as the moment the sinker strikes bottom. Nothing better can be desired during the paying out, but the greater strain brought upon the wire while reeling in tends to draw the pulley down so near the reel that it is difficult and at times impossible to guide it evenly upon the drum; hence the necessity for a simple method of suspending the pulley at the top of the frame, at the same time retaining the dynamometer, or adopting another by which the strain on the wire may be noted.

The dynamometer staff is a brass tube of commercial pattern, cut to the desired length, and an eye of cast brass secured in its upper end. At the lower extremity is a spiral compression spring of phosphor bronze, $1\frac{5}{8}$ inches in diameter and 8 inches long, held in place by a small shoulder and drift pin.

To use it, the sinker having been detached, place the spiral spring over the top of the spur buffer, lift the pulley to the top of the frame, and secure the eye of the staff in the socket at the lower extremity of the crosshead frame by a loose pin provided for the purpose. With the pulley in this position, the wire is guided upon the reel with the minimum of exertion and friction, and the elastic limit of the spring, about 4 inches, being divided off as a scale on the left accumulator tube, the strain put upon the wire is under the constant observation of the operator.

The scale is marked from 100 to 130 pounds, the tension being obtained by clapping a spring scale on the end of the stray line, and with a piece of chalk marking the lines as desired; it is the work of a moment and preferred to a permanent scale, which would require frequent verification. Either arm of the crosshead may be used as a pointer, but the lower one, being nearly on a level with the eye, is preferable.

The adoption of the staff interfered with the use of the main accumulator while reeling in, but the machine being located at the stern and the vessel steaming ahead there was no fear of fouling, and the danger from jerking strains in a seaway being much reduced by the trend of the wire astern no inconvenience was suffered from the new arrangement. The speed of the reel was governed entirely by the strain upon the wire; 110 pounds was considered thoroughly safe practice, 120 pounds was the ordinary working strain, and 130 pounds the extreme limit of safety, which was not exceeded under any circumstances. With the introduction of the dynamometer staff the speed of the reeling engine was increased, the danger from slack turns on the drum disappeared, and a noticeable decrease was observed in losses from defective splices.



Cut 44.—Guide for temperature wire.

The guide for the temperature wire, as improvised by the writer in 1891 and first used aboard the *Albatross* on the cable survey between California and the Sandwich Islands, has an oak frame in which is a long slot carrying a pair of brass rollers, lashings being provided at each end for convenience in securing it in place. To prepare it for use, remove the fair-leader and swivel pulley from the sounding machine, ship the dynamometer staff, lash one end of the guide to it just below the accumulator pulley, securing the other wherever most convenient; then, having mounted the reel containing the temperature wire, run the stray line over the pulley and between the rollers on the guide and bend on the sinker.

With this arrangement of guide, thermometers and water bottles are fastened to the wire and removed from it at a convenient height above the grating, which is a convenience at all times, and particularly so in heavy weather.

THE TANNER SOUNDING MACHINE.

This machine was devised by the writer in 1880, for use on board the United States Fish Commission steamer *Fish Hawk*, which was provided with deep-sea apparatus designed to operate in depths within 500 fathoms. It is a hand machine for sounding with wire, and can be operated by one man, but two will work more rapidly, and, if sounding in 200 fathoms or more, time will be saved by having a relief at the cranks. Soundings in 800 fathoms have been made with the machine, and the reel has even a greater capacity, but it is lightly constructed and not intended to bear the crushing strain imposed upon it by working in greater depths.

It is mounted at the stern of the *Albatross* abaft the Sigsbee machine, carries about 500 fathoms of No. 21 music (Washburn & Moen) wire, with which an ordinary 28-pound lead is used; it is kept in readiness for navigational purposes whenever the vessel is underway, and soundings within its capacity are quickly and accurately made by stopping and getting an up-and-down cast, while from 70 to 100 fathoms may be readily reached without checking the speed by attaching a Bassnett atmospheric sounder or Sir William Thomson's tube to the stray line.

The Tanner machine is used also in deep-sea exploration in depths within 200 or 300 fathoms, and while the Sigsbee machine is preferred in deeper water the former is occasionally used even in 500 fathoms.

It is necessary to keep the wire taut when sounding with this machine as well as with others, for slack wire is liable to fly off the reel or kink, and the latter is usually followed by a break.

The spindle a is made of iron, turned slightly tapering, screwed firmly into the base of the frame *b*, and inclosed within a brass tube. 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* is of cast brass, 22.89 inches in diameter; the initial turns of wire equal 1 fathom, increasing as the score is filled, its capacity being about 2,000 fathoms of No. 11 music.

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

The cranks 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 *h*. 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* is spliced into the eye *o* in the frame, carried around the reel in the V groove, and the free end secured to the bight of the accumulator rope *n* at *m*, one end of the latter 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 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 shaft; remove the nut from the left end of the 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 of the frame and lower it to the deck, returning the shaft and crank to their places. If the frame is to remain on the rail, remove the register and lower the arm *c* by withdrawing the pin *i*, ease up the set screw *q*, swing the arm inboard, then tighten it to hold the machine in position.

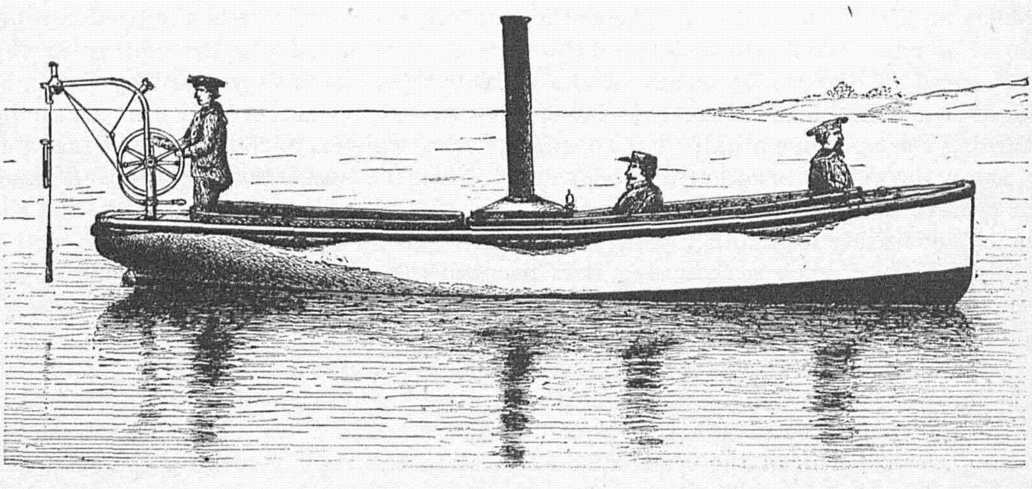
To wholly dismount the machine for transportation or storage, remove the reel, cranks, and register, disconnect the arm *c* at *i*, and unscrew the spindle *a* from the base of the frame *b*. The total weight of the machine is 135 pounds.

If the ordinary sounding wire (No. 11 music) is used, it is necessary to protect it from oxidation by keeping it oiled when mounted, and in a reel tank when not in use. But with a view of having it ready for service at all times without the necessity of giving special care to the wire No. 21 music is used and allowed to remain on the reel without other protection than occasional oiling. It rusts, as a matter of course, but it is serviceable for a year, at least, and sometimes lasts two years. This heavy wire is recommended for use in depths not exceeding 500 fathoms.

The Tanner machines recently made have been simplified in construction by dispensing with the inner and outer shafts and conical friction surfaces for engaging the cranks and substituting therefor a single cylindrical shaft with its ends squared for the reception of sleeves which form cylindrical bearings for the cranks, both being held in place by washers and set screws in the ends of the shaft. The cranks are thrown into and out of action by spring-controlled locking-bolts, carried on their rear surfaces, which pass through holes in hubs of cranks and into the sleeves. The worm wheel and ratchet are carried on the cylindrical body of the shaft, between the sleeves and the frame, and are held with set screws. The reel is also secured in the same manner.

THE TANNER SOUNDING MACHINE FOR BOAT SERVICE.

It is frequently desirable to extend lines of soundings from one or two to several hundred fathoms, with the same vessel and apparatus, and the Tanner machine being well adapted for boat work, was installed at the stern of the *Albatross'* steam cutter, with fittings similar to those on board ship, and has performed excellent service.

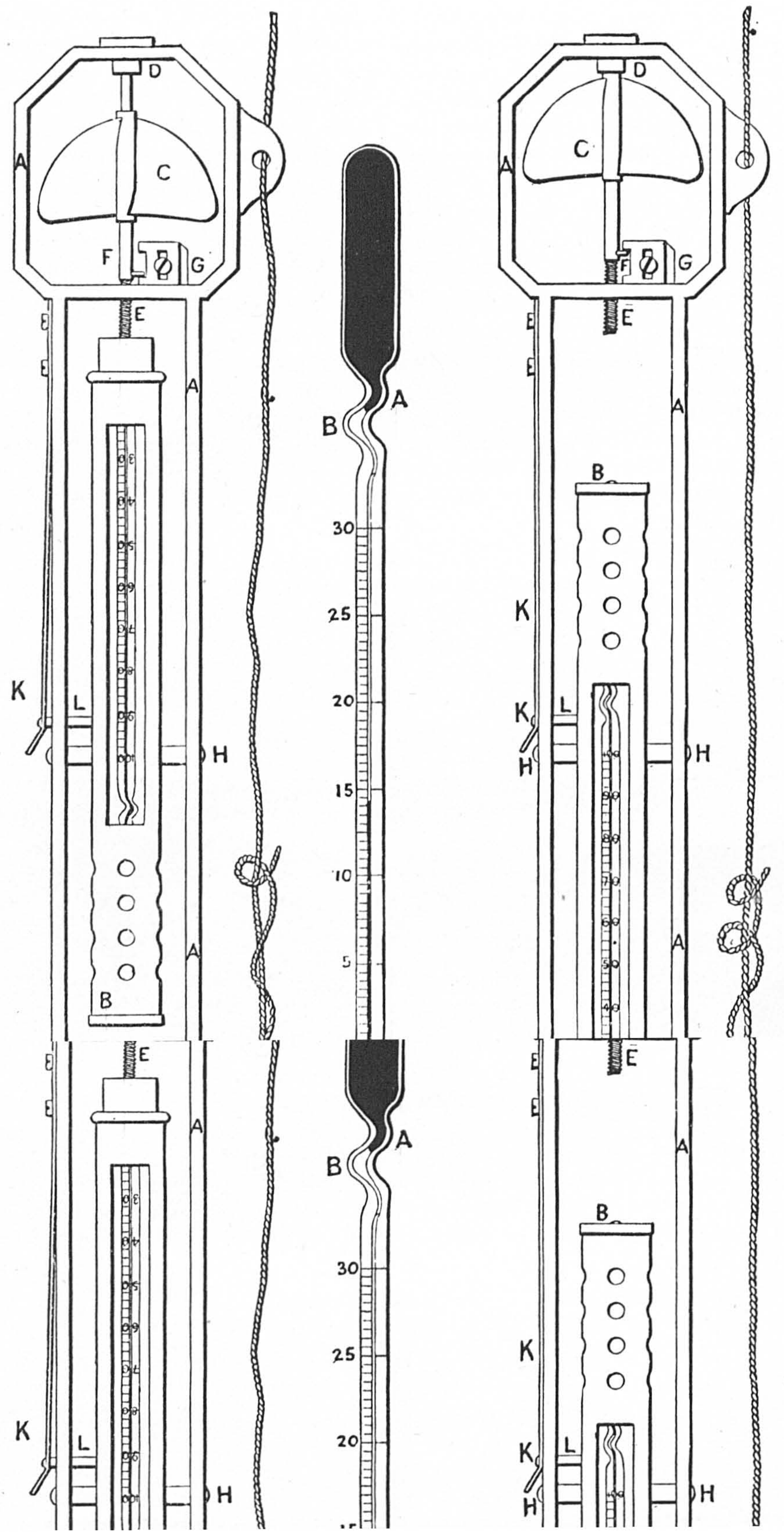


CUT 45.—The Tanner sounding machine mounted in the steam cutter.

When a sounding is about to be taken the cutter is stopped as quickly as practicable, maneuvering to keep the wire vertical during its descent, and as soon as the lead strikes bottom she steams ahead again at full speed, the wire being reeled in while she is under headway. Short base lines are quickly measured by making the stray line fast, setting the register at zero, and steaming directly for the opposite end, attaching as many floats en route as are necessary to support the wire at the surface. The reading of the register is corrected as in sounding. The same method will apply on a smooth stretch of land by mooring the boat and walking away with the wire.

This is not a rigidly accurate method, but, for short lines, the results will be found to compare favorably with those obtained with the surveyor's chain.

PLATE XX.



THERMOMETERS.

Thermometers were procured from various manufacturers during the earlier operations of the Fish Commission and issued for service without previous comparison with a standard. Only the best instruments of reputable makers were used, and observations were confined to air temperatures, surface, shoal water, and moderate depths, hence they did not suffer materially until the scope of temperature observations enlarged in the direction of the deep sea, when instrumental errors became of sufficient frequency to cast discredit upon them.

Systematic and successful efforts were made by the officers of the Commission to improve this branch of the service; greater care was exercised in the selection of instruments; makers were informed of weak points developed in service and encouraged to remedy them; all thermometers were rigidly compared by an officer of the Commission and were accompanied by tables of corrections when issued for service. The accompanying description will include only the thermometers of the *Albatross*, as they represent the types in use on board the vessels of the Commission.

Thermometers for air temperatures are made by J. & H. J. Green, New York. The tubes are 10 inches in length, made extra strong, well seasoned, and graduated on the stems to 1° F. They rate with remarkable uniformity, with a maximum error of 0.3°, minimum of 0.0°, and mean of 0.1°. They are mounted in extra heavy copper cases, open in front, with a cup in the bottom perforated with a central hole.

Wet-bulb thermometers are the same as those above described and are prepared for their special function by having their bulbs enveloped in lamp wick, which being immersed in a suitable cup of fresh water placed beneath the suspended instrument saturates the fibers surrounding the bulb by capillary attraction.

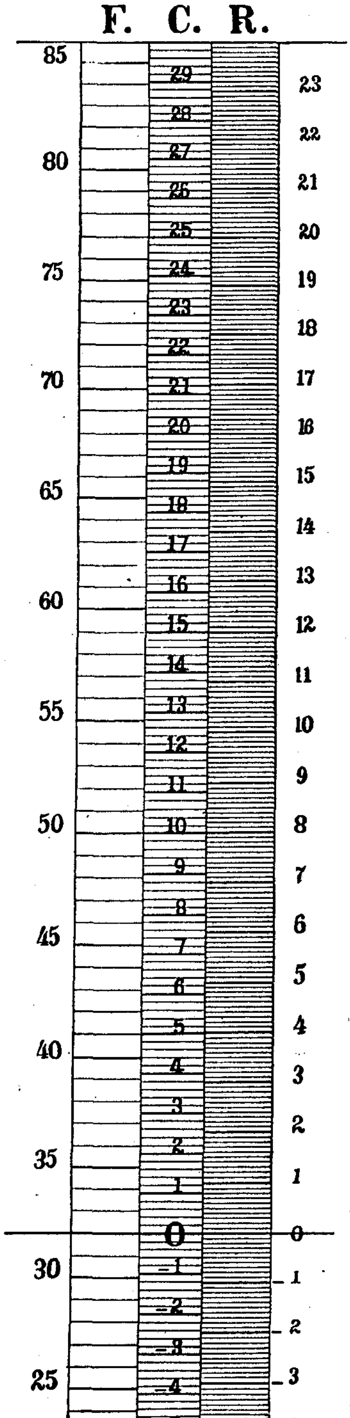
Thermometers for surface temperatures are the same as before described for air, and are prepared for use by inserting a cork into the central hole in the bottom of the frame.

The *Tagliabue thermometers* attached to the Hilgard ocean salinometers are simple tubes, with round bulbs, protected by perforated brass cages and fitted to slide into the front of the salinometer cup. The older make, graduated on the stems to 1° F., range from 30° to 100°, while later forms are graduated to 1° centigrade, and range from —10° to + 50°.

THE NEGRETTI & ZAMBRA DEEP-SEA THERMOMETER.

The following description is copied in part from the catalogue of Negretti & Zambra. The construction of the thermometer will be understood by reference to fig. 2, plate XX, and its shield is shown in fig. 2, plate XXI, in a vertical sectional elevation of the Tanner 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*, and 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*.



CUT 46.—Comparative thermometric scale Fahrenheit, Celsius, and Reaumur.

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 great heat. In the latter case some mercury will pass the contraction *a* and may fall down and lodge at *b*, but it can not 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 can not 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, *c* [plate XXI, fig. 2], 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 XX 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 thermometers.—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. 3) 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 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.

This thermometer was first used by the Fish Commission in 1877, when it was mounted in a wooden case about 13 inches in length, secured to the lead line by a lanyard at the bulb end. A cylindrical cavity contained a quantity of shot, movable from end to end, sufficient to nearly overcome its buoyancy in sea water. On sending the case down the friction of the water, aided by the buoyancy of the case, tended to keep it upright and bulb down in the water, the shot rolling promptly to the lower end of the cavity. Reversing the motion and hauling in the line the case was capsized and the shot run to the other end, tending to keep it down and the bulb uppermost.

This arrangement answered its purpose at moderate depths in smooth water where veering and hauling of the lead line could be made continuous, but the motion of the vessel in a moderate seaway was sufficient to capsize it again and again, and the case lost its buoyancy in about 600 fathoms, the wood becoming waterlogged. Many attempts were made, both in this country and in Europe, to improve the case, and in September, 1880, the writer attached a spring latch to the end opposite the bulb, which, grasping the wire, held the thermometer in a vertical position during its descent and, when ready to haul up, the latch was disengaged by the impact of a metallic messenger sent down on the wire, and the thermometer promptly capsized by the preponderance of weight, the shot having been blocked in the free end of the case.

The next improvement, introduced a few days later, was simply a brass tube, seven-eighths inch in diameter, in which the thermometer was placed and held in position by rubber rings. The bulb end was secured to the sounding line by a lanyard and the other end carried a pair of slip hooks, which, encircling the line, insured a vertical position, bulb down, during its descent. It was reversed by impact of a messenger, as before, and, having no buoyancy, it retained its position, bulb up, even if the reeling in was interrupted or the vessel was laboring in a seaway. The messenger was of brass, cylindrical in form, with rounded ends, and weighed from 3 to 4 ounces.

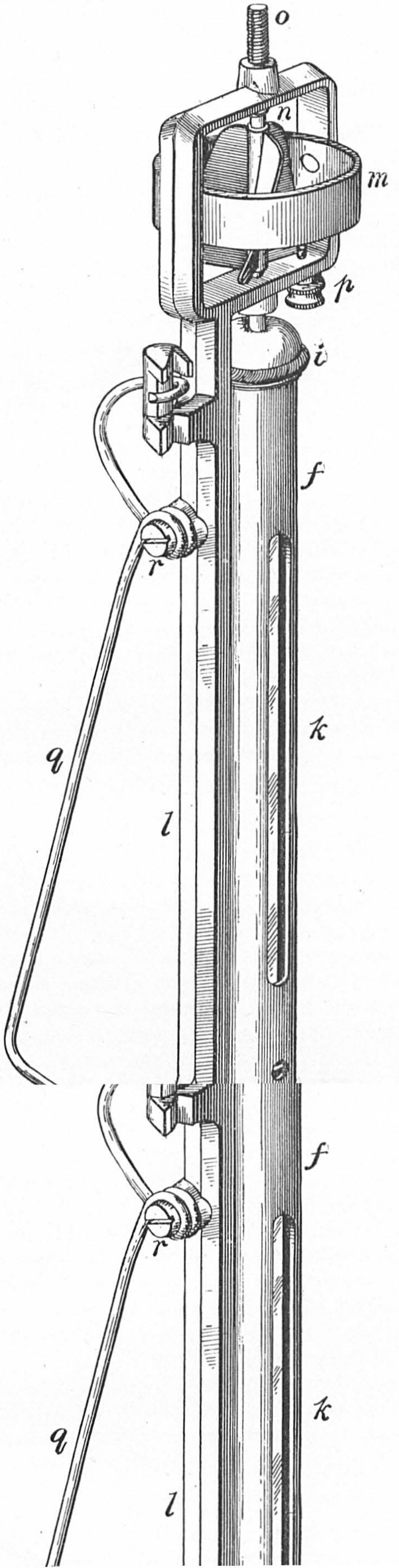
This device became known as the Tanner case and proved efficient in the moderate depths sought by the *Fish Hawk*, but, in anticipation of more extended explorations on board the *Albatross*, then under construction, I considered it necessary to devise some method of registering in deep water without the loss of time incident to the descent of a messenger. The propeller of the Sigsbee water bottle suggested a simple and reliable method of reversing at any desired depth and permitting the use of any number of instruments in series.

The attention of Passed Assistant Engineer William L. Baillie, U. S. N., being called to the matter, he devised the propeller attachment which screwed to the upper end of the Tanner case, the slip hooks being removed for the purpose. The action of the propeller is practically the same as in the Magnaghi frame, received later in the same year. The device became known as the Baillie-Tanner case. It operated perfectly, so far as the prompt and unfailing overturning of the thermometer was concerned, but the weight, bulk, and general form of the free end was such that it subjected the delicate instrument to undue jarring on the way up, frequently shaking the mercury down from the bulb or catch reservoir into the tube and vitiating the observation. It was used in common with the Magnaghi frame, each having its merits, but both were lacking in some essential qualities and were superseded late in the season of 1883 by the device described below.

THE TANNER IMPROVED THERMOMETER CASE AND SIGSBEE CLAMP, USED WITH THE NEGRETTI & ZAMBRA DEEP-SEA THERMOMETER.

Fig. 1, plate XXI, shows the apparatus complete, and fig. 2 a vertical sectional elevation of the metal case containing the thermometer. The frame is of brass, cast in one piece, as light as is consistent with the required strength.

The case *f* is a brass tube of commercial pattern, 1 inch in diameter. It has a piece of metal soldered in its lower end to support the spiral spring *h*, and pivots to the frame at *j*. The cap *i* is screwed upon the upper end of the case, and is pierced with a central hole for the reception of the spindle *o*, carrying the propeller *n*, which is secured to it by a through drift pin. The upper part of the spindle has a screw thread, which works in a thread in the head of the frame. Its lower part has a plain surface, with rounded end, and revolves freely in its bearing and in the hole in the cap *i*. The set screw *p* regulates the distance the thermometer must be drawn up through the water before it is overturned and the temperature registered. The range is from 3 to 25 fathoms. The clamp *q* is the Sigsbee clamp used by him on water bottles and the Miller-Casella deep-sea thermometer. It is of phosphor bronze and performs its work admirably either on the stray line or sounding wire. When clamping to the latter,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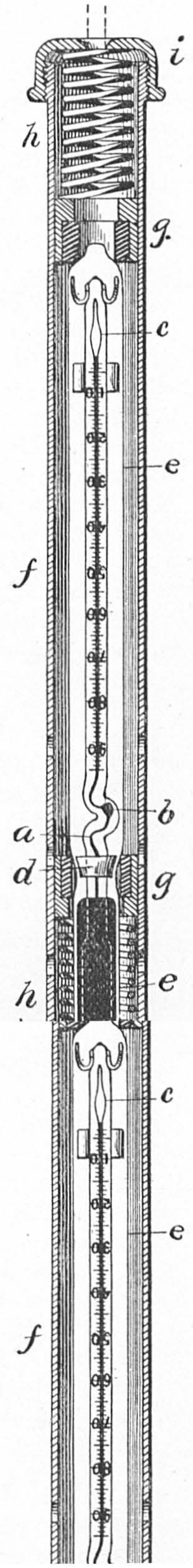
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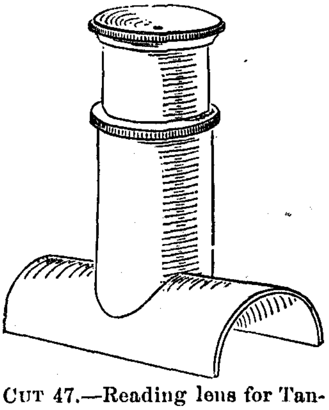
however, the bight of wire between the two jaws of the clamp should be drawn back over the head of the clamp screw *r*, to prevent slipping. The guard *m* is intended for the protection of the propeller against accidental contact with the sounding machine or ship's side.

The method of mounting and protecting the thermometer in its case will be readily understood by reference to fig. 2, where, securely inclosed in its glass shield, it is ever resting in rubber-lined thimbles, which move freely along the inner surface of the case and guard it laterally, while the delicate spiral springs of phosphor bronze protect it longitudinally from the jarring caused by the rapid motion of the reeling engine, which, with the old methods of mounting, sometimes affected the reliability of observations by shaking the mercury down into the tube. The temperature is read through the slot *k* by means of a reading lens. The case is pivoted at *j* in such a manner that it swings freely after it is capsized but can not strike the wire while reeling in.

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. The scale can be read at any time, providing the thermometer has been kept bulb up, as changes of temperature do not affect the reading after the column is once broken.

READING LENS FOR THE TANNER THERMOMETER CASE.

It is a difficult thing to hold a thermometer vertically and exactly opposite the eye, some observers tipping it forward a little, and some backward, with a consequent change in the apparent relative positions of the top of the mercury column and of the scale behind it. Dr. Kidder tested a number of different observers and found that the probable parallax error in reading, by those who use the thermometers in practice, is not far from 0.3°. While this error is of little moment in the ordinary temperature observations in air or at the surface, it assumes greater importance in the deep sea, where variations in temperature are slight, and, to eliminate errors of parallax as far as possible, he introduced a reading lens made by Mr. Joseph Zentmayer, of Philadelphia, which he describes as follows:



CUT 47.—Reading lens for Tanner thermometer case.

The lens is about 3 inches focal length, fitted at right angles to the center of a brass saddle adapted to the convex surface of the thermometer case, and provided with a short draw tube for focusing. The eyepiece opening is made smaller than the pupil of the eye, and there is therefore no variation in the reading, whatever may be the inclination to the perpendicular at which the scale is viewed. The magnifying power of the lens makes it much easier than formerly to read the temperature to fractions of a degree.

THE MILLER-CASELLA DEEP-SEA THERMOMETER.

Plate XXII 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, page 108:

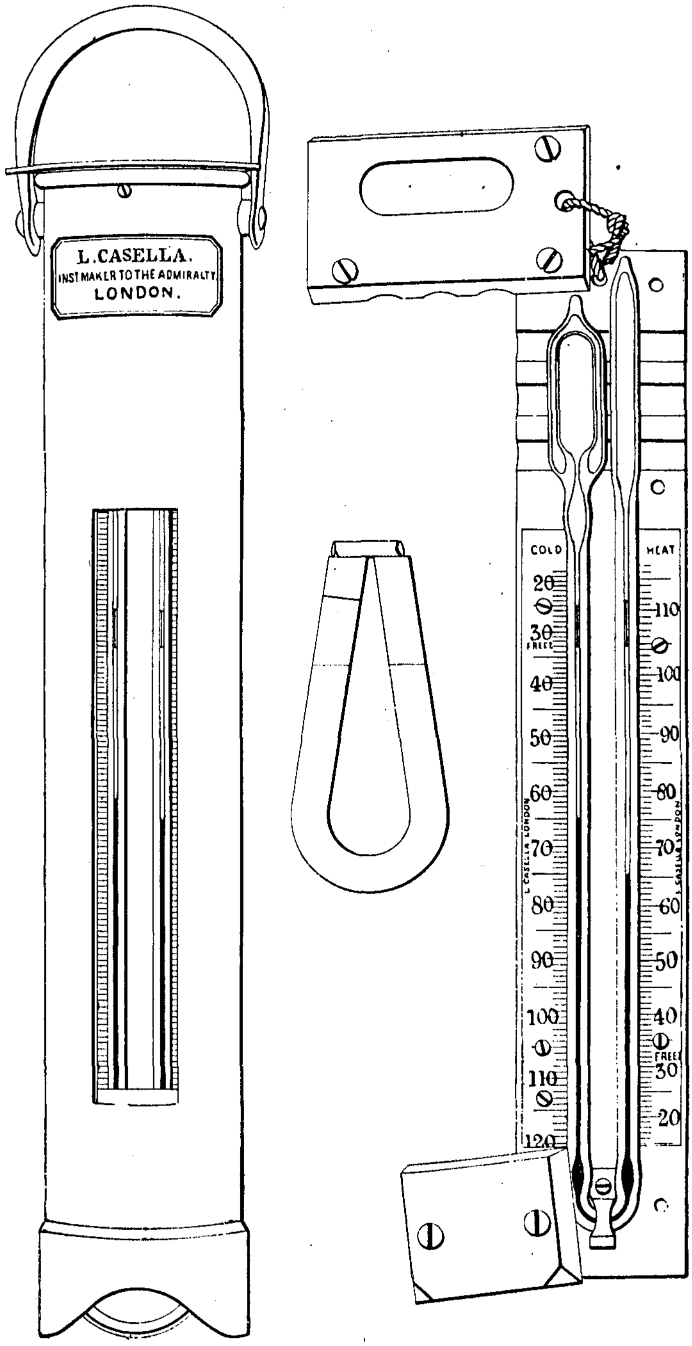
> A glass tube bent in the form of U is fastened to the vulcanite frame, and to the latter are secured white glass plates containing the graduated scales. Each limb of the tube terminates in a bulb. A column of mercury occupies the bend and a part of the capillary tube of each limb.
>
> The large bulb 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 horsehair tied around it near the upper extremity. The ends of the elastic horsehair, 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 downward, and that on the right from the bottom upward. 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 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.

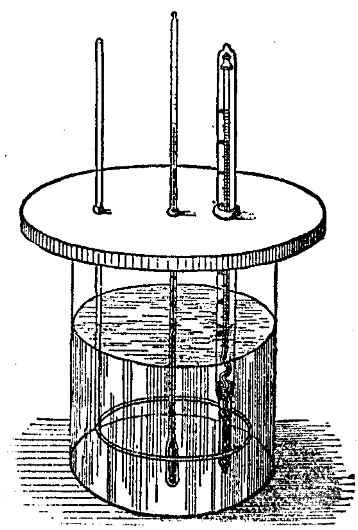


THE MILLER-CASELLA DEEP-SEA THERMOMETER.

KIDDER'S THERMOMETER COMPARISONS AND CORRECTIONS.

Surgeon J. H. Kidder, U. S. N., had charge of the thermometers of the United States Fish Commission from 1883 to 1885, during which time he compared every instrument before it was issued for service. Since then they have been corrected by the United States Weather Bureau. Kidder's methods and appliances were sufficiently simple and effective to serve as a guide for the preparation of similar apparatus on shipboard. The substance of the following is taken from his report on the thermometers of the United States Commission of Fish and Fisheries, 1885. He used two Fahrenheit standards, made by J. Hicks, London, and verified at the Kew Observatory. They were pointed to fifths of a degree, and a good reading could be made to tenths of a degree; they ranged from 10° to 120° F.

A small comparing jar was first used, in which the instruments to be corrected were immersed with the standard. A ring stirrer was provided, and the jar had a wooden cover perforated with suitable holes to allow the instruments to pass through and hold them in place. By agitating the stirrer up and down, the water contained in the vessel was thoroughly mixed and a uniform temperature obtained. This simple contrivance answered very well for ordinary thermometers with bulbs exposed directly to the water, but admitted only two or three instruments at a time, owing to the comparatively small volume of water which it contained. A larger jar with a capacity of 22 gallons was subsequently used.



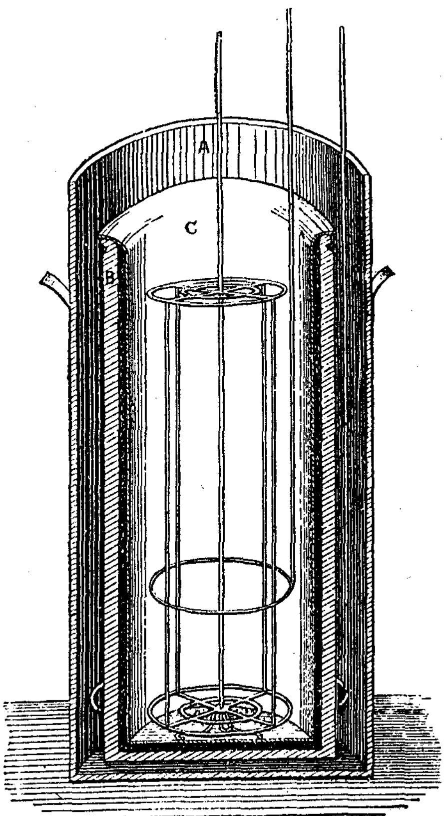
CUT 48.—Small comparing jar.

For the "zero point," or 32° F., the thermometers to be tested were immersed in finely-broken ice contained in a large glass percolator, 12 inches wide by 12 inches deep, with a small opening at the bottom for the escape of water as fast as the ice melted. This percolator is supported upon a suitable iron tripod and holds 8 thermometers without crowding.

For deep-sea thermometers, which are protected against water pressure by double glass bulbs and which are therefore slow and require exposure to a constant temperature for at least 10 minutes, Prof. T. Russel's comparing jar was used, a sectional elevation of which is shown in cut 49.

The outer can A is of galvanized iron, 13½ inches high by 11 inches in diameter; B is an earthenware jar, 11 inches high by 8 inches in diameter; C is a tinned copper pot, fitting pretty closely into B and suspended by a flange at the top. Inside of C is a copper frame, movable about a central spindle, to which the thermometers are attached. A ring stirrer moves in the space between A and B, and another between C and the thermometer frame. When the temperatures to be observed are below that of the air, the spaces between A and B and within C are filled with water, that in the outer space being from 5° to 10° colder than that in contact with the thermometers. It is advised that they should be immersed for a time in water near the temperature sought before transferring them to the comparing jar.

By agitating both bodies of water briskly with the stirrers and observing the standard thermometer in the inner jar from time to time, a sensibly constant temperature will at length be reached, at which the gain in temperature of the water in the inner jar by contact with the warmer air at its surface is very satisfactorily compensated by its loss through the air space between B and C and the badly conducting walls of B. For temperatures higher than that of the air the water in the outer jar must be warmer than that in the inner. No positive rules for differences in the temperatures of the water in the inner an outer jars can be established, yet it may be said, in general terms, that the greater the difference between the temperature of the air and that desired for comparison the greater should be the difference between the temperatures of water in the outer and inner jars.



CUT 49.—Comparing jar for deep-sea thermometers.

To avoid parallax error in reading, the jars were leveled and readings taken by aid of a hand lens, with the eye and top of the mercury column at the level of the top of the outer jar, across the two sides of which the reading is sighted, the thermometer being held in contact with one of the walls of the jar and parallel with the central spindle of the frame to insure its perpendicularity. Comparisons of readings taken in this simple way with readings taken by the cathetometer, the thermometer being secured in a perpendicular position, show no perceptible error. When issued, each thermometer was accompanied by a printed blank corresponding to a stub slip in the rating book and filled out for each point at which a comparison was made.

The following admirable article (pp. 330–336) upon the methods of thermometer correction is kindly contributed by C. F. Marvin, professor of meteorology United States Weather Bureau, and affords valuable information regarding the physical principles involved as well as their practical application in the comparison and correction of thermometers.

NOTES UPON THERMOMETERS AND HOW TO DETERMINE THEIR ERRORS.

A clear understanding of the methods employed in determining the errors of thermometers can not be obtained without a correct conception of the physical principles involved in the measurement of temperature and the action of thermometers in general. The following remarks will therefore preface a description of the methods employed at the United States Weather Bureau for comparison of thermometers:

The several scales of units employed in the measurement of temperatures are all based upon two definite temperatures at which certain simple and easily reproduced physical phenomena invariably occur. The melting of ice formed from pure water furnishes one of these temperatures, called, generally, the freezing point. The second definite point in the scale of temperatures, namely, the boiling point, is established in the temperature of the steam from pure boiling water.

To accurately reproduce a standard boiling-point temperature it is necessary that the escaping steam be subjected to a pressure equivalent to the pressure of a vertical column of pure mercury 760 millimeters high, when its temperature is at the freezing point, and under a gravity equal to that at sea level and at latitude 45°.

The temperature interval between the freezing and boiling points on any thermometric scale is, therefore, established by two definite physical phenomena. The subdivision of the interval into small and convenient units is purely arbitrary and need not be considered here.

The errors to which the ordinary mercury in glass thermometers are subject are the result of three wholly different causes. The sources of errors are:

(1) The inequalities in the diameter of the bore of the thermometer from point to point along the stem. Tubes can not be produced of absolutely uniform diameter, and where the diameter is large, unless compensated for in the graduations, the temperature indicated will tend to be too low, and too high where the bore is narrow. We may include in this source of error any accidental irregularity in the scale of graduations.

(2) The second source of error is found in the character of the expansion of the mercury itself. The amount of increase in volume for a small increase in temperature is not exactly the same at low and high temperatures, and the error due to this cause is further modified by the irregular expansion of the glass envelope. No two kinds of glass will expand in quite the same way.

(3) A third source of error arises from a small, protracted, and gradual shrinkage of the glass in the bulb of the thermometer. Different varieties of glass exhibit marked differences of behavior in this respect. A thermometer heated to the boiling or other high temperature to-day, and which registers correctly when tested at the freezing point will, a month hence, when again tested at the freezing point, often be found to indicate one or two tenths of a degree too high.

It results from the second source of error mentioned above, that, even if a mercury in glass thermometer be constructed with the greatest care, its freezing and boiling points fixed with extreme precision, and its scale of graduations adapted to perfectly compensate for inequalities in the bore, the instrument will yet fail to indicate temperatures correctly, because of the variable rate of expansion of mercury combined with the unknown and more or less irregular behavior of the glass envelope.

It is necessary to have recourse to some other standard for comparison. Fortunately, the expansion of dry air, when free from carbonic acid, or better, of pure, dry hydrogen, is found to be almost perfectly regular over a very wide range of temperatures and is, therefore, capable of being a true index of temperature. The air thermometer, then, is the standard instrument commonly adopted for the measurement of temperature. Its use, however, being a matter of considerable complication, the errors of suitable high-grade mercurial thermometers are determined once for all with great care by extended comparisons with the air thermometer, whereupon the mercurials are available for convenient and frequent use as working substandards representing the air-thermometer scale.

The difference between temperatures on the air thermometer scale and a normal mercury in glass thermometer may amount to nearly two-tenths of a degree at ordinary temperatures and is much greater at temperatures above the boiling point.

It is advisable in all cases that the graduations of mercurial and other similar thermometers be etched on the stem and not engraved on a separate strip of wood or metal, as is often the case.

COMPARISON OF THERMOMETERS.

We determine the error of a thermometer at the temperature of the freezing point by completely covering the bulb and that portion of the stem containing mercury with clean ice shaved up into fine fragments by a jack-plane. This test must be made in a place where the air temperature at the time is above the freezing point, so that the ice will melt steadily. After being exposed to this condition for five or six minutes a reading of the thermometer shows whether or not it is correctly graduated and the amount of any error that may exist.

For any other temperature than freezing, except the boiling temperature, the thermometer to be tested and a standard are placed in a bath of water, if the temperature is above freezing, or of alcohol if below freezing. The liquid being thoroughly stirred so as to render the temperature uniform throughout, a quickly made reading of the two thermometers shows the amount of error in the graduations of the one under test.

When a large number of instruments are to be compared with standards, as is the case at the Weather Bureau, the thermometers are collected together in bunches of 12 each. Only the glass tubes are placed in the bunches, the metal backs of the thermometers being removed during comparison, not only to avoid bulkiness but to prevent the injurious effects and slight corrosion of the metal caused by the water and alcohol baths. The bunches are formed upon flat metal frames adapted to receive six thermometers on each face, front and back, the thermometers being held by rubber bands.

For the freezing-point test a small wooden box 5 inches wide, 4 inches deep, and 18 inches long is employed. To permit the water from the melting ice to escape, the bottom is pierced with irregularly distributed holes 1 inch in diameter and about 2½ inches apart. This box is nearly filled with clean, shaved ice, bunch after bunch of thermometers are placed therein and new ice added and packed closely around each thermometer and piled up above the sides of the box until the bunches are wholly covered, being supported by the ice.

The readings of the thermometers are then made and recorded, the ice being scraped away so as to expose the stems in the vicinity of the ends of the mercurial columns. A small eye-lens is always employed to assist the vision and to insure that the line of sight is exactly at right angles to the stem of the thermometer.

This reading glass consists of a small lens having a focal length of about 1¼ inches. It is set in a brass tube ½ inch in diameter and 3 inches long. The lens is about 1¼ inches from one end of the tube and the opposite end is closed by a metal cap having a small hole in the center, about one-sixteenth of an inch in diameter. In reading a thermometer the open end of the brass tube is set squarely against the glass stem while the eye sights through the small hole in the cap. The eye estimates fractions of a degree to the nearest tenth, or, if the graduations are halves or fifths of degrees, then the estimation is to the nearest hundredth of a degree.

The tests at the freezing temperature are followed by tests at temperatures 42°, 52°, and so on, for every ten degrees up to 102° or 112°. The apparatus employed consists of two cylindrical copper cans, one within the other. The outer can is 12 inches in diameter, the inner 8.5, and each is 13 inches high. Three feet upon the bottom of the inner can make a space of three-quarters of an inch between the bottoms of the two vessels. The inside vessel is fitted with a light metal frame in the form of a square, with one side removed and having three prongs or arms with notches at the ends that fit over the rim of the can. The frame is thus supported over the center of the vessel and on a level with its top. Two bunches of thermometers may be placed within the open square, the sides of which are provided, in addition, with several holes three-eighths of an inch in diameter, through one of which is placed the working substandard, as may be most convenient for use during comparisons. A short fragment of small rubber tubing slipped over the stem of the substandard prevents it from passing entirely through the relatively large hole in the frame and permits placing the bulb of the substandard at the same depth in the can as those of the bunched thermometers. These latter are submerged to within about one-half inch of the top of the stem.

The two cylindrical vessels are not fastened, the one to the other. The smaller sets loosely but about centrally within the other. Each is fitted with a dasher for effectually stirring the water, with which both vessels are filled brimming full. These dashers consist of annular brass plates fitted with an upright rod of brass attached at one side and reaching just above the top edge of the vessels, respectively, where a large thumbscrew head is attached that facilitates grasping the dasher. The dasher in the outer vessel traverses the annular space between the two; that within the smaller vessel encircles the bunched thermometers hanging in the center. The comparator is placed within a shallow tray of the photographer's type, to retain the water which may accidentally slop over.

The comparisons require the services of two persons—the observer and the recorder.

The numbers of the twelve thermometers constituting a bunch are recorded in the record book of observations in two groups of six numbers each, representing the six thermometers on one face of the bunch. An additional space in each group contains the number of the substandard used in the comparison, and the two groups are classed together under a number corresponding to that stamped on the metal plate of the bunch; the side bearing the number is the front, the other is the back.

The comparisons, for example at 42°, are made as follows: Two bunches of thermometers and the substandard are placed in the bath. Ice in small fragments is added to the water until the temperature is less than half a degree above or below 42°. A slight excess of ice is allowed to remain, and if the room in which the comparison is made is comfortably warm the temperature of the water in the outside vessel is regulated to be 1° or 2° lower than that of the inside vessel, in order to lessen the tendency of the temperature of the baths to rise.

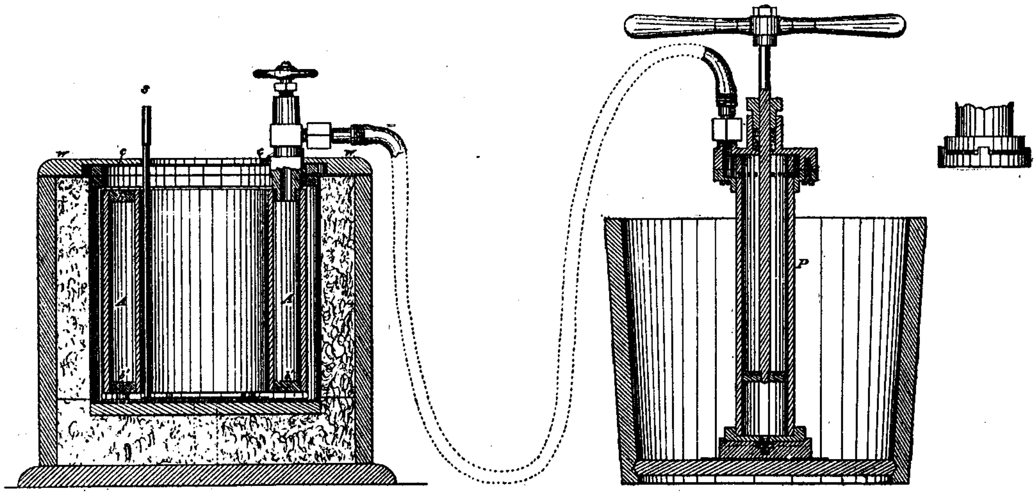
The water is stirred actively by hand, and when the temperature, by a few preliminary readings of the substandard, is seen to change very little the stirring is suspended, a careful reading of the substandard is made and recorded, and immediately followed by recording the readings of the six thermometers on the face of the first bunch, which is lifted in the water a little so as to expose the tops of the columns. The bunch is turned back to the front, the water thoroughly stirred, the substandard and the six thermometers on the back of the bunch read and recorded. The bunch is removed from the water, which is again stirred, and readings of the second bunch are made and recorded in precisely the same manner.

When special accuracy is to be attained the readings at each temperature are repeated as many times as may be desired.

The temperature of the water baths is increased by replacing a portion of their contents, withdrawn by a siphon, with hot water.

When comparisons are made at temperatures below freezing, the low-temperature comparator has been found to answer all requirements in a most admirable manner, and has been used to produce temperatures as low as 65° F. below zero. Still lower temperatures, it seems, are easily obtained, though up to this time no occasion to go to lower temperatures has arisen.

The annular iron flask A is made of the best iron boiler-flue tubing, strongly fitted with the headpieces *b b′*. The outside diameter of the two tubes is, respectively, 6 and 9 inches, the flask being 9 inches high and containing about 1 gallon. The whole stands within a copper can, itself placed within a larger wooden jacket, the interspace being filled with cotton. A top plate of metal, *c c*, partly covers the can, to which it is tightly screwed, leaving a circular opening at the center of about the same diameter as the inside of the flask A. The whole is again covered, except the opening, by a loosely fitting wooden plate, *w w*. The alcohol with which the can is filled can be



CUT 50.—Low-temperature comparator.

stirred in a most thorough manner by means of a disk dasher, S, moving near the bottom of the can and within the iron flask. This passes the alcohol in a rapid manner from the inner portion to the outside around the iron flask and vice versa, with the most satisfactory results.

The iron flask, by means of the screw-threaded outlet of its valve, can be joined by a very short piece of pipe to a flask of ammonia, which, in this case, must always be upside down in order to run off the liquid. If the flask A contains air, generally only a small quantity of liquid ammonia will enter, and this is best effected by opening the valves quite promptly. To further charge the flask it is first necessary to drive out the air, for which the stock ammonia flask is disconnected and a rubber tube or other outlet attached. The ammonia in the gaseous state, when permitted to escape from A, carries with it the air also. The temperature of the alcohol is gradually lowered, and if an additional supply of ammonia is needed any quantity may be drawn from the supply flask out of which the ammonia will now be strongly forced by its greater vapor pressure, due to the difference of temperature of the two flasks. The ammonia gas is best disposed of by passing it into a bottle or other vessel of water, which is thus, in time, converted into excellent aqua ammonia.

One can judge of the quantity drawn off only by the sound and such circumstances. A note, however, is always kept of the weights of the stock flask, giving not only how much has been withdrawn, but its present contents as well. Between 4 and 5 pounds of ammonia are sufficient to lower the temperature to —65° and work at various intermediate temperatures for several hours. The temperature can be readily lowered to any point down to —20° F., simply using the rubber tube and water vessel. At this point, however, the escape of the ammonia gas is slow, owing to its diminished pressure. The pump shown at P is then brought into requisition. The diameter of the barrel is nearly 3 inches and the construction is somewhat peculiar, there being but one valve. Connection with the flask A is made at the top of the pump, the communication with the inside being through the small holes near the top of the cylinder. The piston when in its highest position is above these holes. At the bottom of the cylinder is a large, flat valve, closing upward with gentle pressure. From the valve way the passages to the outside are seen in the side view of this portion of the pump. The valve itself is pierced with a small hole of only about one-sixteenth inch diameter, and the whole pump is securely fastened inside a bucket or similar vessel nearly filled with water, which makes its way into the pump through the small hole in the valve; in some cases of low inside pressure quite a fountain-like jet of water is formed. With the piston in its highest position the ammonia has free communication to the pump cylinder and is rapidly absorbed by the water which is readily renewed by emptying the cylinder with a stroke of the piston. The absorption of the ammonia by the water is very vigorous generally, and the number of strokes of the pump necessary to dispose of a comparatively large volume of gas is correspondingly small.

The pump is remarkably effective, though when not in action the piston must be secured in a lowered position in order to prevent the rise of heated water into the tube and possibly the flask A, though the valve of the latter is generally kept closed when the gas is not being drawn off. During the escape of the gas the flask and its contents are always noticeably colder than the alcohol, so that it is easy to secure very nearly a stationary temperature of the latter for several minutes, shortly after the valve is closed.

Except as otherwise specially mentioned all measurements of the differences in level of the mercurial columns were made with a most excellent and substantial cathetometer made some years since by the Société Genevois. The vertical bar is a cylinder supported on sharp cones at both top and bottom. The two telescopes are each fitted with excellent micrometer eyepieces. Only one of these was used, and its micrometer screw was examined for errors, which were found so small as to be quite unimportant, and no correction for this was necessary. Except in the very first work the distance of the manometer tubes from the objective was 359 mm., and the micrometer reticule was 349 mm. from the objective. The image, therefore, is about the same size as the object.

Many determinations of the value of one division of the micrometer were made during the progress of the work, with only very slightly different results. One division corresponded almost exactly to 0.005 mm., and this could be subdivided to tenths by estimation.

The value of one division of the telescope level was nearly three seconds. The level was at all times carefully watched and sometimes recorded, but corrections for errors of this kind were always unnecessary, as the cathetometer in this respect, as in all others, has proved to be a most perfect instrument.

The comparisons of special forms of thermometers require slight modifications of the processes that have been described.

Alcohol thermometers are much slower in changing temperature than mercurial thermometers, both on account of the less conductivity of the liquid and because of the adhesion of liquid to the walls of the stem. Time must be allowed for the liquid to drain down when observations are made under conditions of falling temperature.

Maximum thermometers are not as a rule compared below freezing, and require a special apparatus for whirling them while packed in ice. The temperature of the water baths should be allowed or caused to gradually increase while comparing maximum thermometers.

The upsetting deep-sea thermometers, owing to the peculiar construction of the bulb, require prolonged exposure in ice; about a half hour is allowed, to make sure that the bulb is at a true freezing temperature. The bunches of these thermometers contain only six instruments, three on a side. The bunch is upset while still packed with ice, which is then partially removed for reading. At other temperatures only one large vessel of water is used. After about five minutes exposure to a stationary temperature, the water being thoroughly stirred, the substandard is read, the bunch upset in the water, and readings made and recorded.

REDUCTION OF OBSERVATIONS.

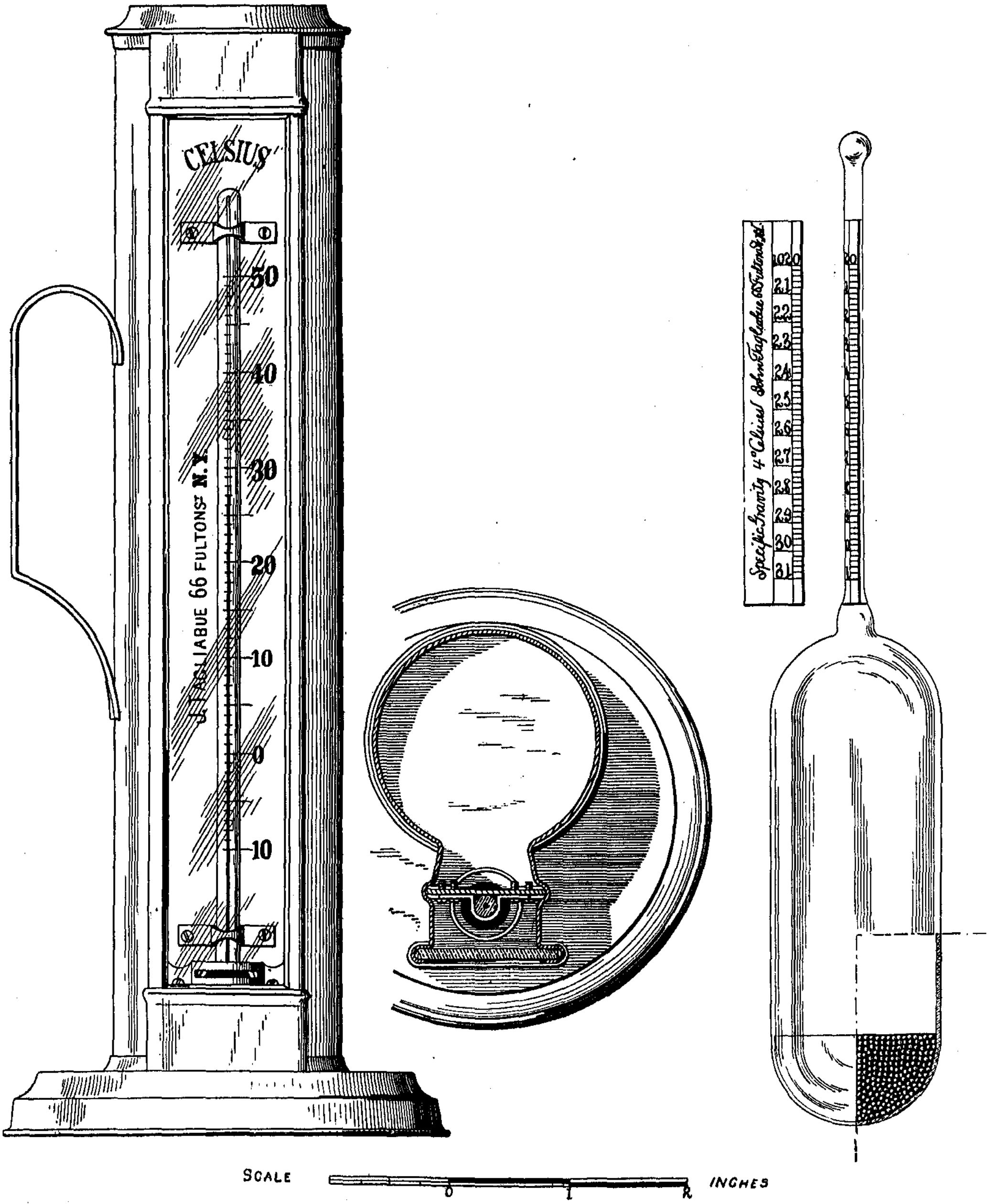
Each substandard, after comparison with the air thermometer, is provided with a table of normal corrections, but these for convenience are computed on the supposition that the correction at the freezing point is 0.0°, for the reason that, as already pointed out under "A third source of error," on page 331, the correction at the freezing point is apt to change from time to time, especially after the substandard has been used at some high temperature, say 130° F., or more. When any doubt exists as to what corrections to apply to the indications of the substandard, it should be tested at the freezing point. Suppose we find the thermometer reads 0.23 of a degree too high, the true correction at the freezing point is therefore −0.23°, and this amount must be algebraically added to each correction given in the table of normals.

The recorded readings of the substandard being corrected by the application of the corrections found in the above manner, we have the true temperature of the water according to the air-thermometer scale during the several comparisons. The correction of a thermometer at the temperature of one of these observations is the quantity which must be *algebraically added* to its reading in order to make the reading indicate the true temperature of the water, that is, to make the reading agree with the corrected reading of the substandard.

Thermometers require recomparison from time to time, but only at the freezing point. Whatever change in the correction is found necessary at this point must also be made in each of the other corrections found in the original comparisons. This is explained in the remarks about the corrections to be used with the substandard.

When a greater or less portion of the mercurial column in the stem of the thermometer is exposed to a different temperature than the bulb, the indications are slightly in error and a correction should be applied. This is sometimes necessary in the use of long substandards. It is to be avoided as far as possible.

PLATE XXIII.



THE HILGARD OCEAN SALINOMETER.

DENSITY OF SEA WATER.

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 15° C. only varies between the limits 1.023 and 1.028 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, a salinometer (plate XXIII) was devised for the Coast Survey by Prof. J. E. Hilgard, which was subsequently adopted for use on board the vessels of the United States Fish Commission. Fahrenheit thermometers were used, and the densities given by the graduation of the hydrometer were referred to pure water at 60° F. The centigrade scale was adopted by the Coast and Geodetic Survey and by the United States Fish Commission in 1890, and all hydrometer observations since then are referred to that scale, the densities being reduced to the temperature of 15° C. referred to pure water at 4° C.

Hilgard's ocean salinometer is composed of a series of cylindrical glass floats numbered 1, 2, and 3, respectively, their bodies 4½ inches in length by 1¼ inches in diameter, the stems 4½ inches in length and $\frac{3}{16}$ inch in diameter, the scales being marked on the interior of the stems. The range of No. 1 is from 1000, or fresh water, to 1011; No. 2 from 1010 to 1021, and No. 3 from 1020 to 1031, which gives sufficient range from fresh water to salt, including the effect of temperature. Each unit in the third place, or thousands of the density of fresh water, is represented by a length on the stem 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 vessel for holding the specimen of water is of copper, cylindrical in form, 9¾ inches in length and 1⅞ inches in diameter, with a base of 3¾ inches. The water cup itself is 8⅞ inches long and 1⅞ inches in diameter. The attached thermometer is inclosed within a water-tight, glass-faced frame, secured to the cylindrical body of the cup, a section of the latter being removed to allow free circulation of water between its interior and the thermometer. The temperatures are read through the glazed front. The floats are packed separately in 1¾ by 10¾ inch tubes or cylinders of tin, in which they are protected by cotton, and the stems have additional protection of hollow, cotton-lined, wooden sleeves, which envelop them, slip inside of the tin tubes, and impinge upon balls of cotton, with which their covers are lined.

A working set of three floats and a cup, the former in their tubes of tin, are packed in neatly fitting woolen-lined apertures in a handy wooden box 11 inches long, 10 inches wide, and 4 inches high, inside measurement. Spare floats are also provided with tin tubes, in which they are always packed, either for transportation or stowage.

To observe the specific gravity of a specimen of sea water, fill the cup, clean and dry the float, lower it carefully into the water, causing it to overflow from the top of the cup, and, when the float has come to a rest, read off the scale at the surface of the water, not from the water immediately surrounding the stem, where it is slightly elevated by the effects of capillary attraction; note temperature of water by attached thermometer, and correct observed density by means of subjoined table.

As before stated, the variation in specific gravity of sea water is so small that the greatest accuracy is required to give value to observations, and experience alone will teach the observer how difficult it is to obtain satisfactory results on shipboard when the vessel is under way, particularly if there is much motion. In order to avoid this fruitful source of error, a supply of the best quality of glass bottles, with ground-glass stoppers, were procured from the manufacturers, C. Dorflinger & Sons, who describe the material as follows:

> This grade of glass is what is called "lead glass" and has been made especially for the work of the United States Fish Commission and the National Museum. It is a glass that is very suitable for making specimen jars and work of this character, and is composed of sand, red lead, pearl ash, nitre, arsenic, and manganese. The quantity of arsenic is so small that it burns out in the melting and there is no trace of it in the glass, neither is there anything in it that sea water will affect.

The water specimens are carefully sealed in these bottles until calm, smooth weather, or till the vessel reaches port, when the temperature of the specimens is brought as nearly to the required standard of 15° C. as convenient and the densities carefully observed. It has been said that the stoppers might not be tight, foreign substances might be accidentally introduced into the bottles, or that the sea water might attack the material of the glass itself, thereby changing the specific gravity, all of which might have happened had not proper precautions been taken.

In the first place, the quality of glass is proof against the action of sea water, at least for the short space of time the specimens are exposed; the bottles are carefully cleansed and dried before using, and they are sealed with as much care as though they contained volatile matter. The water specimens are retained no longer than necessary, usually from a day to a week, never more than two weeks, and the densities are observed with great care, under the most favorable conditions.

Rear-Admiral Makaroff, Imperial Russian navy, author of Le Vitiaz et l'Ocean Pacifique, St. Petersburg, 1894, and one of the highest authorities on the specific gravity of sea water, thought the salinometer cup was too small, but his opinion was based upon a casual inspection only, as he had never seen it in operation. Its adoption by the United States Coast Survey and Fish Commission was upon the approval of the most eminent physicists in the United States, and it has been in constant service for many years without eliciting unfavorable comment in a single instance; on the contrary, it has been commended in the highest terms as the most simple and thoroughly practical appliance ever introduced for the purpose.

The table for the reduction of observed densities to 15° C. is taken from Dittmar, Physics and Chemistry, Challenger Expedition, vol. 1, after applying to his densities one-half of the correction given by him for reducing them to Thorpe and Rucker's results. The temperature at which the density of standard water is 1.02600 has been shifted from 15.56° to 15° C. for the sake of getting an integer number. The table has been rearranged so as to give the densities of the standard water multiplied by 1000, for whole degrees and tenths from 0° to 30.9° C. on one page. The values given should have the figures 10 prefixed; these are omitted for brevity's sake. Thus in the table the density for 2.5° is printed 27.92, but this must be understood to mean 1027.92.

The ratio designated $\varphi(t)$ by Dittmar is omitted, and only its reciprocal is given in the column headed m. The values there given appertain to the temperatures on the same horizontal lines given in the first column. The use of this function is illustrated in the examples in which it appears as a multiplier for the purpose of allowing for the different rates of expansion between standard water and the water the density of which is being determined.

The last column has been added to this table for convenience, and gives the correction for change in the volume of the hydrometer itself. The values given have been computed for the mean reading 1026, and with the assumed coefficient of cubical expansion for glass $a=.000025$.

Table for reducing densities of sea water to 15° C.

°	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	m	a
0	28.08	28.07	28.07	28.06	28.06	28.05	28.04	28.04	28.03	28.03	.951	+0.38
1	.02	.01	.01	.00	.00	27.99	27.99	27.98	27.97	27.97	.955	.35
2	27.96	27.96	27.95	27.94	27.92	.92	.91	.90	.89	.88	.960	.33
3	.87	.87	.86	.85	.84	.83	.82	.81	.80	.79	.963	.30
4	.78	.77	.76	.75	.74	.72	.71	.70	.69	.68	.967	.27
5	.67	.66	.65	.64	.63	.61	.60	.59	.58	.57	.970	.25
6	.56	.55	.53	.52	.51	.50	.48	.47	.46	.44	.973	.23
7	.43	.41	.40	.38	.37	.35	.34	.32	.31	.30	.976	.20
8	.28	.26	.25	.23	.22	.20	.19	.17	.16	.15	.980	.17
9	.13	.11	.10	.08	.07	.05	.03	.02	.00	26.98	.983	.15
10	26.97	26.95	26.93	26.92	26.90	26.88	26.86	26.84	26.83	.81	.986	.13
11	.79	.77	.75	.74	.72	.70	.68	.66	.65	.62	.989	.10
12	.61	.59	.57	.55	.53	.51	.49	.47	.45	.43	.992	.08
13	.41	.39	.37	.35	.33	.31	.29	.27	.25	.23	.995	.05
14	.21	.19	.17	.15	.13	.10	.08	.06	.04	.02	.997	.02
15	.00	25.98	25.95	25.93	25.91	25.88	25.86	25.84	25.82	25.79	1.000	.00
16	25.77	.75	.72	.70	.68	.65	.63	.61	.59	.56	1.003	−0.02
17	.54	.52	.49	.47	.45	.42	.40	.38	.35	.33	1.005	.05
18	.30	.27	.25	.22	.20	.17	.14	.12	.09	.07	1.007	.08
19	.04	.01	24.99	24.96	24.94	24.91	24.88	24.86	24.83	24.80	1.009	.10
20	24.78	24.75	.73	.70	.68	.65	.62	.60	.57	.54	1.011	.13
21	.52	.49	.47	.44	.41	.39	.36	.33	.30	.28	1.013	.15
22	.25	.22	.19	.16	.13	.10	.08	.05	.02	23.99	1.015	.17
23	23.96	23.93	23.90	23.87	23.84	23.82	23.79	23.76	23.73	.70	1.018	.20
24	.67	.64	.61	.58	.55	.53	.50	.47	.43	.40	1.020	.23
25	.38	.35	.32	.29	.26	.23	.20	.17	.14	.11	1.022	.25
26	.09	.06	.03	23.00	22.97	22.93	22.90	22.87	22.84	22.81	1.024	.27
27	22.78	22.75	22.72	22.68	.65	.62	.59	.56	.53	.50	1.026	.30
28	.46	.43	.39	.36	.33	.29	.26	.23	.20	.16	1.027	.33
29	.13	.10	.06	.03	.00	21.96	21.93	21.90	21.87	21.84	1.029	.35
30	21.80	21.77	21.73	21.70	21.67	.63	.60	.57	.54	.50	1.031	.38

The following directions are given to facilitate the use of the table: The observed specific gravity having been taken, record the actual reading of the hydrometer and thermometer, and apply the correction to the latter to get the true temperature t. To the reading of the hydrometer apply the correction a, for expansion of hydrometer, according to its sign, which will give the observed density at $t=$OD. The density of standard sea water at $t=$SD, and the difference between observed density and density of standard water at $t=$OD—SD, being multiplied by the tabular multiplier m, and the quotient applied to standard sea water at 15° C., according to its sign, gives the corrected density of the sample water at 15° C.

EXAMPLE I.	EXAMPLE II.	
°	°	
23.0	10.5	obs. temp.
—0.1	—.2	corr. to thermometer.
22.9	10.3	corrected temp. $=t$.
1021.00	1029.29	observed hydr. reading.
—0.20	+.12	corr. for expansion of hydr. $=a$.
......	......	corr. for hydrometer constant.
1020.80	1029.41	observed density at $t=$ OD.
1023.99	1026.92	density of standard water at $t=$ SD.
—3.19	+2.49	OD—SD.
1.018	.987	*m*, tabular multiplier.
—3.25	+2.46	*m* (OD—SD).
1026.00	1026.00	standard water at 15° C.
1022.75	1028.46	corrected density at 15°.

For observations which have been reduced to 60° F., made with the old hydrometers indicating densities referred to pure water at 60° F., it will suffice to subtract the constant 0.82 from the result in order to convert the latter into absolute densities at 15° C.

Example: Given 1024.00, the density of salt water at 60° F. referred to pure water at 60° F., 1024.00—0.82=1023.18, its density at 15° C.

The above plan of decimal notation in Examples I and II, also in the table, is adopted for the sake of simplicity and convenience. The corrected densities will, however, be recorded in the customary manner, as follows: 1.02275—1.02846.

The remarks on reduction of observed densities, the illustrative examples, and table for reducing densities of sea water to 15° C. are taken from Bulletin No. 18, United States Coast and Geodetic Survey.

SIGSBEE'S WATER-SPECIMEN CUP.

The Sigsbee water-specimen cup (plate XXIV) 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 can not be opened again, except by hand. Therefore these cups may be used in series, any desired number being sent down on the same line. 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, page 93.

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.

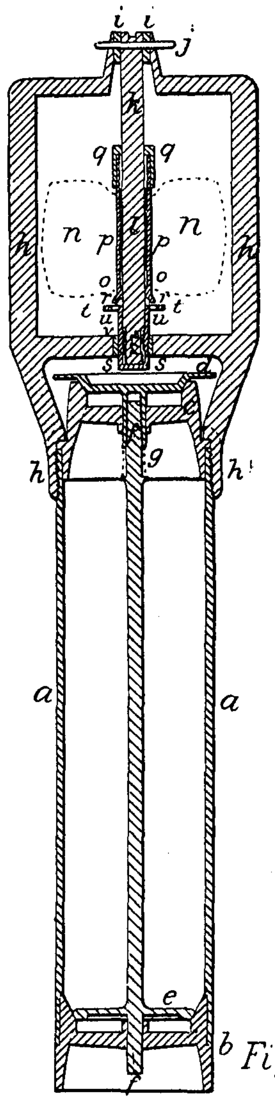


Fig. 1.

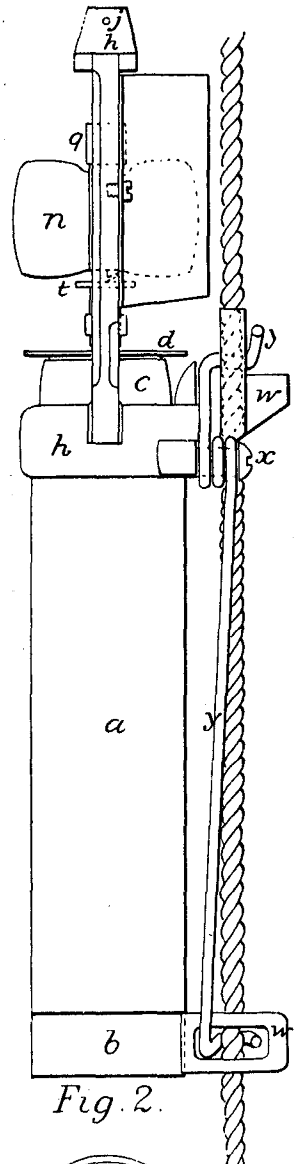


Fig. 2.

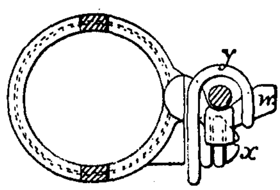


Fig. 4.

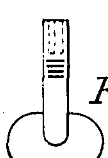


Fig. 5

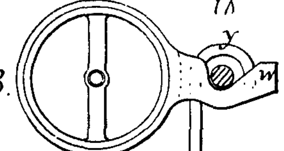


Fig. 3.

THE SIGSBEE WATER SPECIMEN CUP.

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.

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 is 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 seaway 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 can not 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 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.

THE KIDDER-FLINT WATER BOTTLE.

The Kidder-Flint water bottle (plate XXV) 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 when the ascent is begun, and can not be opened again except by hand. Therefore it may be used in series.

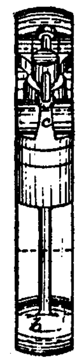
All parts of this water bottle are brass, except the propeller blades, which are of German silver. The cylinder is a tube of commercial pattern; the frames, valves, valve seats, etc., are cast brass.


51.


52.


53.


54.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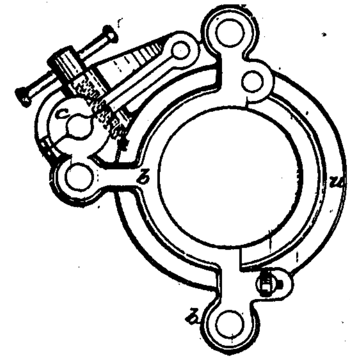
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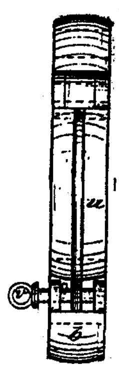
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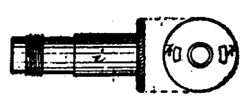
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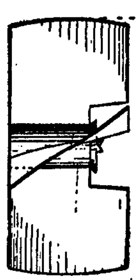
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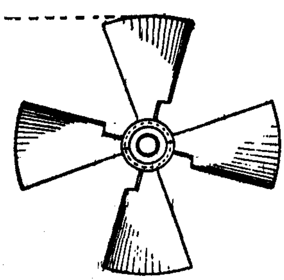

60.

CUTS 51 and 52.—Side and bottom view of outer arms of propeller frame.
CUTS 53 and 54.—Side and bottom view of inner arms of propeller frame.
CUT 55.—Side view of frame *b*, showing clamp *c*.
CUT 56.—Front view of frame *b*, clamp *c*, and clamp *u*.
CUT 57.—Side view of frame *b*, clamp *u*, and pin *v*.
CUT 58.—Side view of sleeve *i* and front view of beveled slots *k k*.
CUT 59.—Side view of propeller, showing beveled lugs.
CUT 60.—Bottom view of propeller.

Preparation for use.—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 *e* and 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

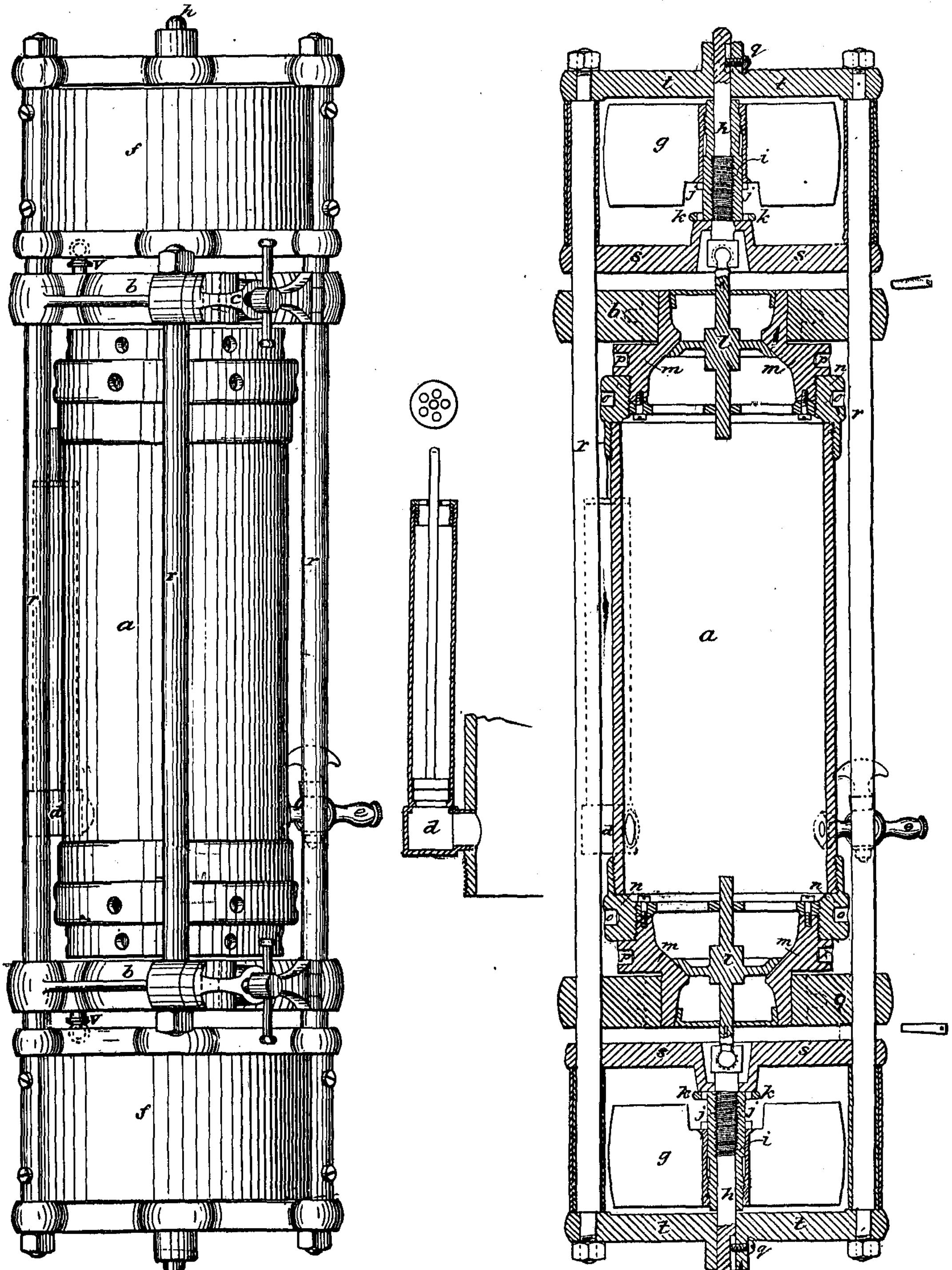


Fig. 1. Fig. 2.

THE KIDDER-FLINT WATER BOTTLE.

Nomenclature.

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

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 frame *b*, the valve stems *l* connected with the shafts *h*, and the cylinder secured in place by the clamps *u* and the pins *v*. The valves should then be opened inward to their full extent by means of the milled head at *k*. Secure the bottle to the rope by the clamps *c*, with the expansion chamber pointing upward, 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.

This water bottle was devised by Dr. J. H. Kidder, of the United States Fish Commission; Surgeon J. M. Flint, U. S. N., attached to the *Albatross*, and the writer. It is an elaboration of the Sigsbee water-specimen cup, carefully and strongly constructed, and, while it has successfully withstood an internal pressure of 150 pounds per square inch, there are still some mechanical imperfections to be remedied before it will be considered entirely satisfactory. It was first used on board the *Albatross* in 1884.

THE DEVELOPMENT OF DEEP-SEA EXPLORATION.

The systematic exploration of the deep sea has been confined almost entirely to the second half of the nineteenth century, and may be said to have commenced with the general introduction of steam, which not only furnished power to hoist the dredge, but brought the vessel under sufficient control for successfully working the apparatus. A sailing vessel, even under favorable conditions, was not well adapted for the work of deep-sea exploration; there were no means of preventing her drifting to leeward when hove to, and this made the preliminary operation of sounding, even in a few hundred fathoms, a difficult matter with the old-fashioned deep-sea lead line, which was slow to sink, and with its great and uncertain angle left the actual depth requisite to the successful operation of the dredge still in doubt. Hemp dredge rope, used prior to 1877, was another serious obstacle to the extension of deep-sea exploration—its size increasing with the depth, and the weights required to sink it to the bottom, in spite of the rapid drift of the vessel, increasing the load beyond the lifting capacity of appliances then found on shipboard.

Müller, one of the first recorded investigators, used a small dredge on the Danish and Norwegian coasts as early as 1779, but 30 fathoms was his greatest depth. Sir John Ross brought up specimens of animal life about 1819 with his "deep-sea clamm" from 1,000 fathoms, which caused much comment, as 300 fathoms had been generally considered the limit beyond which no life existed in the waters of the sea.

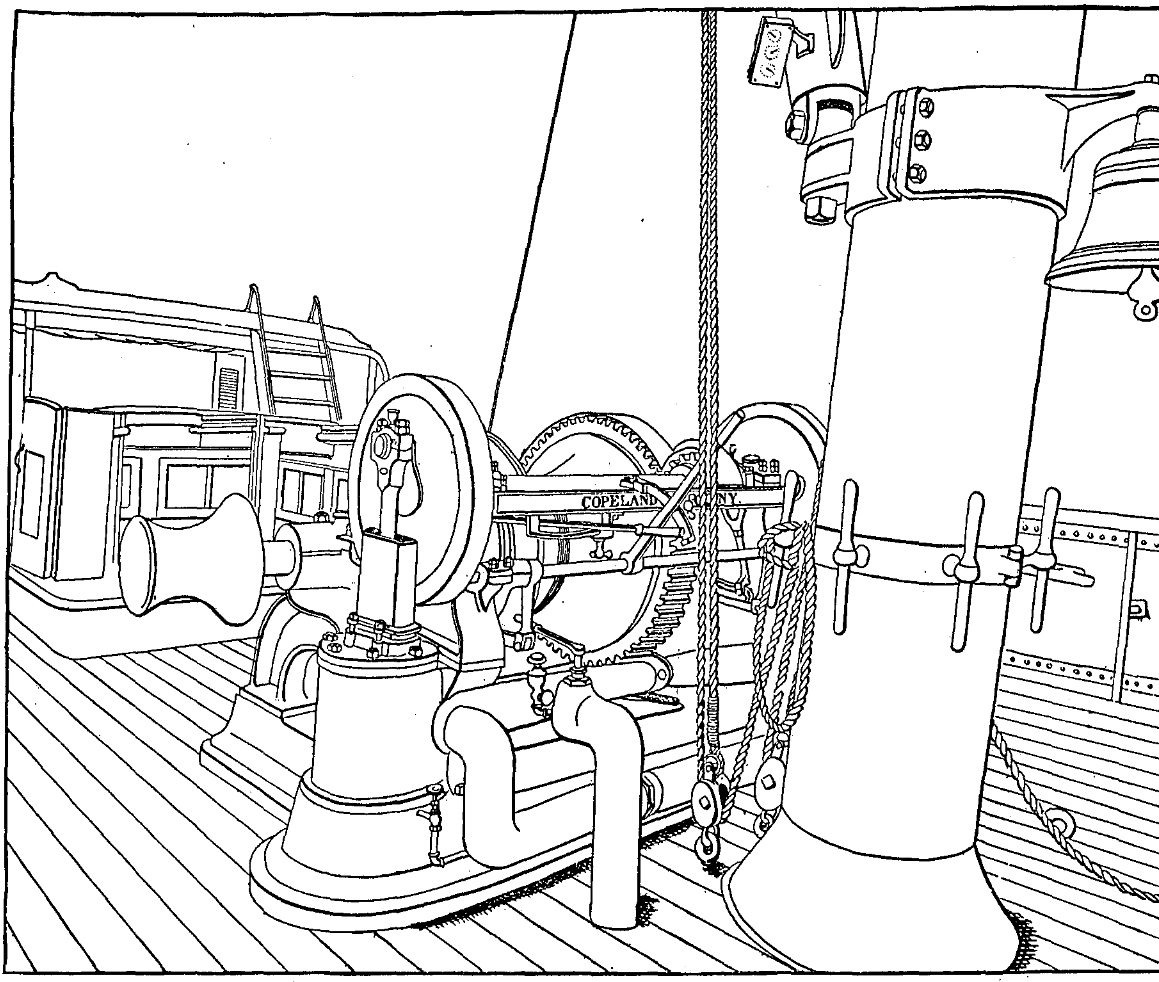
Prof. Louis Agassiz commenced his explorations of the coast waters of the United States in 1847, and Verrill and Stimpson followed in 1859, all confined to depths within 50 fathoms. In 1860 Dr. Wallich reported starfish from 1,200 fathoms, brought up on the sounding line.

From 1866 to 1869 Pourtales made an extended series of dredgings on board the Coast Survey steamer *Corwin*, Acting Master Robert Platt, U. S. N. He made a successful haul in 800 fathoms between Key West and Havana, and reached the unprecedented depth of 1,125 fathoms in the Yucatan Channel.

In 1868 Wyville Thomson and Dr. Carpenter, on board the *Lightning*, dredged in 600 fathoms between Scotland and the Faroe Islands, where they found an abundance of marine life, and, extending their explorations to 1869–70, on board the *Porcupine*, they made a successful haul of the dredge in 2,435 fathoms, which was a great triumph, considering the crude appliances of the day.

The United States Fish Commission commenced dredging operations in 1871, using hemp rope, as their predecessors had done, and, working from small vessels having limited space, with imperfect appliances of a temporary nature, they were restricted to depths not exceeding 150 fathoms.

H. B. M. S. *Challenger*, a spar-decked sloop of war of 2,000 tons and 1,200 horse-power, an unusually commodious vessel, was fitted out for deep-sea exploration and sailed on her memorable scientific cruise around the world in December, 1872. Her equipment included large quantities of hemp dredge rope which, when wet, was heavy and bulky, requiring much labor to properly attend and care for it, yet her large and

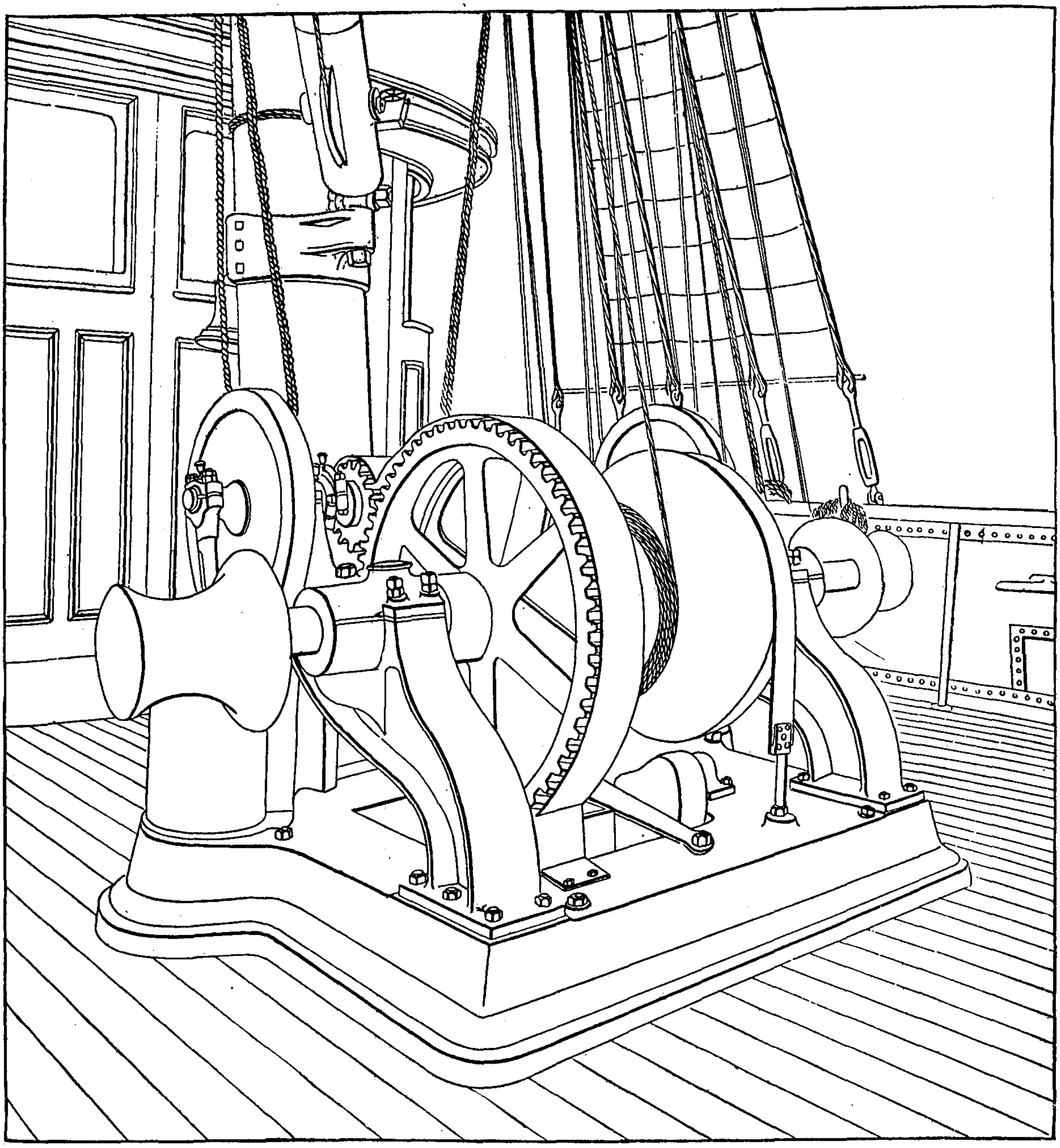


DREDGING ENGINE: AFT, LOOKING FORWARD.

Dimensions.

Greatest diameter of large gypsy head	inches..	36½
Least diameter of large gypsy head	do....	22 15/16
Length of large gypsy head on line of its axis	do....	24
Diameter of inboard end of small gypsy heads	do....	21½
Diameter of outboard end of small gypsy heads	do....	11⅛
Diameter of middle of small gypsy heads	do....	8½
Length of small gypsy heads on line of their axes	do....	12½
Total length over three gypsy heads	do....	113½
Diameter of main shaft	do....	4⅛
Diameter of spur wheel at pitch line	do....	40
Pitch of teeth of gearing	do....	2 1/16
Width of face of gearing	do....	6
Width of face of friction brake	do....	4
Number of journals on main shaft		2
Diameter of journals on main shaft	inches..	4
Length of journals on main shaft	do....	13
Diameter of pinion on pitch line	do....	9

Number of steam cylinders		2
Diameter of steam cylinders	inches..	10⅛
Width of piston trunks fore and aft	do....	9
Width of piston trunks athwartship	do....	2¾
Area of cross-section of each trunk	square inches..	23½
Net area of steam pistons, each	do....	74.84
Stroke of pistons	inches..	10
Number of journals on crank shaft		2
Diameter of crank-shaft journals	inches..	3¼
Length of crank-shaft journals	do....	6
Diameter of crank pins	do....	1⅞
Length of crank pins	do....	2
Length of engine base fore and aft	do....	60
Width of engine base athwartship	do....	96
Height of engine	do....	53½
Weight of engine	pounds..	6,500



DREDGING ENGINE: FORWARD, LOOKING AFT

trained crew were able to handle it with alacrity, coiling it upon specially prepared pins as it was hove up or throw it off as rapidly as required for veering. The dredge and trawl were hoisted by steam power, a donkey engine being provided for the purpose. It had an ordinary gypsy head, around which several turns were taken with the rope, which was then attended by hand. The *Challenger* was the largest and best-appointed vessel ever employed in deep-sea exploration, and her subsequent achievements, including a successful haul of the beam trawl in 2,650 fathoms and a dredge haul in 3,875 fathoms, are sufficient proof of her efficiency.

The introduction of steel-wire dredge rope on board the United States Coast Survey steamer *Blake* in 1877 effected a revolution in deep-sea dredging as complete as the use of pianoforte wire accomplished in the methods of sounding.

The earlier investigations of the United States Fish Commission were conducted on board small vessels loaned by the Navy Department and temporarily equipped for deep-sea exploration. Hemp line was used for sounding, also for dredging and trawling, an ordinary engine with a single gypsy head being employed for hoisting.

A marked advance was made in the equipment of the *Fish Hawk* by the introduction of pianoforte wire for sounding and steel-wire rope for dredging.

All the later improvements bearing upon the work of the *Albatross* were embodied in her equipment, which also included many novel appliances.

DREDGING ENGINE.

Plates XXVI and XXVII 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, etc. 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.

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 XXXI), which is a series of rubber "buffers" moving freely on their longitudinal axes by the tension on the dredge rope, becomes a good dynamometer. 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-eighths 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:

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 horsepower developed by the engine	15.563
Indicated horsepower required to work the engine	1.453
Horsepower absorbed by the friction of the load	1.167
Net horsepower applied to the tension on the rope	12.943
Horsepower accounted for by the dynamometer	12.327
Horsepower absorbed by slipping and bending of the rope on gypsy head	.616

The 15.563 horsepower indicated by the engine is divided as follows:

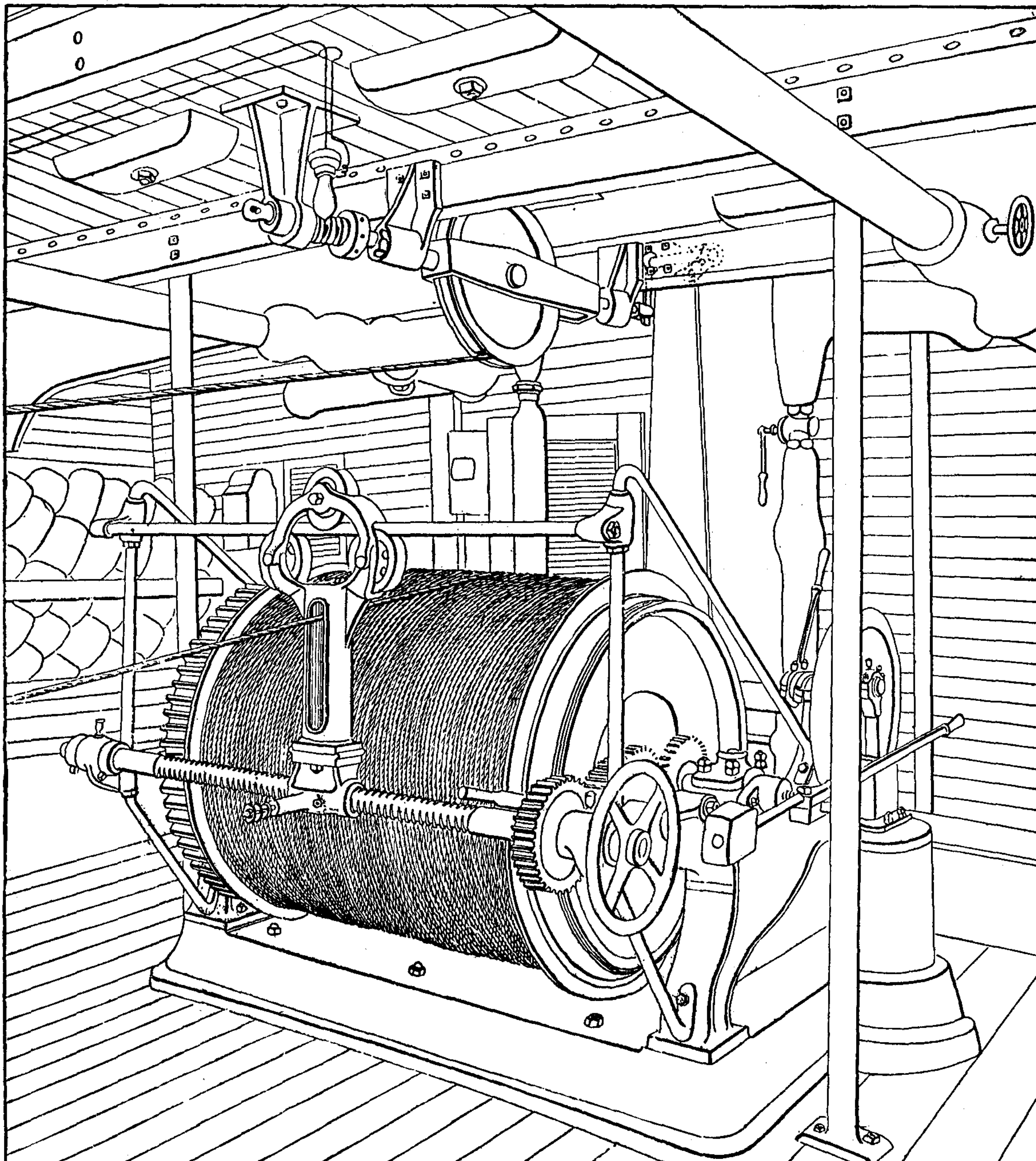
	Per cent.
For pulling in the rope	79.207
For working the engines	9.335
For overcoming the friction of the load	7.500
For overcoming the slip and bending of the rope	3.958
	100.000

REELING ENGINE.

The reeling engine 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 it. The guide is actuated by a double screw, with equal right and left pitches, 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

*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.



REELING ENGINE AND GOVERNOR.

Principal dimensions and weight of reeling engine and wire rope.

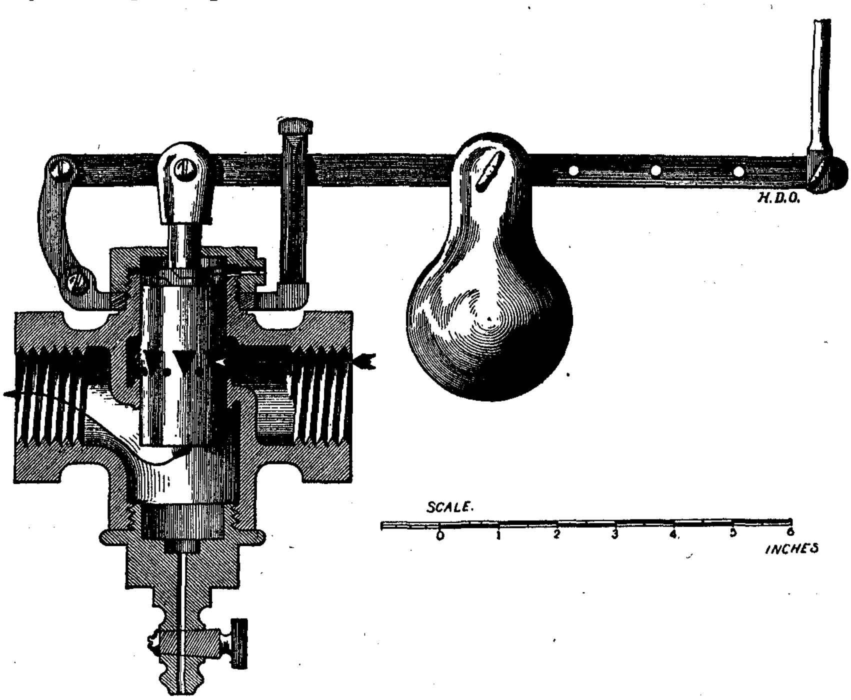
Diameter of drum	inches..	16
Length of drum	do....	36
Width of flanges	do....	17
Ratio of gearing		$4\frac{3}{16}$:1
Number of steam cylinders		2
Diameter of steam cylinders	inches..	$7\frac{1}{2}$
Stroke of pistons	do....	8
Length of $\frac{3}{8}$-inch diameter wire rope reel will hold	fathoms..	4,500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

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

THE GOVERNOR.

The hoisting engine being located on the main 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 former would govern those of the latter. For this purpose the governor (plate XXIX) was devised by the writer. It maintains a practically uniform tension on the dredge rope between the hoisting and reeling engines by causing the speed of the latter to conform to that of the former.



CUT 61.—Watson & McDaniel pressure-regulating valve.

The reeling engine was located on the berth deck to lower its weight in the ship and to protect it and its appurtenances from the weather.

The governor consists of the sheave *a*, within the iron frame *b*, which moves freely on horizontal axes fore and aft, allowing the sheave to revolve in any plane in conformity with the angle of the dredge rope. The forward motion of the frame *b* is checked and governed by the spring *f*, which is adjusted by the nut *e* and screwbolt *g*. On the after end of the frame *b* is a connection to an arm of a bell crank *d*, which, through the connecting rod *h*, actuates a pressure-regulating valve (cut 61) on the steam pipe between the throttle valve and reeling engine.

This valve was introduced at the suggestion of Chief Engineer Baird, U. S. N., as more effective than the original plan of attaching the bell crank directly to the throttle valve. It acts quickly, is not liable to derangement, and is easily adjusted by pinning the connecting rod *h* through a hole in the lever, which gives the valve the desired lift.

A leading block n, 13 feet forward of the drum, may be considered a part of the governor, although detached from it. A spiral spring in its stem gives it a horizontal motion of about 6 inches, for the purpose of taking up a portion of the slack rope when it surges on the hoisting drum, thus reducing the jar and aiding in the maintenance of a uniform tension.

To adjust the governor, unwind a fathom or two of dredge rope from the reel and attach a scale to the bight, between the reel and leading block *n*; close the pressure valve and open the throttle wide; then by adjusting the nut *e*, screwbolt *g*, and connecting rod *h* admit steam to the reeling engine until the desired tension say, 300 pounds, is shown on the scale. It is advisable to verify it occasionally until the attendant becomes familiar with his duties, when he will readily make the necessary adjustment while the engines are in operation, by first shutting off steam through the pressure valve until the dredge rope is seen to slip on the hoisting drum, then gradually admitting it again until the rope is properly wound on the reel without unnecessary tension.

The friction clutch on the drum of the reeling engine is adjusted by a lever, so that the reel slips and ceases to turn when the prescribed limit of tension is exceeded, as happens if the pressure valve fails to act, or if the hoisting engine is suddenly reversed, in an emergency, for the immediate veering of rope.

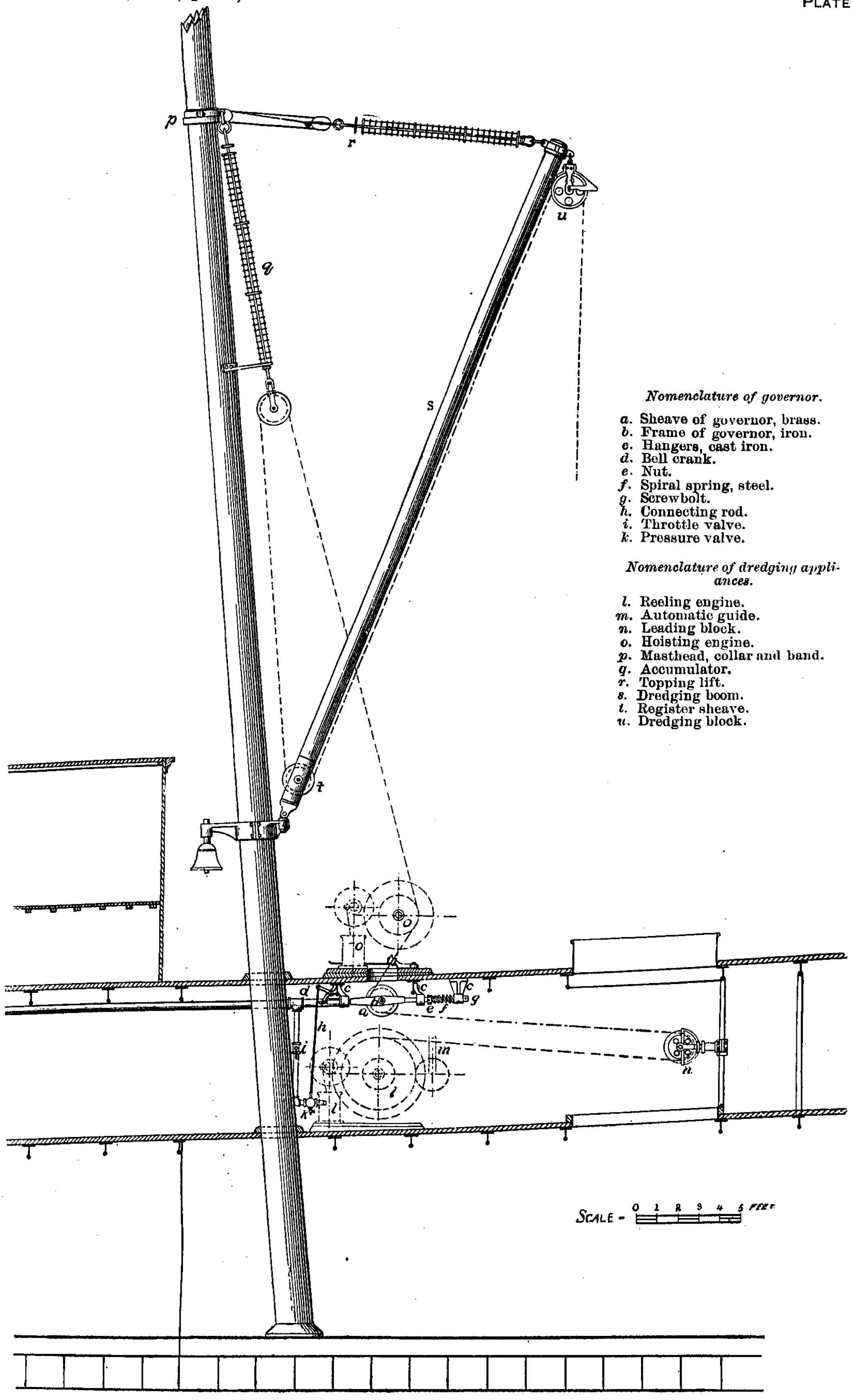
The action of the governor is as follows: When tension is applied to the dredge rope, the pressure on the sheave *a* forces the frame *b* forward until it is arrested by the increasing compression of the spiral spring *f*; the forward movement actuating the bell crank *d* and connecting rod *h* causes the pressure valve to close and shut off steam in proportion to the movement, finally stopping the engine when the limit has been reached. The reverse movement, resulting from diminished tension on the rope, gradually admits steam through the pressure valve and starts the engine.

LEAD OF THE DREDGE ROPE.

The rope having been wound on the drum *l* of the reeling engine (plate XXIX) is first led through the automatic guide *m*, then under and over the leading block *n*, under and over the governor sheave *a*, thence to the hoisting drum *o* of the dredging engine, around which five turns are taken from forward aft and from starboard to port. The end is then carried aloft and rove, from forward aft, through the block at the lower end of the accumulator *q*, which is suspended from the mast, then under the register sheave *t* in the heel of the dredging boom, and finally over and under the dredging block *w* at the boom end.

The dredging boom s is of spruce, 36 feet in length and 10 inches in diameter. Its outer end is inclosed in a heavy brass cap and band, which has four eyebolts at equal intervals on its periphery, one each for the topping lift *r* and dredging block *u*; also one each on the forward and after sides for the boom guys. A capped sleeve of brass incases its heel. It is about 2 feet in length, mortised to receive the register pulley *t*, and enlarged on its sides to form bearings for its shaft. The heel of the boom is supported by a hinged socket bolt which passes through a hole in a heavy composition band on the foremast, upon which it pivots and turns freely and is prevented from unshipping by a nut and washer.

PLATE XXIX.



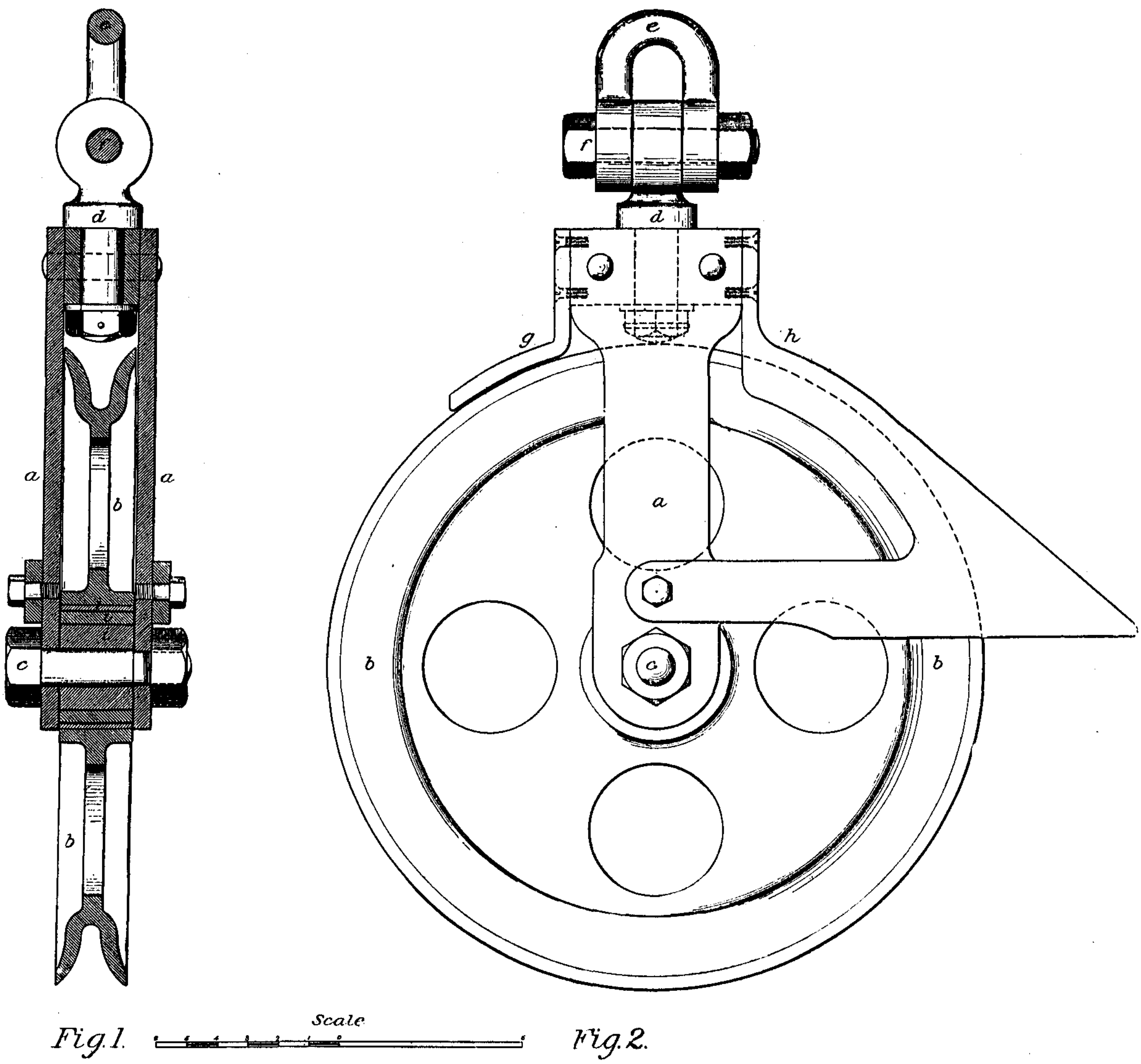
Nomenclature of governor.

a. Sheave of governor, brass.
b. Frame of governor, iron.
c. Hangers, cast iron.
d. Bell crank.
e. Nut.
f. Spiral spring, steel.
g. Screwbolt.
h. Connecting rod.
i. Throttle valve.
k. Pressure valve.

Nomenclature of dredging appliances.

l. Reeling engine.
m. Automatic guide.
n. Leading block.
o. Hoisting engine.
p. Masthead, collar and band.
q. Accumulator.
r. Topping lift.
s. Dredging boom.
t. Register sheave.
u. Dredging block.

LEAD OF THE DREDGE ROPE, SHOWING GOVERNOR.



DREDGING BLOCK.

Nomenclature.

a. Frame.
b. Sheave.
c. Pin.
d. Shackle bolt.
e. Shackle.
f. Shackle pin.
g. Guard.
h. Hood.
i. Bushings.

The function of the boom is to lead the dredge rope clear of the ship's side. When rigged for service, elevated at an angle of 50°, it gives a clearance of about 10 feet. When not in use, it is lowered to a horizontal position with its forward end resting upon the topgallant forecastle.

The register pulley t in the heel of the boom is of brass with a deep, narrow groove, and serves to lead the dredge rope from the accumulator *g* to the lower side of the dredging boom, besides performing its function of registering pulley. The register is attached to the left side of the sleeve at the heel of the dredging boom, is actuated by a worm wheel carried on the shaft of the register pulley, and records the number of fathoms of dredge rope out.

The boom topping lift r is a twofold purchase of 3½-inch manila rope, its hauling part shackles to a link in the masthead band *p;* the lower block is shackled to the upper end of an accumulator which, in turn, shackles to an eyebolt at the boom end. Shackles are used on the topping lift to prevent unhooking in case the dredge rope should part under heavy tension. An accumulator is attached to the topping lift to supplement the action of the main accumulator.

The boom guys, one forward and one aft, are twofold purchases of 2½-inch manila rope, heavier than required for simply holding the boom, but they are used at times in hoisting an overloaded trawl over the rail.

The boom purchase is a twofold tackle with 2½-inch manila rope used for hoisting the trawl on board; it hooks to one leg of a short pendant, the other leg carrying the after boom guy.

The dredging blocks (plate XXX) two in number, used on the lower end of the accumulator and at the outer end of the dredging boom, are leads for the dredge rope; fig. 1 is a sectional elevation, and fig. 2 a side view.

The frame *a* is composed of two pieces of bar iron 5½ inches wide at one end, 4½ at the other, 3½ in the center, and 1½ inch thick; they are secured by riveted bolts to a block of wrought iron 5½ inches in length, 2½ in width, and 2½ in depth, having through its center a 1⅝-inch hole for the shackle bolt *d.* The sheave *b* is of composition 21½ inches total diameter, 18 inches diameter at the bottom of the score, and 2¼ inches in width. It has three antifriction bushings *i i i,* the outer one of steel, fitted rigidly in place, the middle one of phosphor bronze, and the inner one of iron. The two latter move freely, and they are furnished with oil grooves on both inner and outer surfaces. The pin *c* is of cast steel, 1¼ inches in diameter. It has a shoulder at one end, which acts as a spreader for the frame and is held in place by a screw thread and nut.

The shackle bolt *d,* the shackle *e,* and the pin *f* are of the best American iron. The former is held in place by a nut and washer, which allow it to turn freely and act as a swivel. The guard *g* is of wrought iron and is intended to prevent the dredge rope from flying out of the sheave. The hood *h* acts as a guard and assists in turning the block in line with the rope so that it will lead fairly into the score of the sheave. It is a bronze casting. The nuts on the block are secured with drift pins; the guard and hood are used only on the block at the boom end.

The masthead collar and band (plate XXIX) are placed 13 inches below the futtock band on the foremast, and the accumulator and topping lift are shackled to eyes in the band. The collar is fitted in the following manner: A strong wrought-iron band, flanged on its lower edge, is secured to the mast by wood screws; the band, also of wrought iron, is in two parts with jaws on each side, through which $1\frac{1}{4}$-inch bolts are passed and set up with nuts. When properly adjusted, there remain intervals of 2 inches between the jaws, and in these spaces, supported by the bolts, hang two links, one on each side, to which the topping lift shackles. An eye in the forward part of the band supports the accumulator, which is shackled to it.

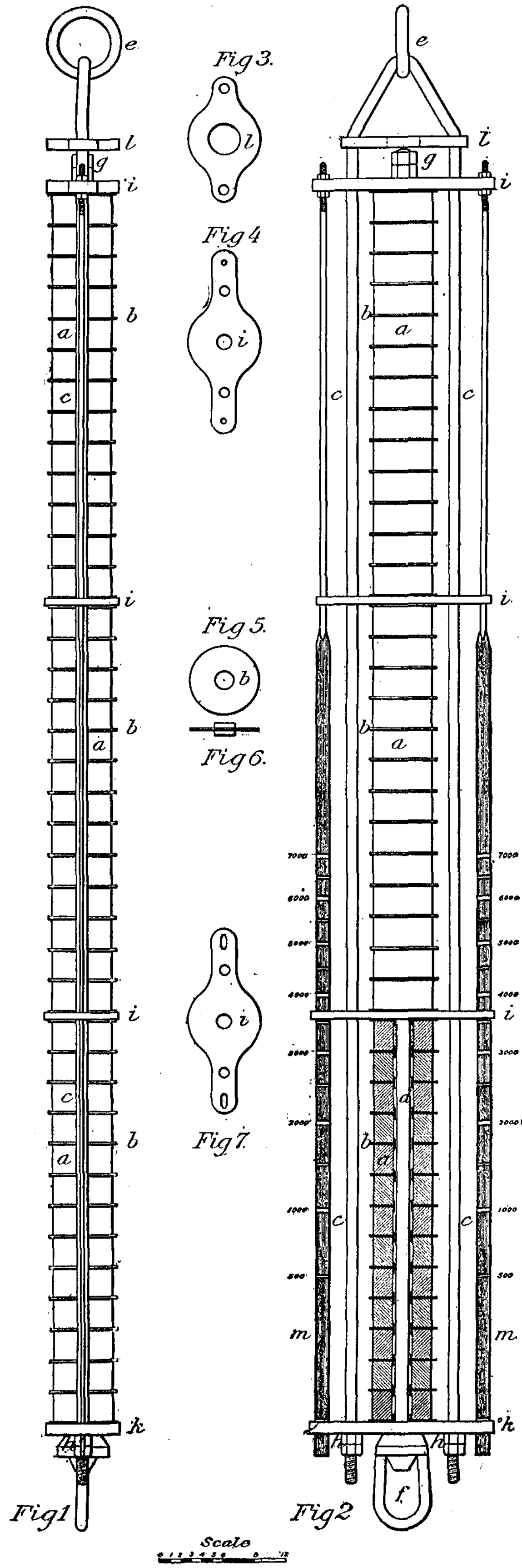
THE ACCUMULATOR.

The accumulator (plate XXXI) performs the several functions of relieving the dredge rope from jerking strains brought upon it by motion of the vessel in a seaway, insuring a more uniform action of the hoisting engine and giving the first warning of increased tension on the rope in case the trawl fouls or buries in the soft bottom when working in deep water. It also acts as a dynamometer, indicating through a graduated scale the strain to which the rope is subjected.

The guide rods c are made of a single length of round mild steel 1 inch in diameter, bent at *e* and *l*, with screw threads and lock nuts at *h*. The tension rod is of mild steel, round in section, $1\frac{1}{4}$ inches in diameter, and 9 feet 9 inches net length—that is, measured inside the crosshead *i* and yoke *k*. It holds 39 buffers without compression, and usually carries 44 in service. 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 other extremity. The total length of the accumulator, including the links at each end, is 12 feet 1 inch.

The crosshead i, yoke *k*, and tie-plate *l* are of wrought iron; the former move freely on the guide rods *c*, the upper one receiving the ends of the tension rod *d* and scales *m*, while the lower ones support the guide rods and scale bars. A front view of the tie-plate *l* is shown in fig. 3, the two upper crossheads *i* in fig. 4, while fig. 7 shows the lower crosshead *i* with slots in each end through which the scales slide. The slots are made wider in the middle section to protect the painted marks on the scale bars. There is a brass washer *b* between each rubber buffer, as seen in fig. 2, where they are shown in section; they are $6\frac{3}{8}$ inches in diameter, $\frac{3}{16}$ inch thick, with a hole $1\frac{5}{16}$ inch diameter in the center. Hubs one-half inch in length extend from each side of the washers (figs. 5 and 6), except those in contact with the yoke and crossheads, which have no hub on that side. The buffers were furnished by the New York Rubber Belting Company, and are composed of their No. 23 compound; they are $5\frac{1}{2}$ inches in diameter, 3 inches thick, and have a hole $1\frac{7}{16}$ inch diameter through the center. They weigh 4 pounds 3 ounces each and cost 67 cents per pound.

The scales m are composed of two flat bars of iron, $1\frac{1}{4}$ inches wide and $\frac{1}{4}$ inch thick, attached to the sides of the accumulator, as shown in fig. 2. The upper ends are round, and carry screw threads and nuts, by which they are secured rigidly to the upper crosshead; thence they pass down through holes in the upper middle crosshead and through slots in the lower crosshead and yoke. The scale bars are graduated from the lower ends by putting gradually increasing strains on the dredge rope, rove through its blocks as for service, and to avoid accident under the higher tensions it is customary on board the *Albatross* to lay accumulator and blocks on deck or on a wharf and to use new rope; the divisions are made by painting white marks of different widths across the bars, the narrow ones representing 500 and the wide ones 1,000 pounds. The graduations once made, adjustments, incident to long service or climatic influence upon the material of the buffers, may be effected by the nuts at the upper ends of the scale bars.



Nomenclature.

a. Rubber buffers.
b. Washers.
c. Guide rods.
d. Tension rod.
e. Link.
f. Swivel link.
g. Lock nuts on tension rod.
h. Lock nuts on guide rods.
i. Cross heads.
k. Yoke.
l. Tieplate.
m. Scale.

THE ACCUMULATOR.

The action of the accumulator as a dynamometer is as follows: Tension on the dredge rope compresses the buffers, causing the scale bars to project beneath the yoke, when the degree of strain is read from the bars at their point of contact with its lower face. The marks are the same on both scale bars and on both sides of the bars, so that they can be read from forward or aft, or from either side of the deck.

The hubs on the brass washers, which prevent the buffers from coming in contact with the tension rod, were devised by Lieut. 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 illustration shows 39 buffers mounted without compression; hence the 500-pound mark on the scale is some distance above the yoke; while in actual practice, with 44 buffers under compression, it would be lowered nearly to it.

STEEL-WIRE DREDGE ROPE.

Steel-wire dredge rope was suggested by Prof. Alexander Agassiz, and first used on board the Coast Survey steamer *Blake* in 1877, when its superiority over all other material was so conclusively demonstrated that it henceforth became the standard for deep-sea exploration. The *Blake's* rope was made by the John A. Roebling's Son's Company, Trenton, N. J. It was composed of 42 galvanized steel wires, No. 19 American gauge, in 6 strands of 7 wires each, laid around a hemp heart. It was 1.125 inch in circumference, weighed 1.14 pound per fathom in air, about 1 pound in sea water, and its ultimate strength was 8,750 pounds. A kink reduced its breaking strain to 4,500 pounds.

Steel wire dredge rope was first used by the U. S. Fish Commission on board the *Fish Hawk* in 1880. It was identical with the *Blake's* rope except that it had no hemp heart.

The *Albatross's* rope of 1882 was made by the Hazard Manufacturing Company, Wilkesbarre, Pa. It was composed of 42 galvanized steel wires of the company's special gauge, approximating to No. 18 American gauge, with 6 strands of 7 wires each, and had a hemp heart. It was 1.18 inch in circumference, weighed 1.32 pound per fathom in air, about 1.2 pound in sea water, and its breaking strain was 12,850 pounds. A kink reduced its strength about 50 per cent. It was made of the best crucible steel and developed great tensile strength, but it was stiff and unpliable, kinked badly, and usually broke without warning, like tempered steel. It was used, however, until 1886, when an effort was made to procure a more pliable rope without sacrificing strength or materially increasing its size.

A quantity of English rope was procured through the agency of J. W. Mason & Co., New York, which was made of the best English mild extra plow steel, composed of 42 galvanized steel wires, No. 18½ B. W. G., approximating to No. 17 American gauge, with 6 strands of 7 wires each, around a hemp heart. It is 1.184 inch in circumference, weighs 1.31 pound per fathom in air, 1.09 pound in sea water, and its breaking strain is 14,000 pounds. It is more pliable than crucible steel rope, less liable to kink, and consequently more durable. The loss of strength resulting from a kink is about 40 per cent.

A long splice, from 20 to 25 feet, is used to join two pieces of dredge rope, and its general features are the same as a long splice in hemp or manila, due regard being had for the difference in material. It requires close observation to detect a well-made splice, and it is as strong as any other part of the rope; at least it was found by experience on board the *Albatross* that it parted away from the splices quite as often as at them.

To turn in a thimble on the working end of the dredge rope, make an ordinary eye splice over a large oblong thimble, sticking the ends three times, tapering them as is usual with hemp or manila rope, and if a neat job is required serve the splice with annealed wire or marline.

A swivel shackle is used to attach the trawl to the dredge rope. Its utility is a mooted question, for the swivel will not work under tension, yet it turns freely the moment the strain is removed from the rope after a long or heavy lift, and this relief may be of service in lessening the liability to kink while lowering the trawl for a subsequent cast.

The preservation of galvanized steel-wire dredge rope from rust is of little moment while it is new, but as the zinc wears off and the steel is exposed its life may be materially lengthened by the systematic application of a suitable preservative. It rarely happens in service that more than one-half of the rope is paid out, and when it is reeled in it is always wet with salt water, which percolates from layer to layer through the rope remaining on the reel, keeping it constantly wet during the working season. It is to the action of sea water thus confined that we trace one of the main causes of oxidation.

It has been the custom on board the *Albatross* to run the rope off from its reel twice a year, winding it directly upon the steam capstan, which is furnished with suitable wooden heads for the purpose. It is carefully wiped as it leaves the reel, the splices and nips or partial kinks are examined, and the necessary repairs made; and a clear day having been selected for the transfer, the rope reaches the capstan quite dry.

The service reel having been examined and painted, the rope is replaced upon it, and during its transit it is again wiped and given a coat of linseed oil, as many men as can work to advantage being stationed between the capstan and reeling engine for this purpose; oil is freely distributed over the rope after it has reached the reel, and by constant dripping from layer to layer during the process of winding it penetrates the interstices of wires and strands, and by the time the rope is all upon the reel it has become thoroughly coated.

The fluidity of the oil may be greatly increased, and its application facilitated by warming it; this may be done by keeping it in a bucket of hot water while it is being applied.

Spare rope on wooden reels requires no attention, providing the storeroom is dry and secure against occasional leakage; otherwise it will be well to see that the reel heads are tight and give the surface of the rope two or three coats of lead-colored paint.

The proper lengths in which dredge rope should be ordered will be governed by circumstances. It can be procured from the manufacturers in any desired length, delivered on wooden reels in convenient form for transfer to the service reel, or for storage. If large storerooms are available and facilities are at hand for handling heavy weights, or if it is practicable to carry the reel mounted upon an axle in readiness for running off wire without changing its position, a single length of 5,000 fathoms would seem to be best for the spare rope.

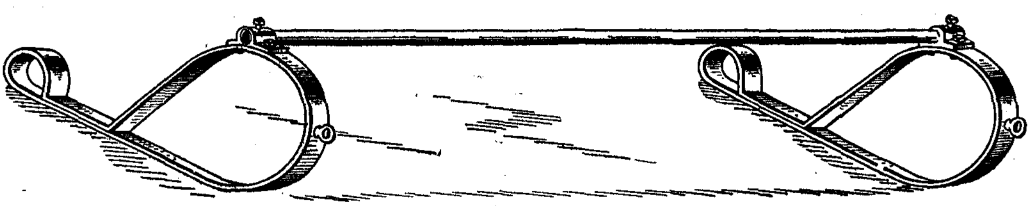
If the working reel is empty and is to be filled, a sufficient quantity should be ordered in one length. On board vessels of ordinary capacity, carrying, as the *Albatross* usually does, 4,000 fathoms of spare rope, there should be one reel containing a single length of 2,000 fathoms, one of 1,000 fathoms, and two with 500 fathoms each. The same wooden axle will answer for all of the reels.

The transfer of dredge rope from a wooden transporting reel to the service reel is a simple operation, providing the former is firmly secured in place and a strong uniform tension is maintained upon the rope. The transporting reel may be placed on deck, in the hold or storeroom or on a wharf, and the rope led through ordinary blocks to the dredging-boom end; thence to the service reel it should be led through its regular channels. The reading of the register should be noted in order that the exact amount of rope upon the reel may be known; in fact, it is good practice, strictly followed on board the *Albatross*, to note the register whenever rope is wound upon or veered from the service reel, either in large or small quantities, entering expenditures or losses from any cause in the record book, also noting the amount remaining in its appropriate place in the correction table; otherwise errors are sure to creep into the applied corrections.

BEAM-TRAWL FRAME.

The beam-trawl frame shown in cut 62 was in general use on board the *Albatross* during the first year of her cruise for both shoal and deep water work, and while it was satisfactory under ordinary conditions it was not considered the best form under all circumstances. Its dimensions are as follows:

Beam: Iron pipe; length, 11 feet; diameter, outside, 2⅞ inches; thickness of metal, $\frac{3}{16}$ inch.
Collars: Cast brass; length of flange, 9½ inches; width, 4 inches; thickness of metal, ⅜ inch.
Bolts: Iron; length, 2½ inches; diameter, ⅝ inch.
Runners: Flat bar iron, 4 inches wide, ⅞ inch thick; length, 5 feet; height, 2 feet 5 inches + 4 inches for the beam; total, 2 feet 9 inches.
Weight of frame, 365 pounds.



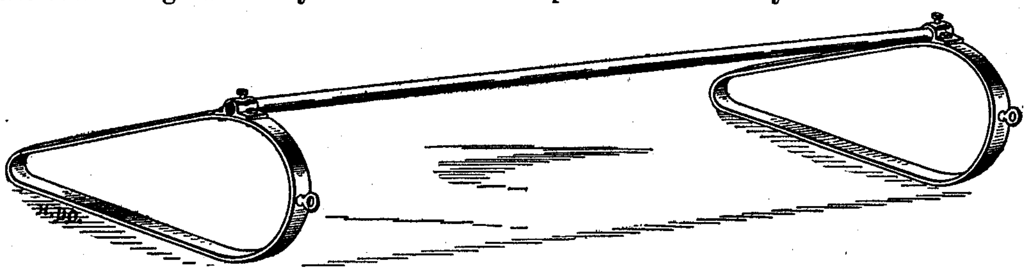
CUT 62.—Beam-trawl frame.

The several parts are interchangeable; the net with its appendages is identically the same as that used with the Tanner beam trawl No. 1 and will be described in connection with it.

THE TANNER BEAM-TRAWL FRAME.

The trawl frame shown in cut 63 is a modification of the form just described. The beam and collars remain the same and are interchangeable; the runners are the same length and height but their form is different, both top and bottom being made the same shape, thus doing away with all sharp angles and equalizing the strain over the various parts of the head of the net, besides carrying it higher in rear of the beam, giving the mouth a wider opening and greatly increasing its strength and efficiency. It is better balanced also and less liable to capsize in lowering or to catch on foul bottom; it is more simple in construction, and lighter by about 100 pounds, which is an advantage in handling it in a seaway. The jackstays and guard nets sometimes attached to the inner surfaces of the runners are useful in shoal water and in moderate depths, where swift-moving forms are mostly encountered.

The frame is composed of an iron beam having a brass collar screwed on each end and held rigidly in place by set screws. Each collar has two holes, through which square-headed bolts, with nuts, are passed for the purpose of securing it to its runner, the bolts being habitually carried in their respective holes ready for use.



CUT 63.—Tanner beam-trawl frame.

Eyebolts, to which the bridles are seized, are secured to the forward ends of the runners by nuts. Beams and runners are interchangeable.

THE TANNER BEAM TRAWL No. 1.

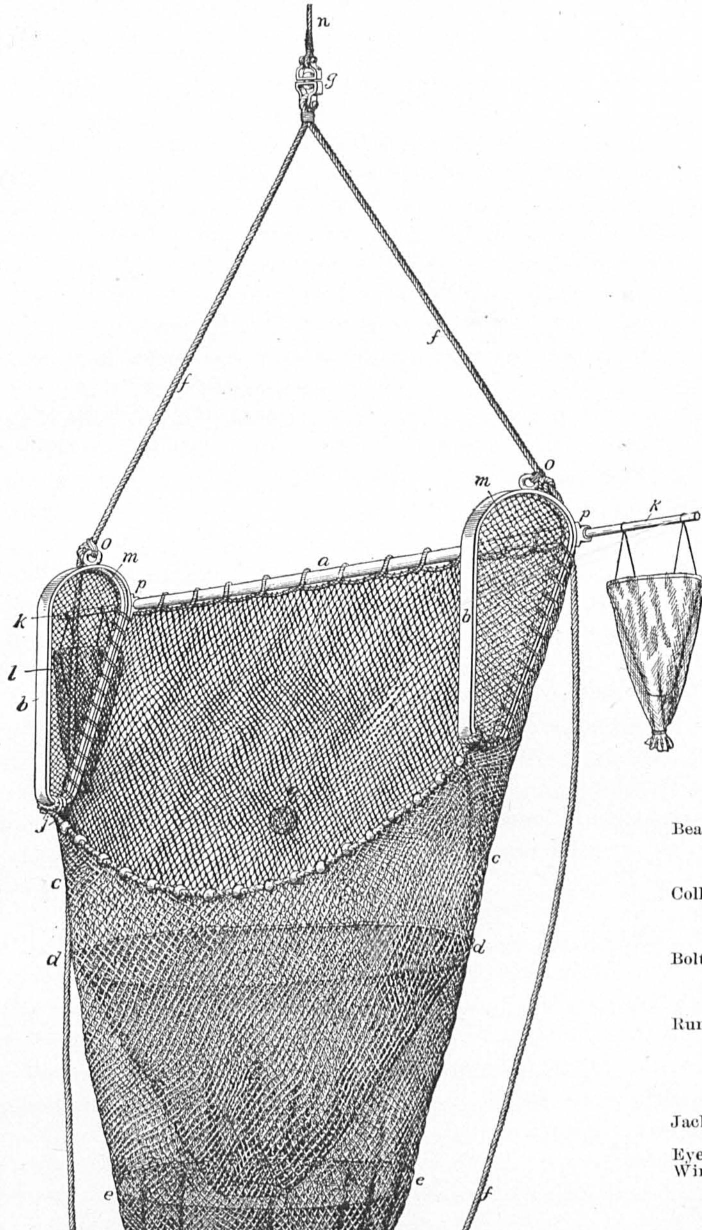
The trawl is here represented completely mounted (plate XXXII), ready for service, showing the method of attaching trawl net, bridles, wing nets, and mud bag, and, as it has become the standard on board the *Albatross* for general work, it will be described in detail.

To assemble the Tanner beam trawl, place the runners *b* and beam *a* in position, pass the bolts through holes in the collars *p* and runners *b*, and set the nuts tight with a wrench; place the head cringles or eyes of the trawl net over the heads of the beam set screws, middle a piece of 9-thread manila, and, commencing with the bight at the center of the beam, lace both ways to the beam ends, thence down the backs of the runners, securing the apron in the same manner, and, if there is end to spare, wrap it around the rear bends above the lead-rope hitches. Bend the free ends of the lead rope to the rear extremities of the runners, as low down as practicable, with a clove hitch, taking jamming turns above, if necessary, to prevent its slipping up; if there are spare ends, stop them along the back of the runners. Adjust the drawstring at the bottom of the pocket *d*, seize the bridle stops *o*, gather in the tail of the net and the bridle legs, pass the lashing *h*, and hitch the mud bag *i* to the eyes of the bridle legs.

The wing nets *l* are kept slung to the arms *k*, and to attach them to the trawl loosen the beam set-screws and slip them into the ends of the beam about 6 inches and hold them in place by again tightening the set-screw. Trawl weights are used to facilitate the sinking of the net, and ordinarily a single weight of 28 pounds is attached to each runner by a long tail rope, and one to the end of the net by a short

Nomenclature.

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



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.

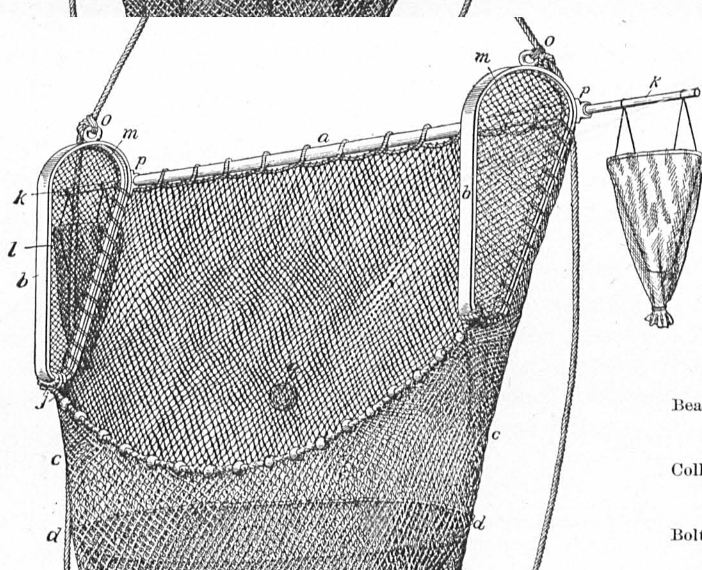
Runners (iron, flat-bar):
- Length, 5 feet.
- Height, 2 feet 5 inches; including collars, 2 feet 9 inches.
- Width, $3\frac{1}{2}$ inches.
- Thickness of metal, $\frac{1}{2}$ inch.

Jackstays (iron, round):
- Diameter, $\frac{1}{4}$ inch.

Eyebolts (brass): Diameter of metal, $\frac{3}{8}$ inch.

Wing nets:
- Arms, wood; length, 2 feet 6 inches; diameter, $2\frac{1}{2}$ inches.
- Nets, material, cheese-cloth; length, 3 feet.

l. Wing nets.
m. Guard nets.
n. Dredge rope.
o. Bridle stops.
p. Collars, brass.
q. Float glass.



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.

one. The long tails are used on the runners in order that they may be released from their weight as soon as the trawl frame reaches bottom, where its tendency is to sink into the mud or ooze, and the short lashing at the end of the net is to prevent the weight from interfering with the mud bag. The float *q* is seized to the back of the net a little forward of the lead rope, and its purpose is to enlarge its entrance.

The bridle is of 3-inch manila rope, 14 fathoms in length, and is fitted by turning a thimble into the bight, taking an overhand knot in both legs about 8 feet from the thimble, and splicing eyes in the ends, longer or shorter, as required to make the legs hang a little slack when the net is loaded.

The bridle stops are of marline; they are used to seize the bridle legs to the eyebolts in the forward end of the runners; the number of turns is determined by experiment, the intention being that they shall break before a dangerous strain is put upon the dredge rope. A Duckham weighing machine is used on board the *Albatross* for determining the strength of the stops, and with the ordinary quality of marline nine turns break with a load of 5,000 to 6,000 pounds, the limit allowed with new rope.

The bridle and bridle stops are practically the same for all of the trawls described except the Tanner No. 3, the only difference being in the length of the legs; those for the beam trawl and the Tanner No. 1 are the same; the Blake trawl requires them about 3 feet longer, and the Tanner No. 2 as much shorter.

Trawl weights are attached to frame and net in sufficient numbers to insure the prompt sinking of the trawl. They are square in cross section, 11 inches in length, 4 inches in diameter at the base, and 3 at the upper end, which is flattened and pierced with a hole for the tail. Manila rope, 15-thread, and 1 fathom in length, is used for the purpose. The apparently awkward shape was adopted to prevent the weights from rolling about the decks in heavy weather. They will stand upright ordinarily, and will not roll under any circumstances. They weigh from 28 to 30 pounds.

Tail lashings for trawl nets are of 15-thread manila rope, about 3 fathoms in length. Soft, pliable rope is preferred.

Floats for trawl nets were formerly made of cork, which answered the purpose in moderate depths, but became water-logged and worthless under the pressures encountered in deep-sea work; hence Norwegian glass floats were introduced. They are spherical in form, 6 to 7 inches in diameter, thickness of glass $\frac{1}{4}$ to $\frac{3}{8}$ inch, and they are inclosed within hand-made netting, having small eyes worked on opposite sides, through which their lashings are secured. Floats are attached to the upper part of the trawl net in rear of the beam, and it is their function to keep it elevated as much as possible, thus increasing the area of the opening or mouth. They have, with few exceptions, withstood the pressure even in depths approaching 3,000 fathoms, and they are seldom broken, owing to their secure position on the trawl net and the protection given them by their covering of netting.

Wing nets were introduced by Capt. H. C. Chester and first used on board the *Fish Hawk* in 1880. Nets of various forms have been used for intermediate collecting, but they were attached to the dredge rope. The present form is a modification of the Chester net, and was devised by the writer in 1884, since when they have been in constant use on board the *Albatross*. They are made of cheese-cloth in the following manner: The material is laid on deck and folded once, a pattern placed upon it, and the two halves cut from the piece at the same time; the side seams are then sewed up, the ends hemmed, and one extremity turned inward 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 tail lashing is sewed to the end of the net to prevent its being lost when cast adrift. There is a drawstring in the end of the pocket and a cord, with a knot in its lower end, is secured to the pocket and allowed to hang down far enough to be gathered in with the end of the net, and secured with the lashing to prevent its turning inside out when the trawl first takes the water. The arms are of wood, with deep scores for the reception of the bridles.

The mud bag is simply a boat dredge minus its net; the lower end of its canvas shield is closed for the purpose of bringing up an unwashed specimen of bottom soil. A detailed description will be found under the title of "boat dredge."

THE TANNER BEAM TRAWL NO. 2.

This trawl is a duplicate of No. 1, except that it is smaller and lighter, being especially designed for use in heavy weather when No. 1 can not be safely operated, or on doubtful or foul ground where the apparatus is liable to be sacrificed. It is much used also for rapid towing in shallow water in the examination of fishing banks.

Its dimensions are as follows:

Beam: Iron pipe, length, 7 feet 6 inches; outside diameter, 2¼ inches; thickness of metal, $\frac{3}{16}$ inch.
Collars, brass; width, 2 inches; thickness, ½ inch; length of flanges, 7 inches; diameter of bolts, ⅝ inch.
Runners: Length, 4 feet; height, 2 feet 3 inches + 3 inches for height of beam; total, 2 feet 6 inches; width, 2 inches; thickness of metal, ⅝ inch.
Weight of trawl frame, 140 pounds.
Rope for bridle, 2½ inches; manila.
Rope for lead rope, 2 inches; manila.
Rope for head rope, 1½ inches; manila.
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.
Float: Norwegian glass globe, diameter, 6 inches.

THE TANNER BEAM TRAWL NO. 3.

This handy little trawl has the same general form as Nos. 1 and 2, and is especially designed for boat service. It was first used in March, 1894, for the scientific exploration of San Diego Bay, California, when it was so highly appreciated that it was at once adopted as a part of the dredging outfit of the vessel. Its dimensions are as follows:

Beam: Iron pipe, length, 3 feet 6 inches; diameter outside, 1¼ inch.
Bolts: Iron, square; diameter, ½ inch.
Runners: Iron, flat bar, 1½ by ¼ inch; length, 2 feet 7 inches; height, 1 foot 1 inch.
Weight of frame, 16 pounds.
Net: Material, cotton, barked, 21-thread; size of mesh, 1 inch square; length of net, 7 feet; jacket material, cotton; thread, 24–6 stow, barked; size of mesh of jacket, ¼ inch square; length of jacket, 2 feet 6 inches.
Rope: Head, leech, lead ropes, and bridle, 9-thread manila; tow rope 15-thread manila.

The several parts of the frame are secured by close-fitting square bolts through holes in the runners and flattened ends of the beam, set up with nuts. The legs of the bridle are secured to the runners with light seizings, and the ends extended to the tail lashing, as in Nos. 1 and 2, for the purpose of recovering the net tail first, in case the trawl is caught on the bottom and the bridle stops part.

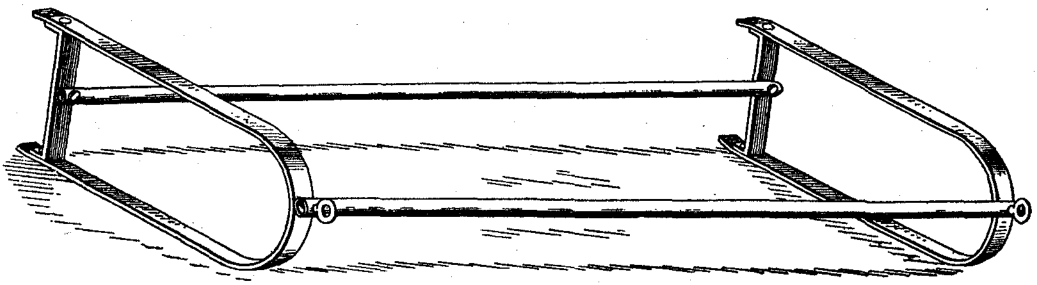
A float of cork is used upon the top of the net to extend its mouth. The pocket is omitted to save weight.

THE BLAKE DEEP-SEA TRAWL.

The Blake Trawl (cut 64) is designed for deep-sea work, as its name implies, and is not well adapted for use on the hard, sandy bottom usually encountered in shoal water, owing to the limited height of the beam and restricted sweep of the lead rope. It is practically a double beam trawl with central beams, and lead ropes on both sides, so that it is a matter of indifference how it lands.

This is a great advantage which all deep-sea explorers will appreciate after operating the beam trawl, the successful use of which depends upon its being landed on the bottom right side up, a feat which the expert will accomplish with rare exceptions, even in the greatest depths; but the inexperienced explorer will frequently discover, to his chagrin, that it has been dragging bottom side up and the haul is a practical failure in consequence. The Blake trawl admits of a change of course in any direction and to any extent while it is dragging on the bottom, providing the dredge rope is not slackened sufficiently to allow it to kink.

The disadvantage in the use of this trawl is the greater wash through its widely distended mouth during the ascent, which is injurious to the more delicate forms, but



CUT 64.—Blake deep-sea trawl frame.

this evil is largely compensated by the cheese-cloth lining and the protecting folds of the net. Its dimensions are as follows:

Beams, front and rear: Material, iron pipe; length, 10 feet; diameter outside, 2¼ inches; thickness of metal, $\frac{3}{16}$ inch; holes in ends, ¾ inch square.

Runners: Material, flat bar iron; width, 3 inches; thickness, ½ inch; length, 4 feet 6 inches; height, 2 feet; holes for beams, ¾ inch square; holes for lead rope, 1 inch diameter.

Bolts: Material, iron; size, ¾ inch square, with thread and nut; length, 3½ inches; rear with flat heads; front with eyes for bridle.

Weight of frame, 200 pounds.

Net; Material, cotton, barked, 30-thread; size of mesh, square, 1¼ inch; length, 20 feet.

Pocket: Material, cotton, barked, 21-thread; size of mesh, square, 1 inch; length, 6 feet.

Jacket: Material, cotton, barked, 16-thread; size of mesh, square, ½ inch; length, 6 feet; lining, cheese-cloth.

Rope, manila; lead and leech ropes; circumference, 2 inches; bridle, 3 inches.

Float, Norwegian glass globe; diameter, 6 inches.

The space between the front and rear beams, and sometimes the inner surfaces of the runners, are filled with netting tightly laced from side to side to increase the lead into the mouth of the net; the former is of undoubted utility, as the upper lead rope sags nearly to the level of the rear beam, thus reducing the area of the opening nearly one-half.

To assemble the Blake deep-sea trawl, place the runners in position and secure the beams to them with the bolts which are habitually kept in the holes in the beam ends; those for the front one have heads terminating in eyes for the bridle, otherwise the beams are interchangeable. Attach the net by seizing the lead ropes through holes in the runners, leaving them with slack enough to sag to the beam; lace the leeches to the rear ends of the runners, and adjust the drawstring in the lower end of the pocket, leaving an opening about 2 feet in diameter.

Seize the bridle to the eyebolts on the runners, using from six to eight turns of marline; gather in the end of the jacket, the cheese-cloth lining, trawl net, and the bridle legs, and pass the tail lashing. Hitch the mud bag to the eyes in the bridle legs, and attach as many trawl weights as required to frame and net, the number being determined by the depth of water, nature of the bottom, strength of current, and the state of the sea.

This trawl is the joint production of Commander C. D. Sigsbee, Professor Agassiz, and officers of the *Blake*, on which vessel it was brought into successful operation.

MATERIAL FOR TRAWL NETS.

The webs from which nets are made for the beam trawl and the Tanner trawls, Nos. 1 and 2, are of three sizes, all barked. For body of net, 30 thread, 1-inch mesh, square, hanging 17 feet or 150 meshes deep; for pocket, 21 thread, 1-inch mesh, square, hanging 6 feet or 54 meshes deep; for jacket, 16 thread, ½-inch mesh, square, hanging 6 feet or 108 meshes deep. For the Blake deep-sea trawl a larger mesh is used, though the web remains the same in all other respects. It is 30-thread, 1½-inch mesh, square, hanging 17 feet or 100 meshes deep. The material for pockets and jackets is the same as that described for beam trawl nets.

Material for the Tanner beam trawl net No. 3 is 21-thread, 1-inch mesh, square, and for the jacket, thread 24–6 stow, ¼-inch mesh, square.

The hang of a web is its natural form, with the meshes square, occupying the same space in length and width. Square measure is the length of one side of the mesh, and stretch measure is the total length of mesh when extended; hence the latter is double the former. Stretch measure is in general use among net-makers.

Lead rope sinkers for trawl nets are oval in form, the larger size about 2 inches in length, 1½ inches in diameter, and a ¾-inch hole through the center, while those for the Tanner No. 3 net are 1½ inch in length, ¾ inch in diameter, and a ⅜-inch hole.

DIRECTIONS FOR MAKING TRAWL NETS.

BEAM TRAWL AND TANNER TRAWL NO. 1.

To make a net for the beam trawl or for the Tanner trawl No. 1, cut from the web 50 feet, stretch measure, or 300 meshes; take 4 fathoms of 1½-inch manila rope, whip both ends, and middle it, also find the middle of one end of the web and hitch it to the headrope with a netting needle, working both ways from the center; make a small eye in the headrope at each corner of the net, to serve as head cringles; then continue down the sides of the apron, stitching them to the same rope for a space of 4 feet 6 inches, taking up 45 meshes. There are 50 meshes in the apron, but the remaining 5 are left unroped for a purpose that will presently appear. The length of leech ropes, although given as 4 feet 6 inches, is intended to reach the lead rope at its hitches on the rear of the runners.

To prepare the other end of the web for the lead rope, cut a sweep of 30 meshes from it; whip the ends of a piece of 2-inch manila rope, 3½ fathoms in length, for the lead rope; slip 18 or 22 sinkers on it, as it is intended for deep or shoal-water work; middle it, and measure off 7 feet each way, marking the points permanently, thus indicating the length of the lead rope, 14 feet. Commencing at the middle of rope and web, hitch them together with a netting needle as before, distributing the sinkers evenly along the former, then splice the leech ropes to it, commencing at the marks and sticking the strands outward.

The leech ropes should be spliced at the 4 feet 6 inches mark, thus leaving the 5 unroped meshes in a bight between the leech ropes and the lead rope, for without this precaution the net will invariably give way at that point first. Now bend the net temporarily to its frame and hoist it up until the web swings clear of the deck; then let a man get into the bight of the web and move back and forth until he has found the lowest point; cut it and stitch the sides together, beginning at the junction of leech and lead ropes, working toward the tail of the net. This done, turn it inside out and stitch the pocket on 12 feet and the jacket 6 feet from the lower end, or so that the bottom of the latter and the tail of the net will hang evenly. Run a drawstring through the lower meshes of the pocket, and seize the float to the back of the net above and a little forward of the lead rope.

A cheese-cloth lining is sometimes stitched to the jacket for deep-sea work, but it is of doubtful utility, as the net usually brings up sufficient bottom soil to protect delicate forms during the ascent of the trawl. If used, it should hang evenly with the jacket and tail of the net, and extend not more than 2 feet above the lashing. When completed the net may be unbent and stowed away until required for use.

Trawl nets have been kept in canvas bags, but the practice is not recommended. They keep better in a bundle, tied as loosely as circumstances will admit.

NET FOR THE TANNER TRAWL NO. 2.

The No. 2 nets are usually made in pairs in order to economize material, which is the same in all respects as that used in the larger nets. Cut from the web a piece containing 108 meshes, or 18 feet stretch measure, and another with 73 meshes, or 12 feet stretch measure; cut both in half lengthwise and use one long and one short piece for each net.

Take 17 feet of 1½-inch manila rope, whip both ends and middle it, also middle an end of the longest web and hitch it to the rope with a netting needle, working each way from the center; make a small eye in the head rope at each corner of the net to serve as head cringles; then continue the roping down the sides of the apron 3 feet 6 inches, or sufficient length to reach from beam to lead rope without strain, taking up 32 of the 35 meshes, the remaining 3 being left unroped.

Cut a sweep of 21 meshes from one end of the shorter web, take 14 feet of 2-inch manila rope, whip the ends, middle it, measure 4 feet 9 inches each way, and mark the points to indicate the length of the lead rope, 9 feet 6 inches; slip on 15 sinkers and distribute them equally; then stitch the rope to the web, and splice the leech ropes to the lead rope. The marks on both should be brought together, leaving the 3 unroped meshes in a bight between them.

Bend the net to its frame, trice it up, and stitch the sides together, turn it inside out and attach the pocket 9 feet and the jacket 3 feet from the lower end of the net. The materials for pocket and jacket are the same as in the larger nets, but the latter is only half the width, the other half being used for the second net of the pair. Run a drawstring through the lower meshes of the pocket and seize the float to the top of the net over the lead rope.

NET FOR THE TANNER TRAWL NO. 3.

The body of the net is made from the web used for pockets in the larger nets, 21-thread, 1-inch mesh, square, hanging 54 meshes or 6 feet deep. Two pieces of 40 meshes each are cut from the web, and using 9-thread manila the head and apron are roped, the latter containing 20 meshes on leech ropes 26 inches in length. For the lead rope take 7 feet of 9-thread manila, whip the ends, middle it, measure 2 feet 3 inches each way, and mark the points to indicate its length, 4 feet 6 inches; cut a sweep of 10 meshes from one end of the second piece, stitch it to the lead rope, first slipping on 8 sinkers weighing about ¼ pound each, and distributing them evenly along its length. Splice the leech ropes into the lead rope, stitch the sides of the net, and square the lower end.

The jacket, 2 feet 6 inches in depth, composed of 24–6 thread stow, ¼-inch mesh, square, is next stitched on, and the float seized in place, the pocket being omitted to save weight.

THE BLAKE DEEP-SEA TRAWL NET.

From the web, which is 30-thread cotton, 1½-inch mesh, square, hanging 17 feet or 100 meshes deep, cut 172 meshes, or 43 feet stretch measure; take about 31 feet of 2-inch manila rope, slip 13 sinkers on one end, then make three small eyes along its length, the first 4 feet from the end, the second 10 feet 8 inches in the clear from the first, and the third 2 feet from the second. Slip 13 sinkers over the other end of the rope and make a fourth eye 10 feet 8 inches from the third; connect the ends with a long splice, leaving 2 feet between the fourth and first eyes, thus forming the two lead ropes 10 feet 8 inches, and two leech ropes 2 feet in length. The web, which is in one piece, is prepared for roping by cutting a sweep of 6 meshes from the first 70; then, with an interval of 18 meshes, cut another sweep of 6 meshes within the next 70, and, with a netting needle, hitch the first sweep to the first lead rope, taking up 70 meshes, then 18 meshes as a leech; 70 on the second lead rope, and 18 on the second leech. Commencing at the lead rope, lace the ends of the web together, then turn the web inside out and attach the pocket and jacket, the former 12 feet and the latter 6 feet from the tail of the trawl net.

Should a cheese-cloth lining be added, stitch it to the jacket so that it will not extend more than 18 inches or at most 2 feet above the tail lashing.

The float is seized to the bight of a bridle the ends of which are lashed to the sides of the net, between the upper and lower parts, in such a manner that it will hang near the lead ropes, but can not float outside of them. Run a drawstring through the lower meshes of the pocket.

GENERAL REMARKS.

The meshes are spaced wider on the lead ropes than on the leeches or ends, and they should be spaced closer near the corners than in the middle sections, in order to equalize the strain on different parts of the net.

In selecting material for lead ropes, particularly for the Blake deep-sea trawl net, better results will follow by using rope that has been a short time in service, as a tackle fall for instance, until the extra turns are taken out of it and it has become pliable and well set. Condemned running rigging has been used, but it is not recommended, owing to its uncertain strength. The practice of bending trawl nets to their frames as soon as they are roped and tricing them up while the side seams are being laced and pockets and jackets attached is recommended, as the finished net invariably sets better when so treated.

A trawl net should set very loosely on its frame when dry, for if it fits snugly then its shrinkage when wet will be sufficient in most cases to impair its usefulness.

The net length is given for head, leech, and lead ropes, no allowance being made for shrinkage by wetting, as that depends largely upon the rope used.

THE DREDGE.

The dredge in ordinary use on shipboard is shown in cut 65. It is composed of a pair of beveled jaws 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 edges of the jaws, and protected from chafing on the bottom by a canvas shield which is drawn over it and laced through the same holes.

Iron arms serve as a bridle. One arm is a little shorter than the other and is secured to the larger one by a seizing which is intended to part whenever undue strain is brought upon it, allowing the dredge to be drawn up by one arm, in which position it would be most likely to free itself from an obstruction. Its dimensions are as follows:

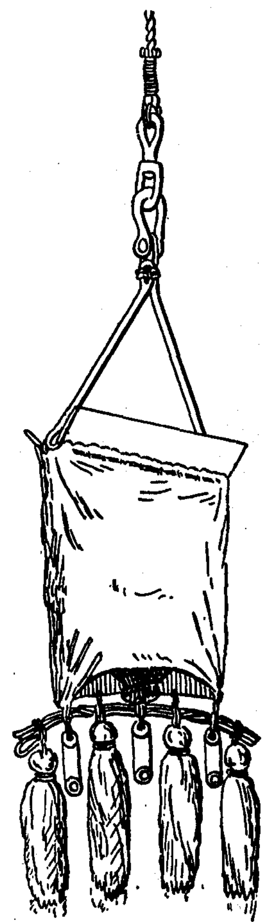
Jaws: Length, 2 feet; width, 2¼ inches; opening between, 8 inches; angle of 12 degrees.

Stud: Length, 6 inches; diameter, round iron, ⅞ inch.

Bridle: Diameter, round iron, ⅞ 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, ¼ inch; jacket material, cotton, barked, 16-thread; bottom lining, cheese-cloth.

Shield: Length, 3 feet 8 inches; material, No. 2 cotton canvas.

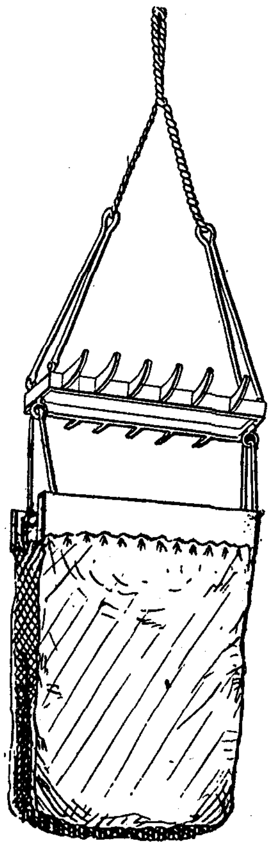


CUT 65.—The common dredge.

THE CHESTER RAKE DREDGE.

This admirable instrument (cut 66) was devised by Capt. H. C. Chester for the purpose of collecting mollusca, annelids, crustacea, etc., which burrow beneath the surface out of reach of any other apparatus in use on board vessels of the U. S. Fish Commission. The rake is shackled to the dredge rope, and a Blake dredge secured to eyebolts on the rear of its frame, follows it as it is dragged over the bottom, and picks up whatever it turns over with its strong harrow-like teeth. Its dimensions are as follows:

Frame: Length, 3 feet; depth of opening, 10 inches; width of metal, 2½ inches; thickness of metal, ½-inch.
Teeth: Length, 7 inches; width of base, 2½ inches; thickness of metal, base, ½-inch.
Arms: Length of long arm, 3 feet 5 inches; length of short arm, 3 feet 3 inches; diameter, round iron, ¾-inch.
Weight, 79 pounds.



CUT 66.—The Chester rake dredge.

THE BLAKE DREDGE.

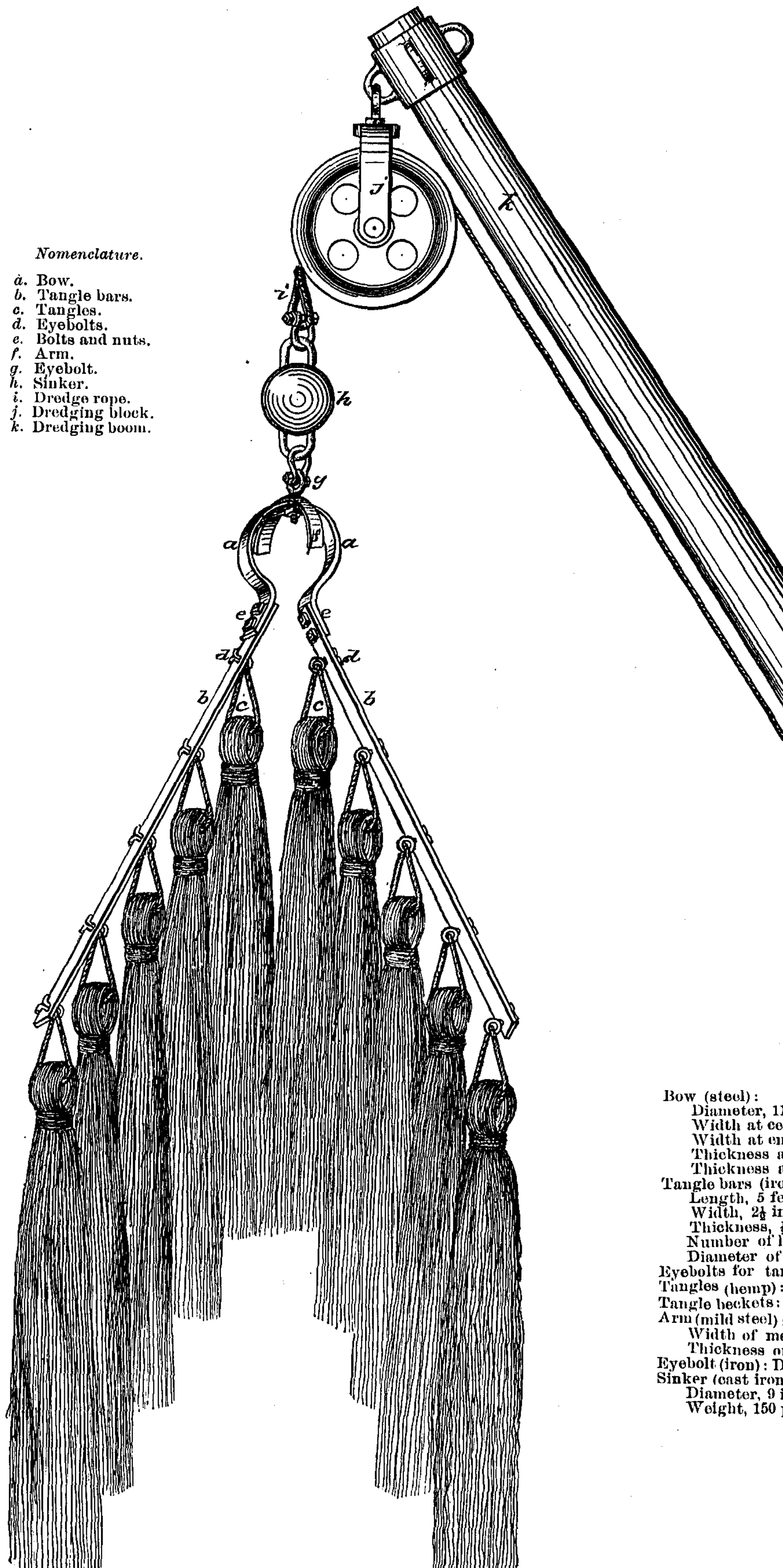
The ordinary dredge, having its jaws set at an angle, naturally grips the bottom and will plow into it and bury itself if the soil is light and soft. This is a necessary feature on hard, sandy bottoms, but a serious detriment in the soft ooze of the deep sea. Various devices were resorted to by Lieut. Commander Sigsbee on board the *Blake*, resulting in his "improved dredge," known aboard the *Albatross* as the Blake dredge (cut 67). The following description is from Sigsbee's Deep-Sea Sounding and Dredging:

By reason of having flaring mouthpieces 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 mouthpieces 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 framework, 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 framework 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.

The following are the dimensions of the Blake dredge as used on board of the *Albatross:*

Jaws: Length, 4 feet; width, 6 inches; thickness of metal, ⅝ inch; distance of holes from edge, ⅝ 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, ½ inch; diameter of braces, ¾ inch.
Long arm, length, 4 feet; short arm, length, 3 feet 9 inches.
Diameter of round iron, both arms, ¾ inch.
Weight of dredge and frame, 81 pounds.
Shield, cotton canvas, No. 2.
Net: Length, 5 feet; size of mesh, square, 1 inch; material, cotton, barked, 30-thread.
Jacket: Length, 3 feet; size of mesh, square, ½ inch; material, cotton, barked, 16-thread.
Bottom lining, cheese-cloth.



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, $2\frac{1}{2}$ inches.
- Thickness at ends, $\frac{1}{2}$ inch.
- Thickness at center, $\frac{1}{4}$ inch.

Tangle bars (iron):
- Length, 5 feet.
- Width, $2\frac{1}{2}$ inches.
- Thickness, $\frac{1}{2}$ inch.
- Number of holes for tangles, 5.
- Diameter of holes, $\frac{5}{8}$ inch.

Eyebolts for tangles (iron): Diameter, $\frac{1}{4}$ inch.
Tangles (hemp): Length, 4 feet.
Tangle beckets: 21-thread ratline stuff.
Arm (mild steel): Semicircular, diameter, $1\frac{1}{2}$ feet.
- Width of metal, $2\frac{1}{2}$ inches.
- Thickness of metal, $\frac{3}{8}$ inch.

Eyebolt (iron): Diameter of metal square, $\frac{5}{8}$ inch.
Sinker (cast iron):
- Diameter, 9 inches.
- Weight, 150 pounds.

THE TANGLES.

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. Its dimensions are as follows:

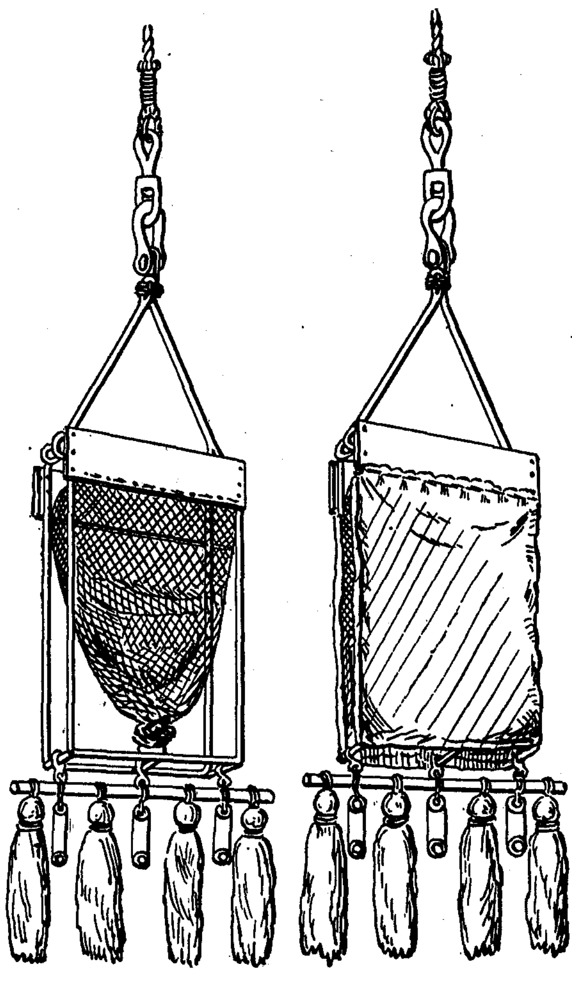
Jaws: Length, 1 foot 7 inches; width, $2\frac{1}{4}$ inches; opening, $7\frac{1}{2}$ inches; angle, 12 degrees.
Stud: Length, $6\frac{1}{4}$ inches; diameter, round iron, $\frac{5}{8}$ inch.
Bridle: Diameter, round iron, $\frac{1}{2}$ inch; length, 1 foot 5 inches.
Weight, 15 pounds.
Net: Length, 1 foot 8 inches; size of mesh, square, $\frac{3}{16}$ inch; material, cotton, 3-thread, bottom double.
Shield: Length, 2 feet 8 inches; material, No. 3 cotton canvas.

THE OYSTER DREDGE.

The oyster dredge is of the ordinary commercial pattern used in Chesapeake Bay. The rake is a flat bar of iron 6 feet in length with numerous projecting teeth. The bag is composed of a network of wire links and has a capacity of about 15 bushels. The dredge mouth is kept open by an iron frame. This dredge is used solely for the collection of mollusca.

THE TANGLES.

The present form of tangles (plate XXXIII) was devised by the writer in 1884 and they have since been used on board the *Albatross* for collecting on rocky bottoms, coral reefs, and other foul ground, capturing a great variety of specimens where no other appliance can be made available.



CUT 67.—The Blake dredge.

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 $\frac{1}{4}$ 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 are made separate 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, plate XXXIV, fig. 2, is an outgrowth of the cradle sieve, fig. 1, which was formerly used for 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.

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.

THE STRAINER.

The strainer, fig. 3, was introduced on board the *Albatross*, in 1883, by Mr. James E. Benedict, resident naturalist, for the purpose of straining all water used for washing mud and ooze from specimens in the table sieve. By this means minute forms of crustacea, annelids, foraminifera, etc., are recovered at small expense of time and labor.

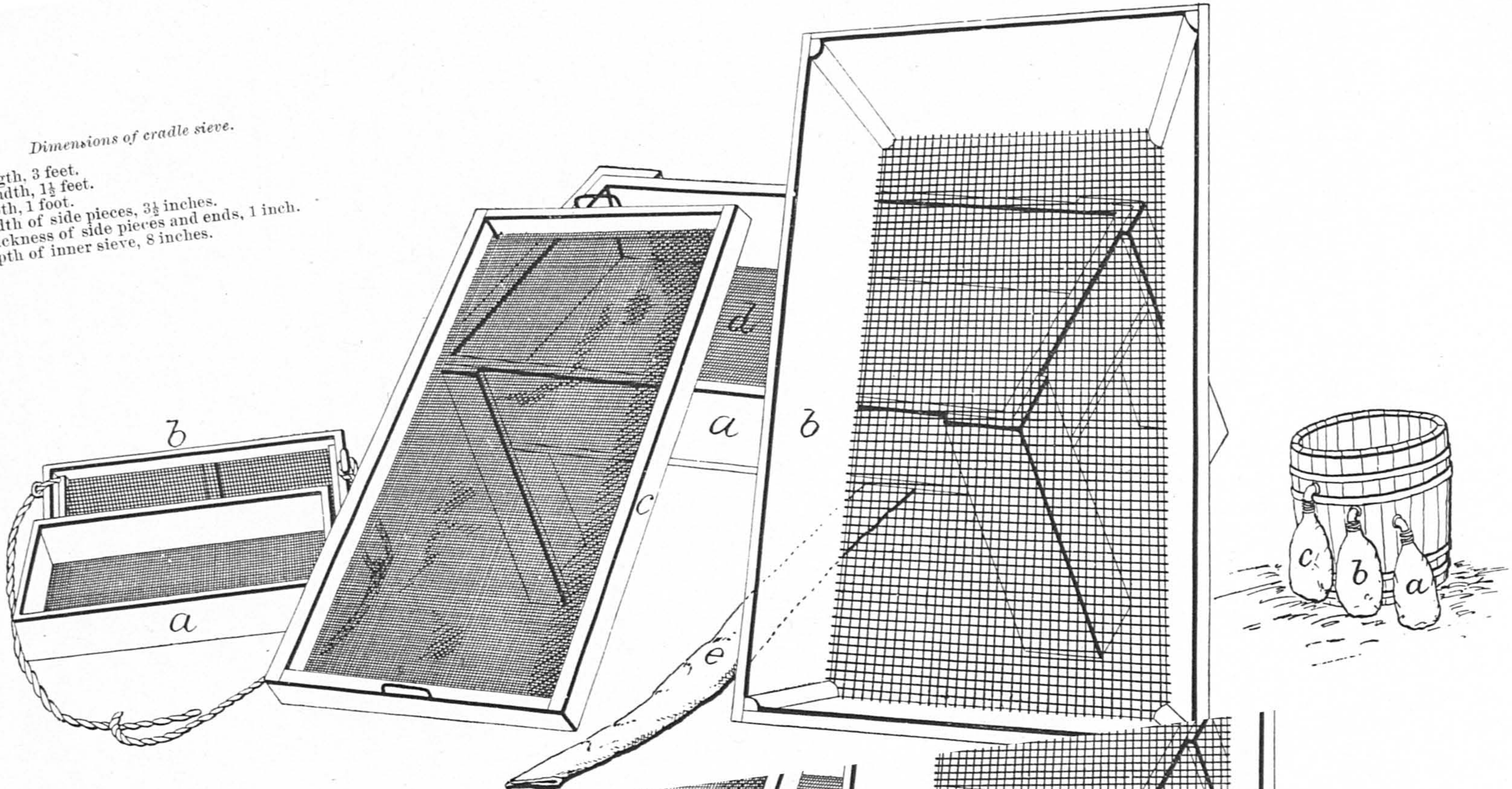
Its construction is very simple. An oil barrel was cut down until it would slide under the table sieve. Three iron drain-pipes are inserted in the side, one diagonally over the other, and attached to them are three strainers, *a*, *b*, and *c*, made of linen scrim, through which the water is drained 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 is substituted, the water being discharged directly into the strainer.

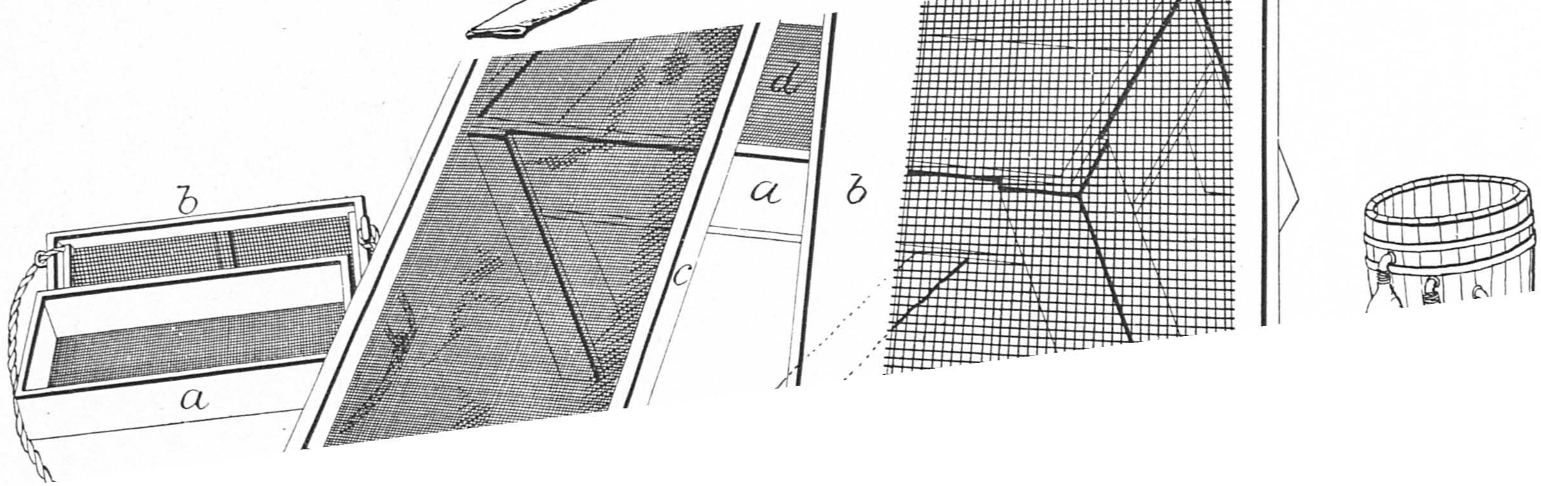
THE TANNER IMPROVED DREDGING QUADRANT.

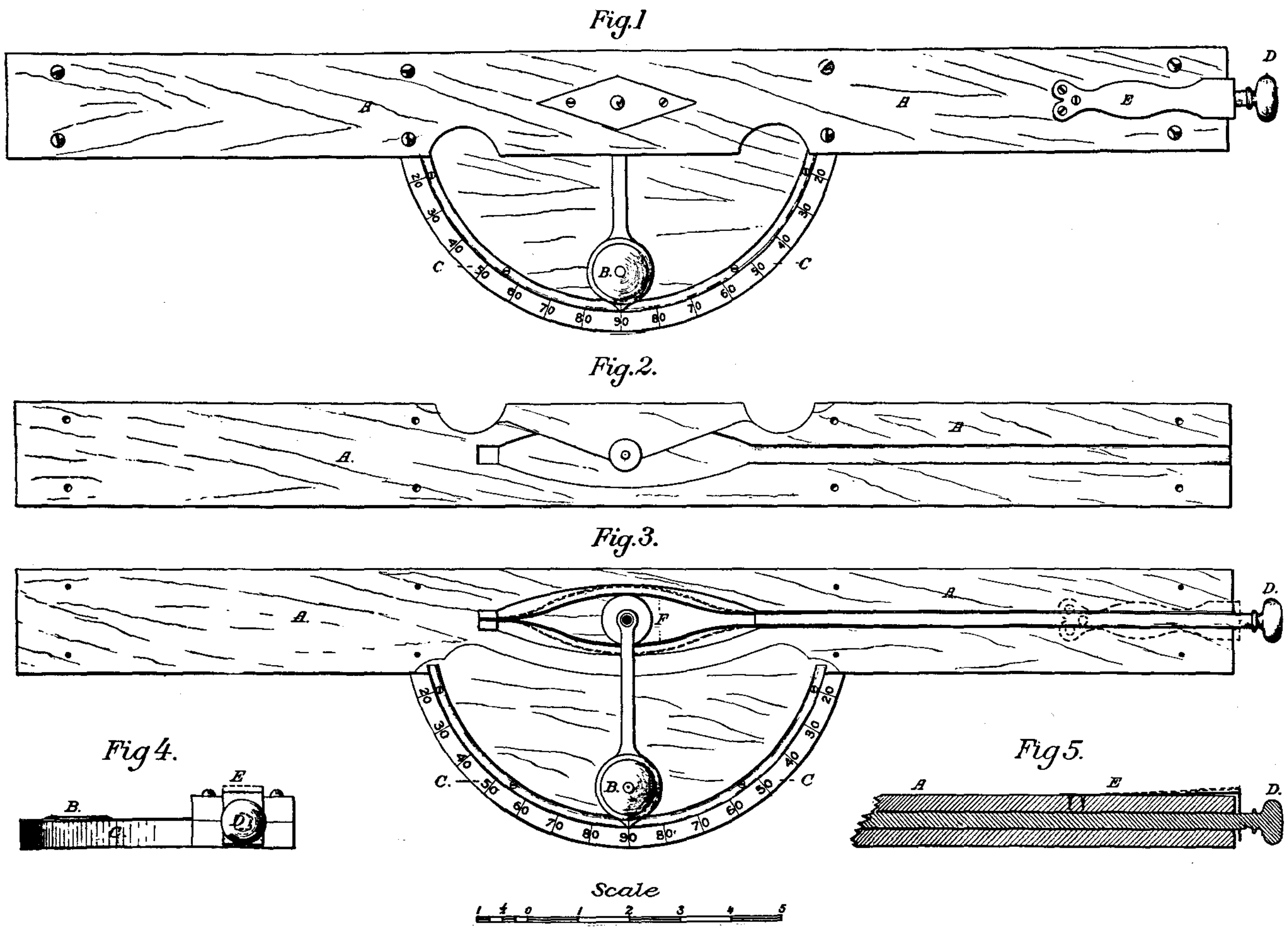
The dredging quadrant (plate XXXV) in its original form was designed by the writer as the most convenient and practical method of ascertaining the position of trawl or dredge in deep-sea exploration by observing the angle of the dredge rope. The present form is simply a refinement of the original.

Dimensions of cradle sieve.

Length, 3 feet.
Breadth, $1\frac{1}{2}$ feet.
Depth, 1 foot.
Width of side pieces, $3\frac{1}{2}$ inches.
Thickness of side pieces and ends, 1 inch.
Depth of inner sieve, 8 inches.







THE TANNER IMPROVED DREDGING QUADRANT.

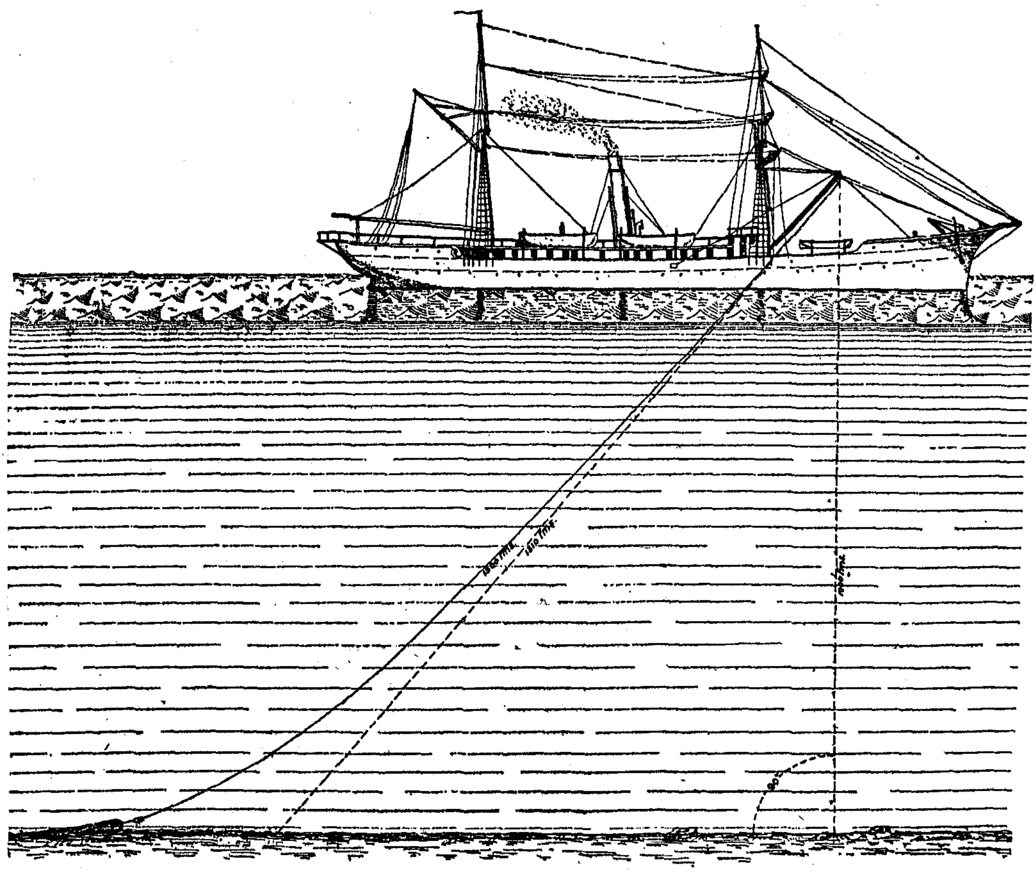
FIG. 1. Instrument ready for use.
FIGS. 2. and 3. A sectional view.
FIG. 4. End view at D.
FIG. 5. Sectional view of the rod D, frame A, and spring E.

Nomenclature: *A*, Frame. *B*, Pendulum. *C*, Scale. *D*, Rod. *E*, Spring catch. *F*, Elliptical spring.

The frame A is composed of two pieces of black walnut, or other suitable wood, each 2 feet in length, 2 inches wide, and ½ inch thick, scored on their inner surfaces to receive the rod, springs, and pendulum.

The back part of the frame has a semicircular projection, to which the scale C is secured. The pendulum B is of brass, 4 inches in length, weighted with lead at its lower end to insure prompt action. There is a disk at its upper extremity with a milled surface, and it is suspended on friction bearings which allow it to swing freely.

The rod D has a knob on its outer end for convenience in working, and to its inner end is attached the elliptical spring F, composed of spring brass, which is intended to



CUT 68.—The angle and scope of the dredge rope.

grip the milled head of the disk and hold the pendulum securely in place whenever the notch in the rod D is freed from the spring catch E. To release it from the embrace of the spring, press on the knob with the palm of the right hand until the notch in the rod D is engaged by the slot in the spring catch E; the elliptical spring F is thus distended, the friction removed from the disk, and the pendulum given unobstructed movement.

The scale C is of brass, secured to the frame by brass screws; it is graduated on both sides from 20° from the perpendicular to 90° or horizontal, so that it can be used on either side of the vessel, whether backing or going ahead. A guard of round brass rod is secured inside of the scale to strengthen the frame and prevent its warping, also to protect the pendulum point which swings between it and the scale.

To use the dredging quadrant grasp it in both hands, straight edge up, knob to the right; see that the pendulum swings freely; then take a favorable position (cut 68), cast the eye over the straight edge of the quadrant, inclining it to the angle of the rope, at the same time sweeping it back and forth until they are parallel; then lock the pendulum by pressing the spring catch E with the thumb of the right hand. The angle of the rope from the perpendicular may then be read from the scale.

The following illustrative example explains the principle of the dredging quadrant and its practical application:

Given the depth, 1,000 fathoms, and the angle 40°, what is the scope of dredge rope required to insure the landing of the trawl on the bottom?

Enter Table II, Bowditch, or any table for the solution of plane right triangles, with 40° 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 bottom. Experience teaches that about 200 fathoms is sufficient with above depth and angle; therefore, with a scope of 1,500 fathoms, and the angle of the rope maintained between the limits of 35° and 40°, a successful haul may be anticipated so far as the landing of the trawl on the bottom is concerned.

The speed at which it can be dragged varies from 2 to 2½ knots per hour, depending upon the state of the sea, the currents, and the character of bottom. It can be regulated after a little practice so as to confine the angle of dredge rope within the limit of 5°; hence there is a wide margin as to its scope, which is governed largely by the speed at which it is desired to drag the trawl or dredge over the bottom.

SURFACE AND INTERMEDIATE COLLECTING.

The surface tow net was among the first devices of the naturalist for collecting minute animal and vegetable forms on the surface, and the same apparatus has been used at intermediate depths, although its range was confined within narrow limits, usually but a few fathoms, and even then it was not entirely satisfactory, as specimens would naturally find their way into the net while it was being hauled to the surface, the exact depth of their habitat remaining a mystery.

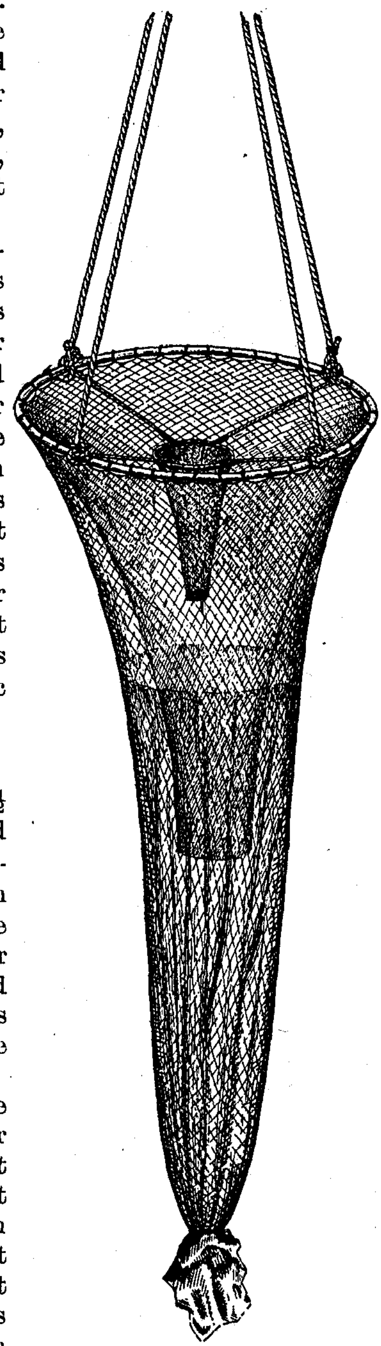
The ring of the surface tow net in common use is from 12 to 18 inches in diameter, made of ¼-inch iron or brass rod. The best nets are of silk gauze, or bolting-cloth, although they may be made of cheese-cloth or other suitable material. They are usually towed with a small line either astern or over the side when the vessel is moving slowly through the water.

The dip net has been in constant use on board the *Albatross*. Its ring resembles that of the surface tow net, but is usually made of heavier wire, and it has a shank which is inserted into a staff, preferably a bamboo pole of sufficient length. The net is of silk bolting-cloth.

This device may be used at any time when the vessel is lying without headway or moving very slowly through the water. Its greatest achievements have been in connection with the electric light. At night, preferably from one to three hours after dark, the vessel lying broadside to the wind and without headway, an ordinary

Edison 50-candle incandescent lamp, attached to a properly insulated cable, is lowered from the lee gangway, 6 feet or more from the ship's side, just sufficiently to keep it submerged with the ordinary motions of the vessel. Slow-moving forms which are floating on the surface collect in large numbers at the water line as the vessel sags slowly to leeward and more active species gather to feed upon them. As soon as the light is lowered, the latter gather around it, as moths about a candle, sometimes in great swarms, and it is then that the net reaps its richest harvests.

Surface collecting has always been a marked feature in the work of the *Albatross*, and improved methods were sought from the first. The opportunities for this line of investigation, without interfering with other work, were unprecedented, as the net above described could be used whenever the vessel was hove to for sounding, etc., and the tow net was available from the time the trawl was put over the rail until it was on board again, from half an hour to six or eight hours later. Observing this, it seemed that something might be done to develop this field of inquiry, and various devices were tried from time to time with greater or less success until, on the 8th of May, 1885, the present form of surface tow net, devised by the writer, was first used and became a part of the regular scientific outfit.


CUT 69.—Improved surface tow net.

IMPROVED SURFACE TOW NET.

The ring is of $\frac{5}{8}$-inch galvanized iron, 4 feet $1\frac{1}{2}$ inches in diameter; the net has a $\frac{1}{2}$-inch mesh, thread 24–6 stow, barked, 10 feet in length, same size throughout, and has a pocket of the same material 5 feet in length, which is formed by turning in a portion of the upper end of the net, thus doubling the material for 5 feet from the ring. A small cord is passed around the net between the parts, and is included in the turns of the lashing which secures the net to the ring. There is a drawstring in the lower end of the pocket.

A mosquito-net lining is secured on the lower inside portion of the net, and hangs a foot below it, in order that it may have sufficient slack to insure the outer net taking the strain of towing. An ordinary surface net with 12-inch hoop and a silk-gauze bag, 20 inches in length, is suspended in the mouth of the larger net by four bridles of small stuff secured to the ring; it is intended to collect minute forms that might pass through the coarser material of the large net. A $2\frac{1}{2}$-inch manila rope bridle with four legs is secured at equal distances around the ring, and a 3-inch rope hitched through the bight is used for towing.

In preparing the net for use it is advisable to lash the lining separately as near the end as practicable and place it inside of the net, lashing the end of the latter in such a manner that the former will rest entirely upon it, relieving the more delicate material from the strain of towing; otherwise it will be ruined by the great volume of water passed through it. It is towed from the swinging boom at about 2 knots per hour, and, when the vessel is engaged solely in surface collecting, two nets are used at the same time, one at each boom.

TOW NETS FOR INTERMEDIATE DEPTHS.

A large tow net was devised by the writer, at the instance of Professor Baird, for the purpose of taking fish at the surface and at intermediate depths. It was used for the first time on May 8, 1883.

The ring was made of 1-inch round iron, and was 10 feet in diameter; the net, 1-inch mesh and 20 feet in length; the bridle had four legs, which were seized at equal distances around the ring, and the steel-wire dredge rope was used as a tow line.

This apparatus was towed at various depths, from surface to bottom, at speeds ranging from 2 to 7 knots per hour, but it failed utterly in so far as the capture of pelagic forms was concerned; any fish which had sufficient celerity of movement to escape a beam trawl would avoid this net. The trouble seemed to arise from its "firing," for when used at night its tracks several fathoms below the surface could be distinctly seen. On one occasion, when a school of mackerel was attacked with it on a dark night, we could see the mass separate only a few feet in advance and then promptly close again in its rear, and not one was caught. The school was so dense that it seemed impossible to drag so large a net among them without catching one or two at least; but after an hour or more of towing in every direction at varying speeds from 1 to 8 knots, without the capture of a single specimen, we gave it up as a failure.

Surface tow nets attached to the dredge rope were used on board the *Challenger* for intermediate collecting, but a knowledge of the depths at which the specimens were secured was still lacking. The same practice was followed on board the *Fish Hawk* until we improved upon it by adopting wing nets, which were attached to each end of the trawl beam, and performed the functions of collectors from surface to bottom, and thence to the surface again. They were like an ordinary surface tow net with a pocket added. The material was cheese-cloth, and being much finer than any portion of the trawl which they accompanied, they usually contained a miscellaneous collection of small forms, many of which would not have been secured by any other method in practice at that time. Of course, we had little knowledge of the depths at which the various forms were secured. Such as were common to both wing net and surface net were, in a general way, assigned to areas within the influence of sunlight, while those found in the wing nets alone were allotted to depths more profound.

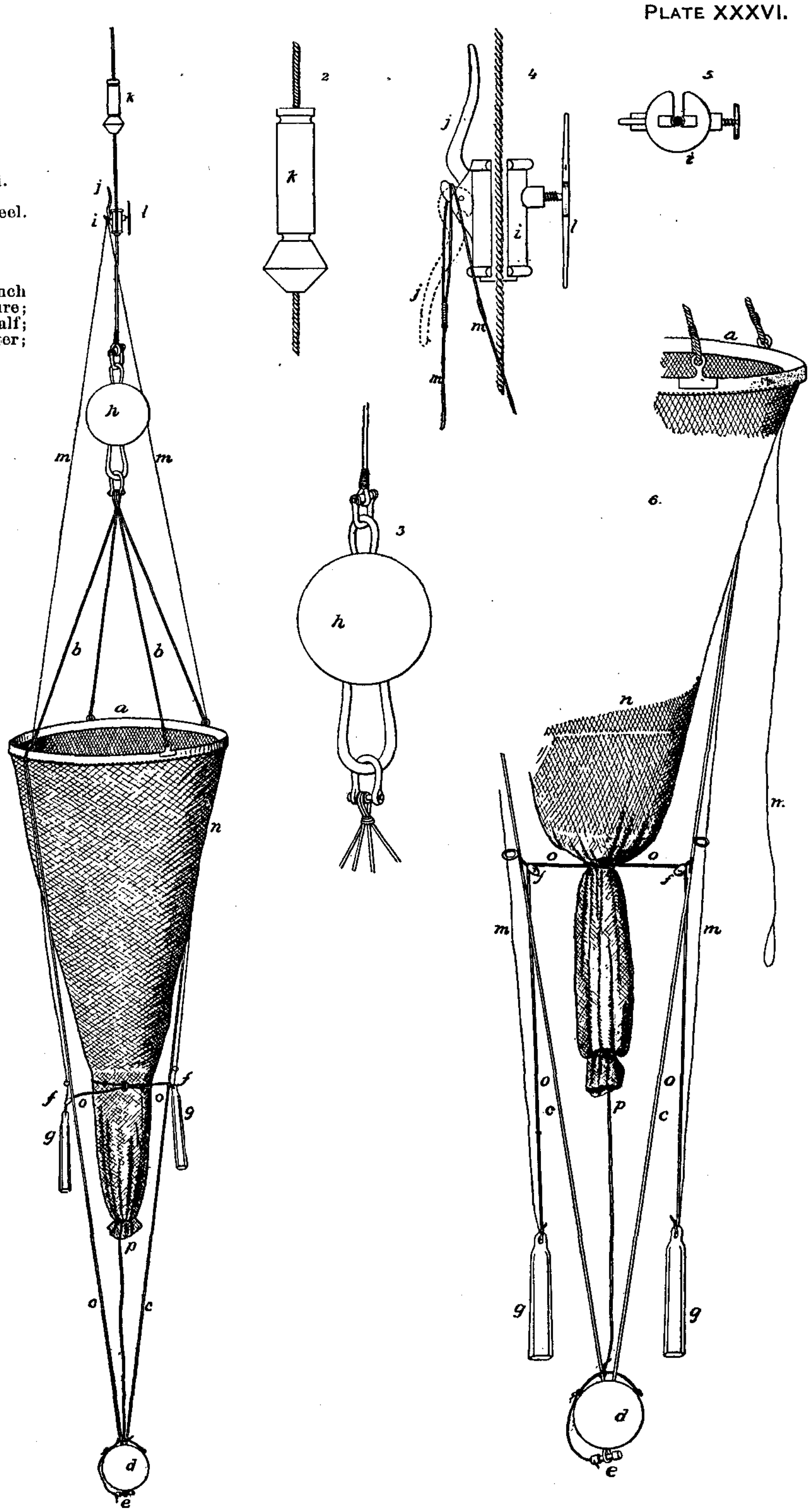
THE TANNER INTERMEDIATE TOW NET, FIRST PATTERN.

This net (plate XXXVI) was improvised at sea from materials at hand after the failure of other apparatus. Its purpose is to collect animal life from known intermediate depths, and although it has been superseded by a later pattern it is reproduced as a guide to others who may wish to construct a similar net with the slender resources usually available on shipboard.

The ring *a* is of brass, 2 feet 9 inches in diameter, with a four-legged bridle *b*, secured to eyes spaced at equal distances around it and shackled to the lower link of

Nomenclature.

a. Ring, brass.
b. Bridle, ratline stuff.
c. Lower bridle, 2-inch manila.
d. Sinker, 60-pound sounding shot.
e. Toggle, wood.
f. Blocks for draw string, brass.
g. Weights for operating draw-string, lead.
h. Sinker, cast iron, with wrought links.
i. Friction clamp: frame, brass; tumbler, steel.
j. Tumbler.
k. Messenger, cast iron.
l. Wrench, steel.
m. Tripping-lines, cod line, cotton or flax.
n. Net, cotton thread 24-6 stow barked, ¼-inch mesh (square), ½-inch stretch measure; first lining, mosquito net lower half; second lining, silk gauze lower quarter; guide rings for drawstring, brass.
o. Drawstring braided cord or cod line.
p. Lashing, cod line.



THE TANNER INTERMEDIATE TOW NET, FIRST PATTERN.

FIG. 1. Apparatus ready to be sent down. The messenger *k* is also shown on the tow line, above the friction clamp *i*.

FIG. 2. Enlarged view of messenger, showing scores in which the lashings are placed to hold the two parts together when it is sent down.

FIG. 3. Enlarged view of sinker, with links and shackles, showing the manner of attaching the tow line and net.

FIG. 4. Side view of friction clamp *i*, with tumbler *j* and wrench *l*.

FIG. 5. End view of clamp *i*.

FIG. 6. Enlarged view of net, showing the lower part closed as follows: The messenger was sent down and its impact overturned the tumbler, released the tripping lines, which allowed the weights to fall, and by their weight bring sufficient strain on the drawstring to close the bag as shown.

the sinker *h*. The dredge rope is shackled to the upper link and serves as a tow line. The lower bridle *c* has two legs, each 10 feet in length, of 2-inch manila rope, the free ends seized to opposite sides of the ring and a 60-pound sounding shot toggled to the lower end as a sinker to insure the apparatus going down vertically. The net *n* is cylindrical in form, 5½ feet long, the lower half lined with mosquito net and the lower third with an additional lining of silk bolting-cloth. The tail lashing *p* having been adjusted, one end is carried down and made fast to the lower bridle at *d* to keep the net in place while it is being lowered.

Four small brass rings are stitched to the net at equal intervals, a few inches below the upper edge of the silk lining, through which is rove a drawstring of braided signal halyard stuff, or soft white cod line, which makes a round turn, the ends being finally passed in opposite directions through the same ring, rove through blocks on the bridle legs and bent to the weights *g*, which weigh 14 pounds each. Two tripping lines *m*, of cod line, with eyes in their upper ends, are hooked over the tumbler *j* of the friction clamp *i*; the other ends are passed down through leads on the ring *a* and bridle legs *c*, and bent to the weights *g*, suspending them at the height of the drawstring blocks, allowing the drawstring to hang loosely about the net and the latter to retain its natural form while going down and until it is closed by the action of the messenger.

To use the net, prepare it as in fig. 1, lower it vertically, from 20 to 25 fathoms per minute, until it reaches the desired depth, and tow it from 1½ to 2 knots per hour, heaving in, veering and varying the speed, in order to maintain it at the proper depth, which can be determined within a few fathoms by observing the angle of the towline with the dredging quadrant.

To recover the net, stop and back until the towline is vertical, heaving in during the operation in order to maintain the net at the same depth at which it had been towed; then send the messenger down to act on tumbler of friction clamp, release tripping lines, and close lower part of net (fig. 6). The messenger is in two parts, which are held on the towline by seizings of marline. It sinks from 100 to 110 fathoms per minute, and the impact can usually be felt by grasping the towline. When the lower net is closed, steam ahead at the usual towing speed and heave in at the rate of 25 to 28 fathoms per minute, according to the state of the sea.

The net has been used successfully in 1,700 fathoms, yet it was looked upon as a makeshift. Its principal weakness was due to the action of the sinker *d*, which was necessary in lowering, but caused the net to tow at such an angle that the useful area of the ring was greatly reduced, whereas fully three-fourths of the area is operative in the improved pattern.

THE TANNER INTERMEDIATE TOW NET, IMPROVED PATTERN.

This apparatus (plate XXXVII) is the same in principle as that already described, and its function, the collection of animal life from known intermediate depths, is also the same, but its efficiency and certainty of action are increased, and it is more easily operated. Its frame is composed of brass pipe and fittings of commercial pattern, carrying a net so arranged with drawstring, movable weights, tripping lines, friction clamp, and messenger that its lower part can be closed at will.

General description.—The ring *a* is 2 feet 5 inches inside diameter, composed of brass pipe $1\frac{1}{16}$ inch outside diameter, bent in a circular form, the ends joined by a union. On the ring are four tees, two on each side, spaced 6 inches apart, and secured in place. The half of the ring opposite the union is filled with lead, which gives it a preponderance of about 10 pounds.

The arms b are of brass pipe of the same diameter as that of the ring; the lower ends are screwed into tees which move freely on the ring between those above mentioned, the upper ends having a hinge joint held in place by the shackle pin.

The legs c, four in number, are also of brass pipe, $\frac{13}{16}$ of an inch outside diameter and 5 feet $5\frac{1}{2}$ inches total length, with net length (from lower side of ring to apron) of 5 feet. The lap of legs over the apron is $4\frac{1}{2}$ inches, and the upper ends screw 1 inch into their respective tees.

The apron d is of sheet brass $\frac{1}{8}$ inch thick, 18 inches in length; straight on the upper edge, the lower part semicircular with a radius of 10 inches. It is secured to the flattened extremities of the legs by two screwbolts *e* in each end, $\frac{5}{16}$ inch in diameter and $2\frac{1}{4}$ inches in length. An oblong hole in the central upper part of the apron is for the purpose of securing the tail of the net, in order to prevent its floating up or becoming entangled while being lowered.

The functions of the apron are threefold: First, to afford rigid and secure fastenings for the lower ends of the legs; second, by its form to aid in guiding the net down vertically when lowering, and, finally, to give the apparatus a tendency to take a horizontal position when towing, thus increasing the area of collecting surface within the ring. The heavy weights are all at or near the ring while the net is being lowered and towed, and there is a preponderance of 70 pounds on one side of it, so placed as to cause the apron to expose its flat surface to the water and greatly increase the tendency of the light rear end to seek the level of the more ponderous weighted ring whenever it is moving forward.

Blocks f, four in number, for operating the drawstring, are of brass, $1\frac{1}{4}$ inches in length. Two of them are secured to a pair of legs by through bolts, riveted 2 feet 4 inches above the apron; the others are seized with wire to the tees holding the upper ends of the other pair of legs, upon which the movable weights traverse.

The movable weights g, of lead, two in number and weighing 30 pounds each, are provided to put the required tension on the drawstring when it is desired to close the net. They are egg-shaped, 4 inches in diameter by 9 inches long, and have an inch hole through the center; $\frac{3}{8}$-inch holes in lugs at their upper extremities furnish a convenient method of attaching the drawstring and tripping lines.

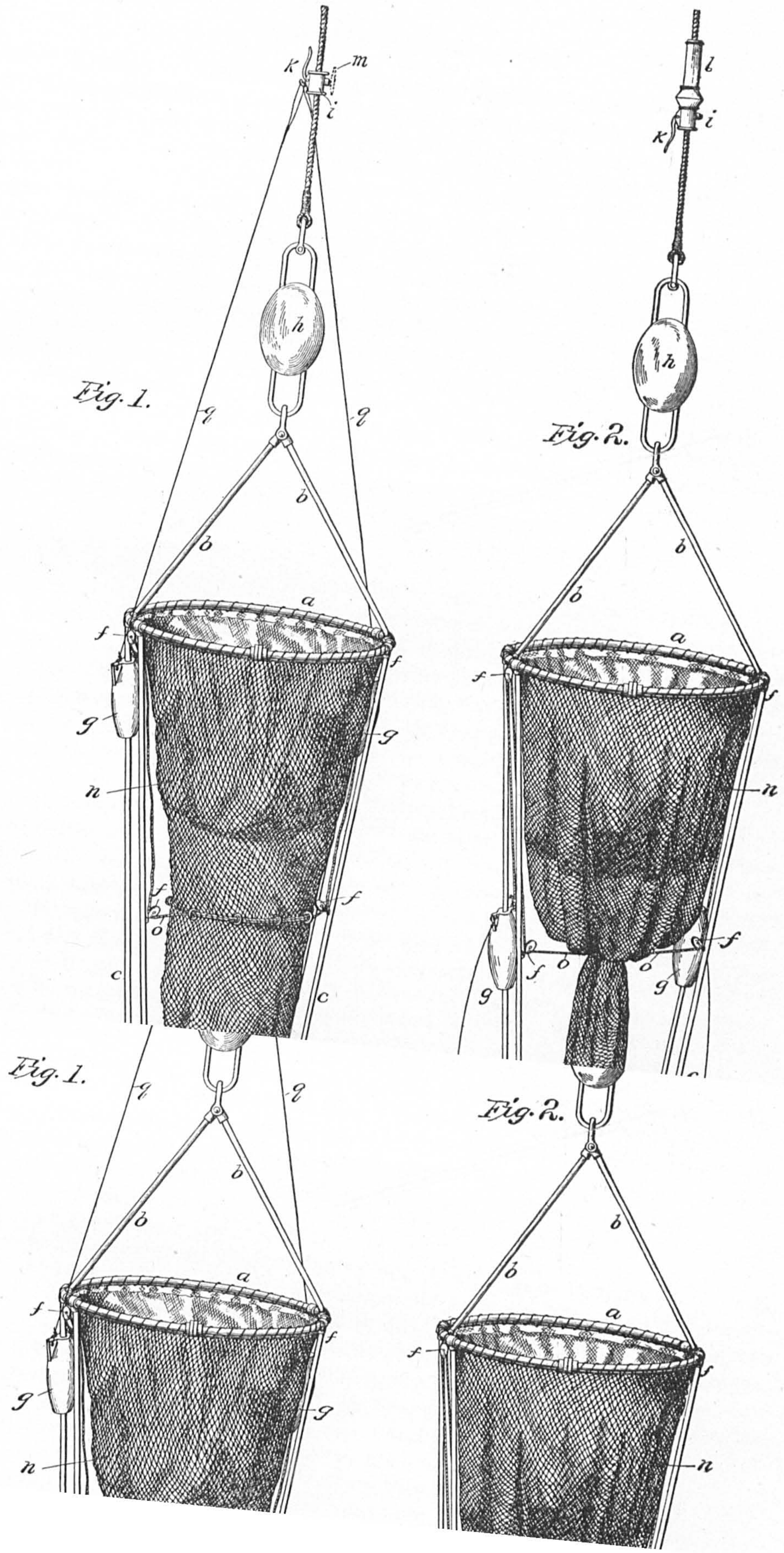
The sinker h is of cast iron, 130 pounds weight, oblong in form, with projecting links of wrought iron at each end, through which shackles for attaching tow net and dredge rope pass. The sinker is used to facilitate lowering the net, and to prevent kinking the steel dredge rope or tow line.

The friction clamp i is composed of brass and steel, the barrel of the former metal, the eccentric tumbler *k*, sliding chocks, striking face, and adjusting screw of the latter. A small steel wrench *m* is provided to work the adjusting screw.

The messenger l is of cast iron, 9 pounds in weight, made in halves, with two scores on the external surface for convenience in passing lashings. To use it, pass the halves over the rope and take a few turns of a lashing. The hole in the messenger is sufficiently large to allow it to pass freely over splices in the dredge rope.

The net n is $\frac{1}{4}$-inch square mesh; thread 24–6 stow, barked; it is seized to the ring with seine twine, and hangs 5 feet 6 inches in length, the same size throughout. It is lined with mosquito netting the whole length, and there is an inner lining of silk gauze extending up 3 feet 6 inches from the lower end. The outer net is intended to

PLATE XXXVII.



take the strain in towing, the linings pressing against it on all sides and acting simply as collectors. The lower end of the net is closed by a cod-line lashing *p*, which includes the outer net and mosquito-net lining, the silk gauze or inner lining being secured separately and placed inside of the others as an additional protection against wear and tear. After the outer net is securely lashed, the ends of the same lashing are taken through the hole in the apron and knotted, leaving about 6 inches slack to allow for closing the net, shrinkage, etc.

Six guide rings of $\frac{3}{16}$-inch brass wire and 1-inch diameter are secured at equal intervals around the outer surface of the net *n*, to support the drawstring *o*. They are placed about 2 inches above the blocks *f* on the legs *c* in order to allow the net to close without bringing undue strain upon its upper body.

The drawstring o is a braided cord 13 feet in length and $\frac{1}{4}$ inch diameter, used to close the lower part of the net *n* after towing and before it is hoisted to the surface. Cod line, or other material of the proper size, will answer the purpose, but braided cord is preferred as less liable to kink while lying loosely during the process of lowering and towing; moreover, it presents a smooth surface to the net, reducing the wear on the web caused by repeated opening, closing, towing, and hoisting.

The tripping lines q, two in number, are of cod line, 9 feet 6 inches in length, with 7-inch loops or eyes on their upper ends.

To assemble the apparatus: The ring being intact, with the arms lying side by side across it, their lower ends attached to their respective tees, raise the arms and shackle the sinker in place. Shackle the tow line, or dredge rope, to the other end of the sinker, and suspend the ring at convenient height; screw the legs into their respective sockets, which will be recognized by marks of a center punch, ÷ ∴∵ ⁖⁖ ⁘⁘ ; then place the apron in position and secure it by the screwbolts. The movable weights *g* are carried on the pair of legs nearest the weighted side of the ring, the lower drawstring blocks being on the other pair farthest from it.

Seize the net to the ring, run the drawstring through the small rings on the body of the net, taking a round turn and an overhand knot, then run the ends through the lower and upper blocks and hitch them to the movable weights through holes in their lugs; hitch the ends of the tripping lines through remaining holes in the lugs, place the friction clamp on the rope, slip the loops over the lip of the tumbler, and slide the clamp up the rope until the weights are suspended about 4 inches below the ring and tighten the adjusting screw with the wrench, keeping the tumbler elevated and pressed against the rope until the clamp grips it with sufficient force to hold it in place. It should not be secured too firmly, as it is intended that it should slide down the rope with the messenger after the impact of the latter has reversed the tumbler.

Having ascertained the point on the rope at which the clamp should be secured it may thereafter be attached in the same place without further attention to the tripping lines, which may be hooked over the lip of the tumbler and the weights suspended at the proper distance below the rings, by simply taking in a trifle more or less at the hitch.

The length of tripping lines, 9 feet 6 inches, is intended to give sufficient drift for the weights to close the net even if the clamp slips down the rope without the tumbler having been capsized. A single weight will securely close the net if from any cause the other fails to act.

To use the net, having assembled it as directed, overhaul the drawstring until the net hangs entirely free; bring the vessel to a dead stop and lower away at the rate of 25 fathoms per minute until the depth is reached. Then, having determined upon the angle at which it is to be towed, enter Table II, Bowditch Navigator, and find the length of rope required to maintain the net at the proper depth and steam ahead slowly, veering gently until the predetermined scope and angle are attained. The latter can then be maintained with sufficient accuracy by frequent observations with the dredging quadrant and properly regulating the speed.

A correction, to be subtracted from the figures taken from Table II, Bowditch, will be required for the catenary curve, as the sinker and the net being afloat at an intermediate depth will sink more rapidly than the rope which is being dragged laterally from 150 to 200 feet per minute through the water. It is quite impossible to give an invariable rule for making this correction. It may be said, however, that the angle of 40° has usually been adhered to on board the *Albatross*, which involves a speed of 2 knots per hour, approximately. Under these conditions a deduction of 8 fathoms per 100 fathoms in depth may be made up to 500 fathoms; 9 fathoms per 100 between 500 and 1,000 fathoms; and 10 fathoms per 100 between 1,000 and 2,000 fathoms.

This approximate rule is applicable to the stated conditions only, but will serve as a general guide until the explorer learns from experience the corrections required by his own methods and apparatus.

ILLUSTRATIVE EXAMPLE.

Depth at which the net is to be towed	500 fathoms
Angle of the tow rope	40°
Length of rope required, Table II, Bowditch	650 fathoms
Correction for catenary curve, 8 fathoms per 100 fathoms depth	—40 fathoms
Length of tow rope required	610 fathoms

To recover the net, having towed it a sufficient length of time, stop the engines and back slowly until the tow rope hangs vertically, reeling in sufficient rope to maintain the net at a uniform depth; send the messenger down and release the weights by reversing the tumbler, when they will exert a sudden and sufficient force on the ends of the drawstring to securely close the lower part of the net.

The messenger sinks at the rate of 100 to 110 fathoms per minute, and its impact can usually be felt by grasping the rope, but this method is not always reliable, hence it is advisable to use time intervals, allowing the safe limit of 100 fathoms per minute.

Having closed the lower bag, steam slowly ahead and reel in at the rate of 25 to 28 fathoms a minute until the net is on board. The upper portion from the mouth to the drawstring remaining open, will usually be found to contain an assortment of specimens collected on the way up.

A few turns of a lashing should be taken around the net immediately below the drawstring as soon as possible after the apparatus reaches the deck and while it is hanging vertically by the tow rope, to avoid the possibility of opening communication with upper and lower compartments by the accidental slackening of the drawstring. This done, the frame should be lowered gently on deck, the lashing removed from the tail of the net and the parts turned back, leaving the inner or silk gauze lining exposed; remove its lashing, carefully open the bag over a pan of prepared sea water which has been carefully strained to remove any surface forms it might have contained, and finally rinse the net in it to remove minute specimens adhering to its sides or lodged in the numerous folds.

The contents of the lower bag secured, the drawstring is removed, the upper bag turned inside out into a tub of water, and the specimens secured by thorough rinsing, after which the lashing is taken off and the net carefully washed, usually by towing a few minutes if the vessel should be moving slowly through the water; otherwise by washing and repeated rinsings until all trace of life is destroyed. The last rinsing should be in fresh water, and the frame should be wiped off to prevent oxidation.

If the apparatus is to be stowed away, remove the apron, unscrew the legs, and hang the ring with net attached in a convenient place to dry. The tripping lines and the drawstring should be hitched to arms or rings and dried. When ready to store, reeve the drawstring in place, roll the net up snugly, and stop it with the ends of the drawstring; remove the shackle pin and fold the arms across the ring, using the tripping lines to hold them in place and to confine the net as far as possible within the ring, thus making a snug and convenient package.

FISHING GEAR.

The cod hand lines used aboard the *Albatross* are a modification of the *Georges* gear, and may be described as follows:

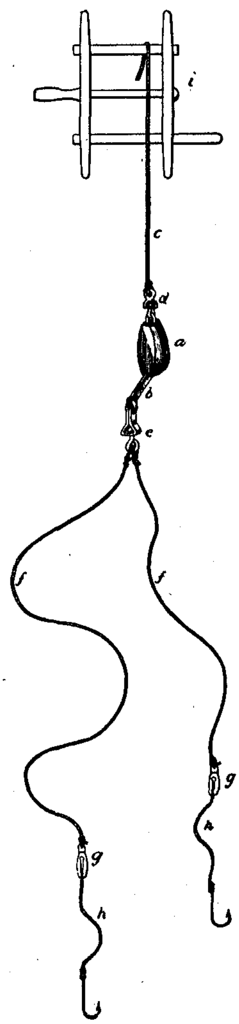
The material for hauling lines is received in lengths of 25 fathoms and weighs 18 pounds per dozen or 300 fathoms. A full-length hand line is composed of six 25-fathom lines spliced together. The *Albatross* has a few of these which are coiled in tubs, while those of 50 and 75 fathoms are carried on hand reels.

Tarred cotton, 10 to 14 pounds per dozen lengths of 25 fathoms each, is used for snoods. There are two on each line secured to the swivel on the bight, one leg 6 feet in length, the other about 4 feet. Their lower ends are attached to hook swivel slots either by a wall knot or by splicing.

The gangings are composed of a single strand of hemp line, about the size of the hauling line, secured to the hooks by hitching the bights around their shanks, then laying the two parts together and making wall knots on the ends, by which they are secured to the hook swivel slots. No. 14 cod hooks are in general use on the trial lines, although other sizes are used as occasion requires.

The following is a list of the fishing lines that are kept in readiness for use:

Squid lines.
Whiting lines.
Cod hand lines, 2, 3, and 4 pound leads.
Red-snapper lines.
Bluefish lines, for trolling.
Sea-bass lines, style used in Southern States.
Sea-bass lines, style used by New York smackmen.
Bluefish lines, for still baiting.
Shark lines.
Cod trawl lines.
Halibut trawl lines.
Haddock trawl lines.
Mackerel hand lines.



Nomenclature.

a. Sinker: Lead, weight 5 pounds.
b. Horse: Brass.
c. Hauling line: Tarred cotton.
d. Swivel: Brass.
e. Snood swivel: Brass.
f. Snoods: Tarred cotton.
g. Hook swivel slot.
h. Gangings: Hemp line.
i. Hand reel: Wood.

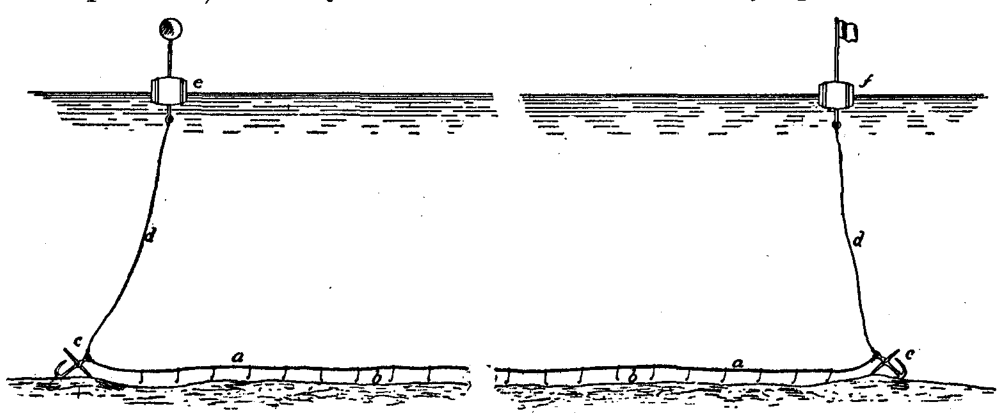
CUT 70.—Cod hand line.

The following miscellaneous apparatus is used in fishing:

Anchors, Chester patent, net.
Anchors, Chester patent, trawl.
Buoys, halibut trawl.
Buoys, keg.
Compasses, dory.
Fish forks.
Fish pew.
Floats, covered glass—Norwegian.
Gaffs, deck, cod.
Gaffs, dory, cod.
Gaffs, iron, halibut.
Harpoons, assorted.
Hooks, ice.
Hurdy-gurdy, or patent trawl roller.
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, gill net.
Molds, for sinkers.
Mold, for mackerel jigs.
Nippers, woolen.
Splicers, line, iron.
Swivels, snood.
Swivels, slot.
Slingding spreaders.
Tubs, trawl line.
Whale gun.
Whale gun, bomb lance.

TRAWL LINES.

The *Albatross's* trawl lines are practically the same as those used in the New England fisheries. They have tarred cotton ground-lines, 300 fathoms to the tub, 18 pounds per dozen, and carry 300 No. 14 cod hooks. The buoy ropes are of 9 to 12



CUT 71.—Cod trawl line.

a Ground line; *b* Hooks; *c* Anchors; *d* Buoy ropes; *e* Outer buoy; *f* Inner buoy.

thread tarred manila; keg buoys, with staff and black ball or flag, are used, and the moorings are 16-pound Chester-patent anchors.

The gangings are about 3 feet in length, and spaced 6 feet apart on the ground line, to which they are attached by sticking them through a strand and knotting the ends, or by a peculiar hitch known to fishermen, which is quickly made and will not slip. The baited hooks are placed carefully outside of the coil of ground line in the tubs.

Two men are required to set a trawl line from a dory, one pulling as directed, while the other throws the buoy overboard as soon as it is bent to the line, and pays the latter out as fast as he can until he reaches the lower end, when he bends it and the ground line to the anchor, throws it over, and pays out the line, hook by hook, with a peculiar twist of the arm, which throws them clear.

The bottom end of one tub of line is bent to the upper end of the next until the required length is reached, when the ground line and lower end of the buoy rope are bent to the anchor, the latter thrown overboard, the rope paid out, and the buoy bent and thrown into the water. A flag is usually carried on the staff of the inner buoy, and a black ball on the outer one.

Two men are required to haul the trawl; one in the bow heaves the line in over a patent roller fastened to gunwales of dory and worked with a crank, while the other, standing just abaft him, removes fish from the hooks and coils the line in the tubs.

GILL NETS.

The equipment includes a variety of gill nets which may be used as drift nets or anchored either at the surface, at the bottom, or at intermediate depths. They all have floats at the top of the net and sinkers at the bottom, the former having sufficient buoyancy to support the net at the surface. In the event of its being set beneath the surface extra weights are added, and its position at or above the bottom depends upon the length of the anchor ropes.

The following is a list of the gill nets furnished the *Albatross*.

Kinds and dimensions of gill nets.	Length.	Depth.	Size of mesh.	Twine.	Kinds and dimensions of gill nets.	Length.	Depth.	Size of mesh.	Twine.
	Fath.	*Fath.*	*Inches.*			*Fath.*	*Fath.*	*Inches.*	
Trammel net (2)	15	2½	2 6	35–3 12–16	Shad gill net	50	4	4½	35–3
					Do	50	4	4½	35–3
Mackerel gill net	30	2½	3¾	16–6	Cod gill net	100	2	7	40–10
Do	30	2½	3	16–6	Do	100	2	8	40–10
Do	30	2½	2½	16–6	Herring gill net (2)	20	2½	2¾	20–6
Menhaden gill net	15	2	3½	16–6	Do	20	2½	2½	20–6
Do	15	2	2½	16–6	Red-snapper gill net (2)	50	3	9	....

These nets are not all carried at the same time, owing to lack of space. A few of those most commonly used are retained, and others are taken when required.

The following nets are used for surface and shoal-water collecting:

Casting net: Diameter, 5½ feet; mesh, 1½ inches.
Surface tow nets, small: Silk bolting-cloth.
Surface tow nets, large: Netting ½-inch square mesh, twine 20–6, barked, and mosquito net lining.
Wing nets: Cheese-cloth, cotton.
Tub strainer nets: cheese-cloth, cotton.
Dip nets: Silk bolting-cloth.
Dip nets: Cheese-cloth, cotton.
Scoop nets.
Fyke net.

Seines are among the most useful apparatus for collecting alongshore, and the vessel is provided with the Baird collecting seine and the drag seine.

The Baird collecting seine was devised by the late Prof. Spencer F. Baird for the use of naturalists in the collection of specimens along the margins of the sea, lakes, and rivers. It was originally from 9 to 15 feet in length; very light, compact, easily carried by one man and operated by two; but it has since been made in various sizes, and much enlarged, even to 110 feet in length. The three sizes generally used will be described. Stretch measure will be used to indicate the size of mesh.

The Baird seine No. 1 is 15 feet in length and 3½ feet in depth; the middle section of 5 feet, including the bag, 4 feet long, is ¼-inch mesh; the wings, each 5 feet in length, are ⅜-inch mesh. It has ordinary wooden floats and lead sinkers, about 9 ounces to the foot on the middle section, decreasing gradually toward the extremities. A wooden staff on each wing facilitates hauling.

The material of the net is the best quality of cotton seine twine, 20–6 barked.

The Baird seine No. 2 is 25 feet in length and 4½ feet in depth; the middle section of 9 feet, including the bag, 6 feet in length, is ⅜-inch mesh; the wings are 8 feet long, 4 feet being ⅝-inch, and the remaining 4 feet at the extremities 1-inch mesh. Twine, floats, sinkers, and staves are the same as those used with No. 1.

The Baird seine No. 3 is 45 feet in length and 6 feet in depth. The middle section of 15 feet, including the bag, 8 feet in length, is ½-inch mesh; the wings are each 15 feet long, the inner half ⅝-inch mesh, and 1 inch at the extremities. The twine, floats, sinkers, staves, etc., are the same as on the smaller nets.

The drag seine is the largest collecting net used on board the *Albatross*. It is 150 feet in length, 20 feet deep in the bunt, and 2½-inch mesh. It is the ordinary 25-fathom ship seine, fitted in the usual manner.

NAVIGATION: APPARATUS AND METHODS.

The principal implements used in the navigation of the vessel comprise three Negus and one Bliss & Creighton box chronometers, the latter being used as a hack; also a comparing watch. The Ritchie liquid compasses are used for standard, steering, telltale, and boat service. The standard compass has an azimuth circle and alidade, and another is fitted with tripod and circle. A pelorus is provided for taking bearings of objects which can not be seen from the standard. The usual number of sextants and octants are provided; also an artificial horizon.

The Bliss and Walker taffrail logs are used to measure the vessel's speed through the water, and the common hand-lead measures the depths within its capacity, while the Tanner sounding machine, either alone or with the Bassnett atmospheric sounder, or Sir William Thomson's tubes attached, is used in deeper waters. Both telescopic and binocular marine glasses are provided, and for convenience in platting there is a three-arm protractor, a Negus course-indicator, Sigsbee's parallel rulers, drawing instruments, etc.

The chronometers are placed under a lounge in the chart room, the transporting cases being screwed to a false bottom on the deck. In this position they are secure from shocks, and the top of the lounge, opening and shutting on hinges, fits tightly enough to prevent drafts of air or any great changes of temperature. The most powerful disturbing element on the rates of the chronometers has been the vibration of the hull, caused by the dynamo engine, which is usually in operation from dark until 11 p. m. They appear to run equally well together while this vibration takes place every day, and during any material interval that it does not take place at all; but an interruption of either state of repose or vibration is almost invariably accompanied by a change in the record differences in the daily comparison book, showing that their rates are temporarily disturbed.

On reaching port the chronometers are rated as soon as possible by comparison with the time obtained by telegraphic connection with some observatory clock; or, when such connection is not possible, equal altitudes of the sun are taken, and the errors corrected back if the discrepancy is greater than the probable limits of personal and instrumental errors of observation and platting.

The standard compass is placed about 15 feet forward of the smokestack, on the deckhouse, where it was located by a magnetic survey; it was found that in this position the needle was least disturbed by the various magnetic forces exerted by the metal of and in the ship; it is also in a convenient position for use, being handy for taking bearings and under the eye of the officer of the deck when under way.

The standard compass is not compensated, and the local deviation is obtained by swinging ship under steam, observing azimuths of the sun on every point, making a circle with port helm, then with starboard, the mean of the results being accepted as correct. The curve of deviations being platted upon a Napier diagram, a table of magnetic courses is deduced for convenience in laying the ship's head.

The heeling error is obtained by listing the vessel to starboard and port and observing azimuths of the sun as before.

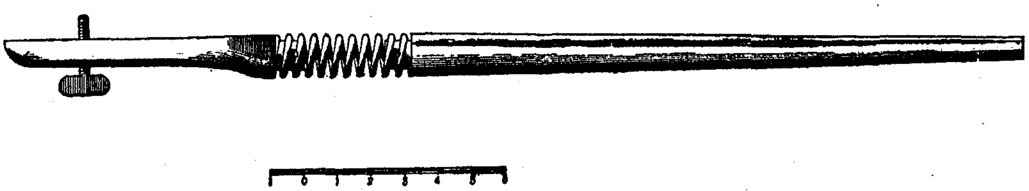
In general terms it may be stated that the changes of deviations due to inclination are such that when heeled to starboard the ship's head is thrown to windward, or toward the higher side, when on any course in the northern semicircle; in the southern semicircle, when heeled to starboad, the ship's head is thrown to leeward, or toward the lower side.*

When heeled to port the ship's head is thrown to leeward when on any course between southeast and northwest through north, and to windward when on any course to the southward of southeast and northwest. While building, the ship's head pointed N. 29° 30′ W; the ways were in latitude 39° 44′ N., longitude 75° 33′ W.

The sextants and octants are of the ordinary type. One, the lunar sextant, has an attachment called the Tanner flexible staff, its purpose being to eliminate the nervous tremor of the observer or the effect of wind upon the instrument when observing with the artificial horizon.

It is an ordinary wooden staff, 2 feet 6 inches in length, not unlike a walking stick, its upper end flattened on one side and pierced with a ⅜-inch hole, and a spiral spring of phospher bronze is inserted between the severed parts, 8 inches from the head of the staff, forming a flexible universal joint.

A brass plate with screw thread and thumbscrew is let into the back of the sextant handle, and to mount the apparatus for use it is only necessary to connect staff and handle by means of the thumbscrew.



CUT 72.—The Tanner flexible staff.

A convenient position for observing is to sit on a camp stool, with elbows resting on the knees, and the staff planted firmly on the ground, at an angle that will afford the desired support and enable the observer to change the position of his instrument at will through the flexion of the joint.

The staff should be made of light material, in order to interfere as little as possible with the handling and reading of the sextant.

The taffrail logs, both the Walker and Bliss, are excellent instruments when properly cared for. The former is preferred when running steadily for a considerable time at high speed, while the latter is more convenient for short distances at varying speeds when the fractions of a mile are required, and the necessity for hauling in and putting out is of frequent occurrence, as in sounding and dredging. It is good practice for a vessel engaged in such work to keep one Walker log as a standard, using it for no other purpose, as the propellers of working logs are always liable to injury by coming in contact with the stern of the vessel or being struck by sharks or other fish.

The Bassnett atmospheric sounder used in connection with the Tanner sounding machine for measuring depths within 100 fathoms, without changing the speed of the vessel, is, when used intelligently and properly cared for, a very useful and almost indispensable adjunct for coasting at night or in foggy weather.

It operates on the principle of the compression of a column of air proportioned to the increase of pressure as it sinks beneath the surface. It is composed of a glass

* She has recently been supplied with compensating binnacles.

tube inclosed within a shield of brass, in which appropriate slits expose portions of the tube longitudinally. The upper end of the tube is air and water tight, and at the lower end is a valve which turned in one direction admits water and prevents its escape; thus the top of the column of water indicates the depth in fathoms, read from a scale attached to the body of the sounder. A reverse movement of the valve allows the water to escape, and it is only necessary to replace it in its former position to prepare the apparatus for another cast.

The action of the sounder depends upon the valve being tight and this is assured only by constant and intelligent care. It should be rinsed in fresh water, dried and oiled after using, and requires frequent examination and adjustment to guard against oxidation, and to see that the valve can be moved by hand, while it is sufficiently tight to prevent leakage.

Sir William Thomson's tubes have their interior surfaces coated with a chemical preparation that becomes discolored upon contact with sea water, and the compression of the column of air or the penetration of the column of water is measured on the tube by a scale showing fathoms of depth. It works on the same principle as the Bassnett tube, and is sometimes preferred because it has no valve to be cared for. The disadvantage is that the number of soundings are limited to the supply of tubes, which can not always be renewed when most needed.

No vessel should be considered seaworthy unless she carries some reliable apparatus for ascertaining the depth to 50 fathoms at least without slackening her speed.

The Rogers portable micrometer telescope is a very reliable and useful instrument. A description and method of using it is to be found in the revised edition of Bowditch's Navigator, page 177. A modification of that method was adopted on board the *Albatross*, which required less computation and avoided the necessity of picking out each time the log. cotangent of such a small angle. Lieutenant Schroeder describes it as follows:

The greatest angle this instrument can measure is 1,750 micrometer divisions, or about 1° 45′, and it is seldom that an angle of over one-half or three-quarters of that is observed with it. In such small angles the functions may be considered as proportional to the arcs, that is, the cotangent of the angle measured is equal to the cotangent of one micrometer division divided by the number of those divisions. The log. cotangent of one division being accurately determined once for all, the rule for finding the distance is simply to add that function to the logarithm of the height, and from the sum subtract the logarithm of the number of divisions.

Example: A light-house 200 feet high is found to subtend an angle of 1,700 micrometer divisions. The value of one division of the instrument on board the *Albatross* is 3″.655, of which the log. cotangent is 4.7515377, or in practice 4.75154.

SHORT METHOD.

200 feet	log. 2.30103
1 M. D	log. cot. 4.75154
	7.05257
1.700 M. D	log. 3.23045
6,639.3 feet	log. 3.82212

RIGOROUS METHOD.

3.″655 × 1.700 = 6.213″.5 = 1° 43′ 33″.5.

200 feet	log. 2.30103
1° 43′ 33″.5	log. cot. 1.52097
6,637.4 feet	log. 3.82200

The smaller the angle, the smaller of course will be the discrepancy.

For rapid work in a hydrographic survey or reconnaissance, 10 feet is found to be a convenient length of staff to handle, and the logarithm of 10 being 1.00000 makes the computation all the easier. A board 10 inches broad, painted white, with a 2-inch black stripe down the middle, will be found to be an easily distinguished target.

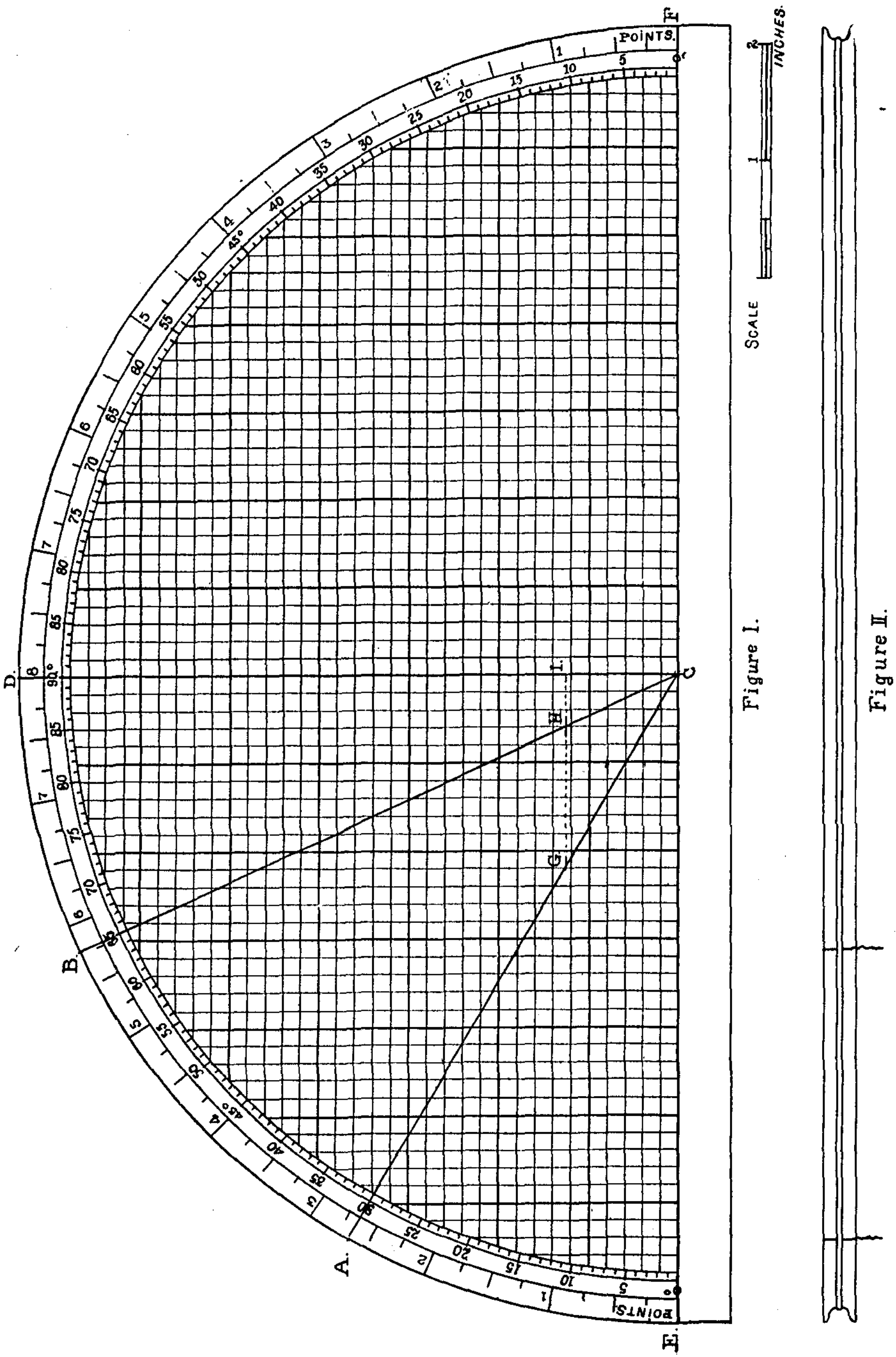


Figure I.

Figure II.

THE BLISH DISTANCE FINDER.

THE BLISH DISTANCE-FINDER.

This is a simple and admirable little instrument devised by Lieut. John B. Blish, United States Navy, and used on board the *Albatross* for several years, where it was found particularly valuable when coasting at night or during stormy weather.

With the course and distance, and two bearings of a point of land, without computation or reference to books or charts, the distance-finder will give the distance of the point at the time of the first and second bearings, the distance to be run from the second bearing to bring it abeam; also the distance at which it will be passed if the course is maintained. Repeated observations will show whether the vessel is actually making her course.

The distance-finder, as improvised and used on board the *Albatross*, is shown in plate XXXVIII; fig. I is a plan, and fig. II a sectional view. Scales of degrees and points are marked on the arc; C D, C E, and C F are scales of equal parts, which may be used as miles or fractions of a mile. A and B are silk threads pivoted at C and drawn under an elastic band which rests snugly in a groove surrounding the instrument, as shown in fig. II. The elastic band permits free movement of the threads of silk, yet holds them in place when set. The vessel is supposed to be heading at all times from C to E, hence all bearings are plotted in points or degrees from E.

To use the distance-finder, take a bearing of a point, note the number of degrees or points it bears from the ship's head, set the arm A, counting the degrees from E, and note the reading of the log; steer the same course until the bearing of the point has changed sufficiently to make a practicable angle, then take a second bearing, and set the arm B on the number of degrees or points the object bears from the ship's head, counting from E as before; also note the distance run between the first and second bearings. With the distance by log, taken from the scale of equal parts C E or C D on a pair of dividers, find G H between the arms A B parallel with C E. Then G will be the position of the ship when the first bearing was taken, and H when the second bearing was taken; the interval C G is the distance of the vessel from the point when the first bearing was taken, C H the distance from the point when the second bearing was taken, H I the distance to be run to bring the point abeam, and C I the distance at which the vessel will pass the point.

If the vessel is to pass within 5 miles of the point, it will be found convenient to have the divisions on the scale of equal parts represent half miles instead of miles. In reading the scale fractions are estimated in tenths to correspond with the divisions of the patent log.

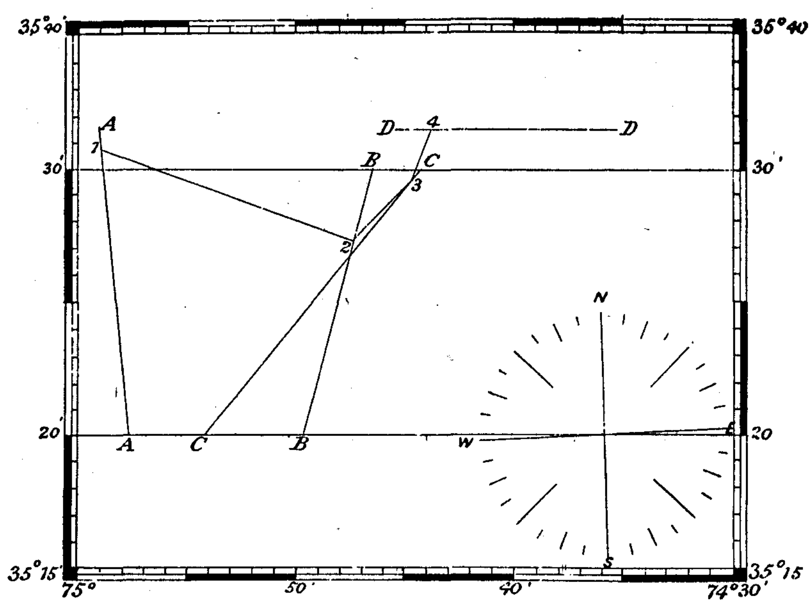
EXAMPLE:

First bearing 30° *from ship's head (or* E).
Second bearing 65° from ship's head (or E).
Distance by log between first and second bearings, 8 miles.
Set the arm A on 30° for the first bearing, and the arm B on 65° for the second bearing.
Thus 8 miles, the distance run by log, equals G H.
C G, measured on scale of equal parts, equals 12.6 miles, the distance of point at first bearing.
C H equals 7 miles, the distance of the point at the second bearing.
H I equals 3 miles, the distance to be run from the second bearing to bring the point abeam.
C I equals 6.3 miles, the distance the point will be from the vessel when it is abeam.

The intervals C I and H I are most used in practice, but should C G and C H be required, they may be measured on the scale with dividers, or by grasping the arm A at G, or the arm B at H, and carrying them to the scale. The distance-finder in use on board the *Albatross* was improvised by Ensign Henry B. Wilson, United States Navy. The scales were marked with india ink on Irish linen writing paper, which was then glued to a wooden back, and finally given several coats of shellac varnish to protect it from moisture. Sewing silk was used for the arms, which were held in place by an ordinary elastic band fitting closely in the groove, and a small round nail was used for a pivot from which they worked. The left quadrant of the semicircle is used in the description and example; the right one may be used in like manner by assuming that the ship's head is in the direction of F instead of E.

The instrument is used as though the vessel was always on the line C E, steering toward E, but in reality she was at G when the first bearing was taken and at H at the time of the second bearing, steering toward I on the line G H I, the pivot C being the point on which both bearings were taken.

The distance-finder is constructed on the principle of Table 5 A, Bowditch Navigator.



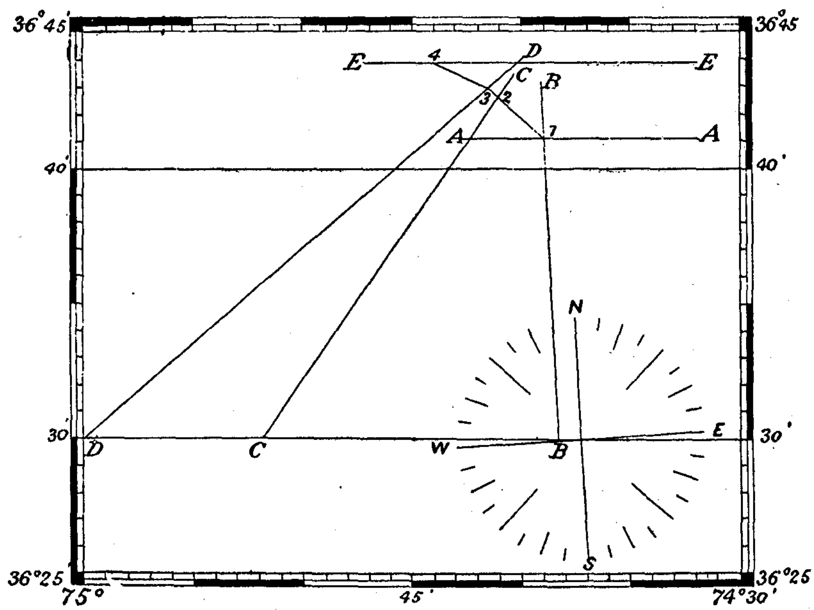
CUT 73.—Case I.

SUMNER'S METHOD.

In the navigation of the *Albatross*, and the location of dredging, sounding, and other stations, Sumner's method of finding the position at sea is used *in extenso*. All positions, however determined, are plotted as lines, and not points—the intersection of two such lines, corrected for the intervening run and current, defining the exact position. The lines of position consist of portions of circles of equal altitude of the sun, moon, stars, and planets; parallels of latitude deduced from meridian or ex-meridian altitudes of the same bodies; lines of bearings of headlands or well-known objects on shore; circles of equal distance from known objects, found by micrometer or by their dipping below the horizon. Computations are made from forms and examples to be found in Bowditch's Navigator.

Case I.—On April 28, 1883, single altitudes of the sun were observed at 6.43 a. m., 8.47 a. m., and 10.23 a. m., a sounding being taken at the time of each sight. The meridian altitude was observed at noon. The three time-sights were worked out for latitudes 35° 20′ N. and 35° 30′ N., placing the vessel respectively on the lines AA, BB, CC; and the meridian altitude placed her in latitude 35° 31′ 35″, DD. From the first sounding, ran 10 miles ESE. (mag.) to the second, where the temperature of the surface water and the current showed that the edge of the Gulf Stream had been reached. From the second to the third the drift in trawling and current was estimated at 3 knots NE. From the end of the third cast to noon the drift and current were about 2 miles NNE. These being plotted, place the ship in the positions 1, 2, 3, 4.

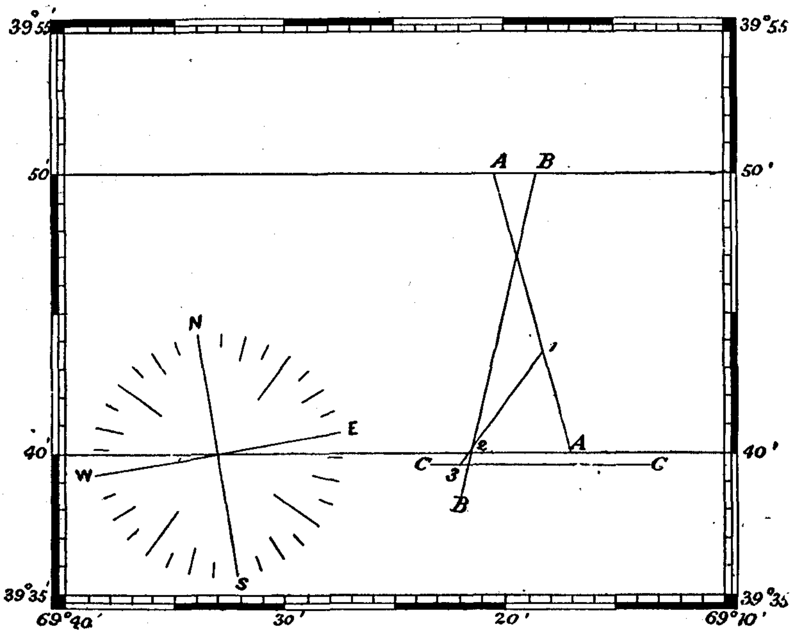
Case II.—While sounding at about 7 a. m., May 1, a meridian altitude of the moon was observed, showing the latitude to be 36° 41′ 05″ N. At the same time a single



CUT 74.—Case II.

altitude of the sun was observed and worked out for latitudes 36° 30′ and 36° 40′. The ship was therefore at the intersection of the two lines thus found, AA, BB. While trawling, two more sights of the sun were taken, at 10.09 and 10.49; and being worked out with the same latitudes as before, placed the ship on the lines CC, DD. Finally a meridian altitude of the sun was observed, which placed the ship in latitude 36° 43′ 54″ at noon, EE. The drift while trawling, until the last time sight, was to NW., 2½ to 3 knots in all; and then, after the sight NW. by W. ½ W., 2¼ miles to noon. No current noticeable. Plotting the track, the ship was found to have been in the positions 1, 2, 3, 4.

Case III.—At 3 and 5.45 p. m., August 1, single altitudes of the sun were observed and worked out for latitudes 39° 40′ N. and 39° 50′, giving lines AA and BB. At about 7.30 an altitude near meridian of * Antares was taken, which placed the ship at that time on the parallel of 39° 39′ 23″, line CC. The drift in trawling during the afternoon was SW., and the distance estimated at 4 knots between the first and second sights and $\frac{3}{4}$ to 1 knot from the second to the third. Plotting the track the ship was found to have been in positions 1, 2, 3. No current observed.



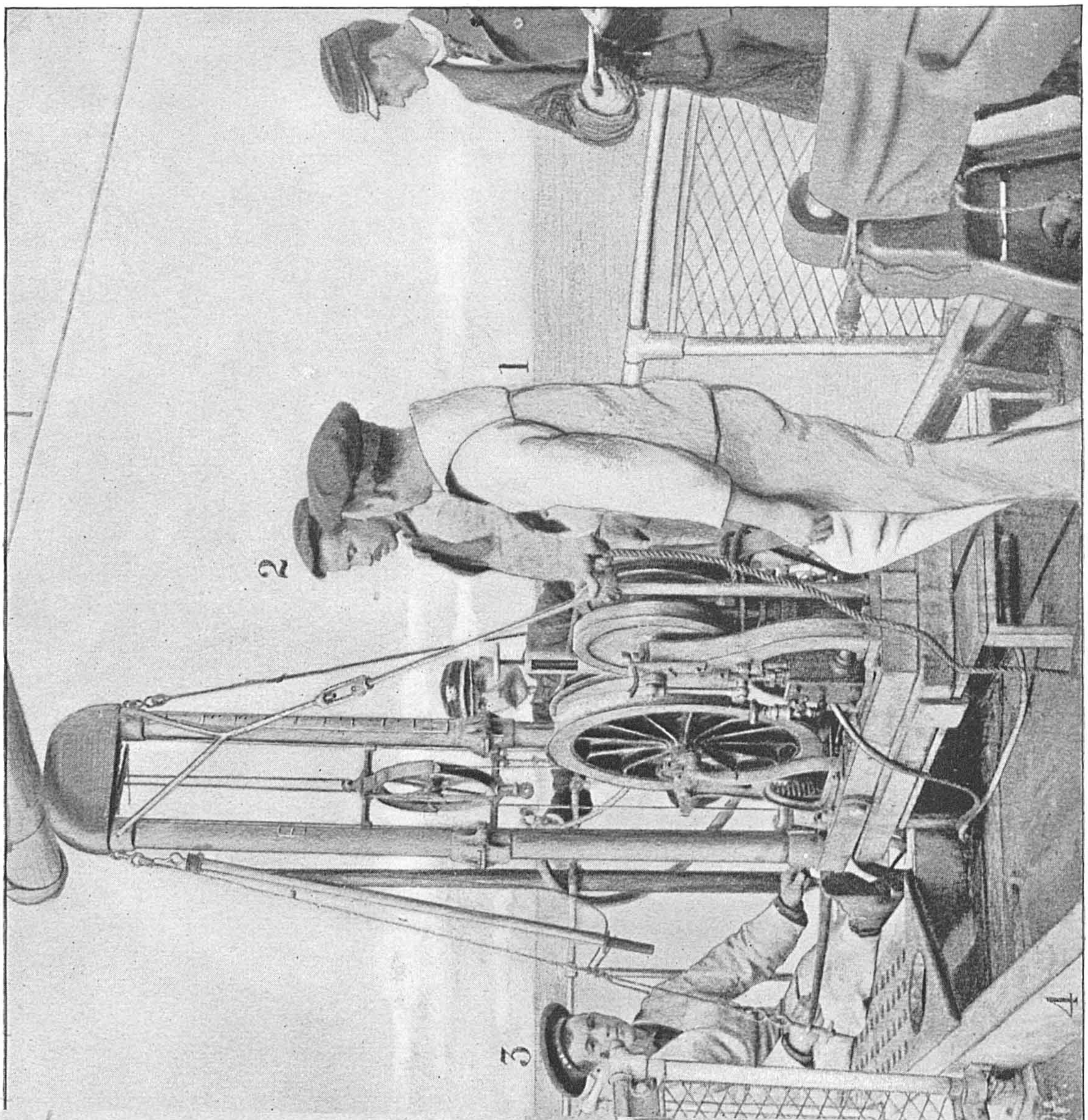
CUT 75.—Case III.

OTHER METHODS.

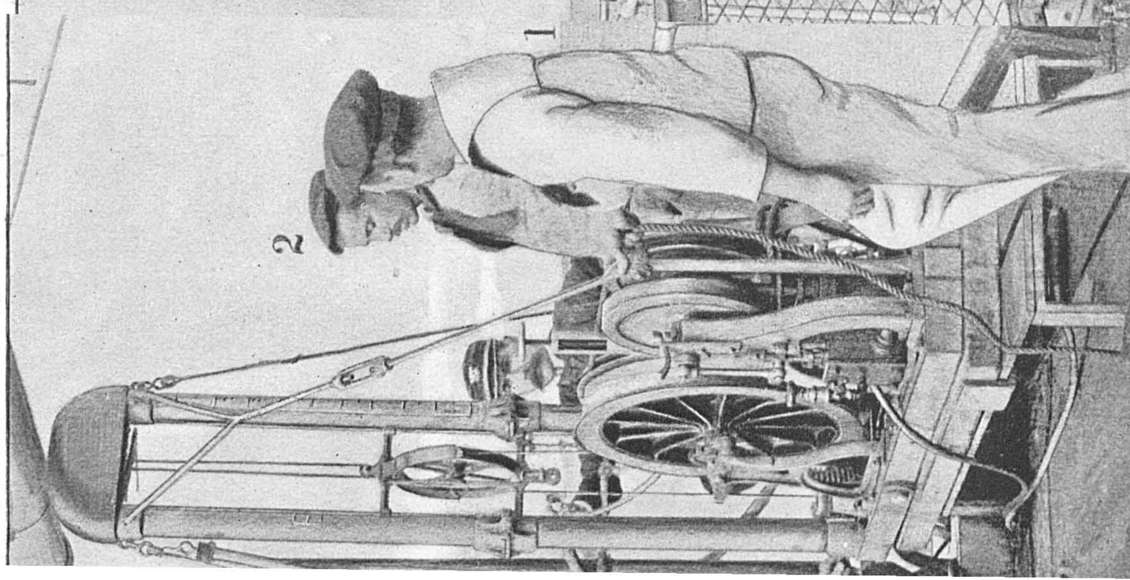
In addition to the above-mentioned methods, advantage is taken whenever possible of the simple "four-point problem" of finding the distance from an object by reading the taffrail log when it bears exactly four points off the bow, and again when it bears exactly abeam, the distance from the object at the second bearing being equal to the distance run between the two, plus or minus the current.

At each sounding the current is carefully estimated by noting the direction and speed of the ship necessary to keep the sounding-wire vertical after the sinker has passed below the surface drift. A fair guide is thus afforded as to what allowance should be made in shaping the course to the next position, as well as in correcting the run up to that point. Such help is particularly desirable when clouds by day or night prevent taking frequent observations.

PLATE XXXIX.



STATIONS AT THE SIGSBEE SOUNDING MACHINE—WIRE GOING DOWN.



T THE SIGSBEE SOUNDING MACHINE—WIRE GOING DOWN.

THE CONDUCT OF DEEP-SEA EXPLORATION.

The economical use of material and forces at the disposal of the commander in the conduct of extended deep-sea exploration assumes greater importance than is usual in ordinary operations either on land or sea.

The relation of speed to the fuel supply and the amount of work to be accomplished will be among the first considerations, and after he has decided upon the daily coal consumption the best results will be obtained by—

1. Carrying sail whenever the wind serves.
2. Keeping the chief engineer informed regarding the service to be required of the engines, and giving due warning to the engineer of the watch when approaching a station, and the probable detention.
3. Having due regard to the fact that the *Albatross* has twin screws, capable of working independently or together, and that one engine will frequently perform the duty as well or better than both when, as in sounding with light winds, it is desired to hold the vessel in position without gaining headway or sternboard, or if very low speed is required, as in operating the trawl or dredge.
4. Using one engine only, whenever it will answer the purpose, will reduce the wear and tear and lighten the duties of the engineer of the watch, which are sufficiently trying at best when the vessel is engaged in sounding or dredging.

The operations included in the full occupation of a station follow in their natural sequence:

1. Sounding, including surface and bottom temperatures and water specimens.
2. Serial temperatures and specific gravities.
3. A haul of the trawl.
4. A haul of the dredge.
5. A haul of the tangles.
6. Surface and intermediate collecting.
7. The use of trial lines.
8. Setting trawl lines.
9. Setting gill nets.
10. Current observations.

SOUNDING.

Soundings are made under the direct supervision of the officer of the deck, who is responsible for the prompt and systematic execution of the necessary evolutions and accuracy of measurements. He should, before reaching a station, satisfy himself by personal examination upon the following points:

1. That the crew of the sounding machine are at hand, and that each man understands his duties, also the duties of every other member of the crew.
2. That there are no slack turns of wire on the reel, or, should he discover any, have them run off on a spare reel and properly rewound. Slack turns will never occur with a properly drilled crew except the reel collapses, a rare occurrence with the Navy reel.
3. That the stray line and its splice are in good condition. Should a defect be discovered too late to renew the splice without delaying operations, substitute a Tanner link, which can be attached to the wire in a moment and will answer the purpose until such time as a new stray line can be spliced on.
4. That the belt is sound and in good working order, and that there is a spare one on the machine. If in doubt as to the reliability of the old one, cut it away and bring the spare one into use.
5. That the register is set at zero when the sinker is at the water's edge; the pointers securely fixed to their stems; that the spur wheel meshes properly in the worm wheel, and that all of its gearing works freely.
6. That the friction rope is in place and in good condition, and that the auxiliary brake is in working order.

7. That the Sigsbee sounding rod is in good order generally, swivel and tumbler working freely, and the spring in the latter properly adjusted. That the two parts of the cylinder are screwed together tightly, the valve properly seated, and its spring in action.

8. That there is a supply of bailed sinkers in the racks near the sounding machine, and that the sounding rod will pass through them freely.

9. That all moving parts of the machine, including the reeling engine, are properly oiled and cared for.

10. That the deep-sea thermometer used for bottom temperature is in good order; that the column breaks promptly, propeller moves freely; that the instrument is properly cushioned by the rubber gaskets and spiral springs which suspend it in its case, and that the clamp is in working order. The Negretti & Zambra deep-sea thermometers are used on board the *Albatross*, and being delicate ments they should be carefully treated in order to obtain the best results. They should be habitually carried bulb down, with columns connected, and it is a good plan to keep them in a bucket of water between stations, as it insures their safety and keeps them at a temperature approximating to that of the surface water.

11. That the Sigsbee water specimen cup is in good working order generally; and, if it is intended to bring up a water specimen at the next station, that the interior of cup is clean and free from foreign substances, valves adjusted, propeller and sleeve working freely, and the clamp in good condition.

12. That a quart or more of sperm oil in a suitable vessel is secured to the frame of the sounding machine forward of the reel with sponge, waste, or other material for oiling the wire.

13. That the wire clamp and guide are in their respective places.

14. That the portable incandescent lights are led out and hung in place if the next station is to be occupied at night.

The engineer of the watch should be warned half an hour at least before reaching the station, and again five minutes before making the signal to stop the engines. The necessary preparations should then be made on deck and the sounding crew sent to their machine. Arriving at her station with calm weather and smooth sea, the vessel is stopped without changing her course, but if it is blowing and a sea running she would be turned stern to by putting the helm up, slowing down, and backing the lee engine until the wind is on the quarter, then backing both until the vessel loses headway, taking care not to get a sternboard. Once in position, it can usually be maintained by slowly backing the lee engine.

If sounding in considerable and approximately known depths, it is not necessary to wait until the vessel is at a stand stern to sea; the sinker may be started down as soon as the wind is on the quarter and the wire brought up and down during its descent. The *Albatross* frequently gained from 100 to 200 fathoms in this manner.

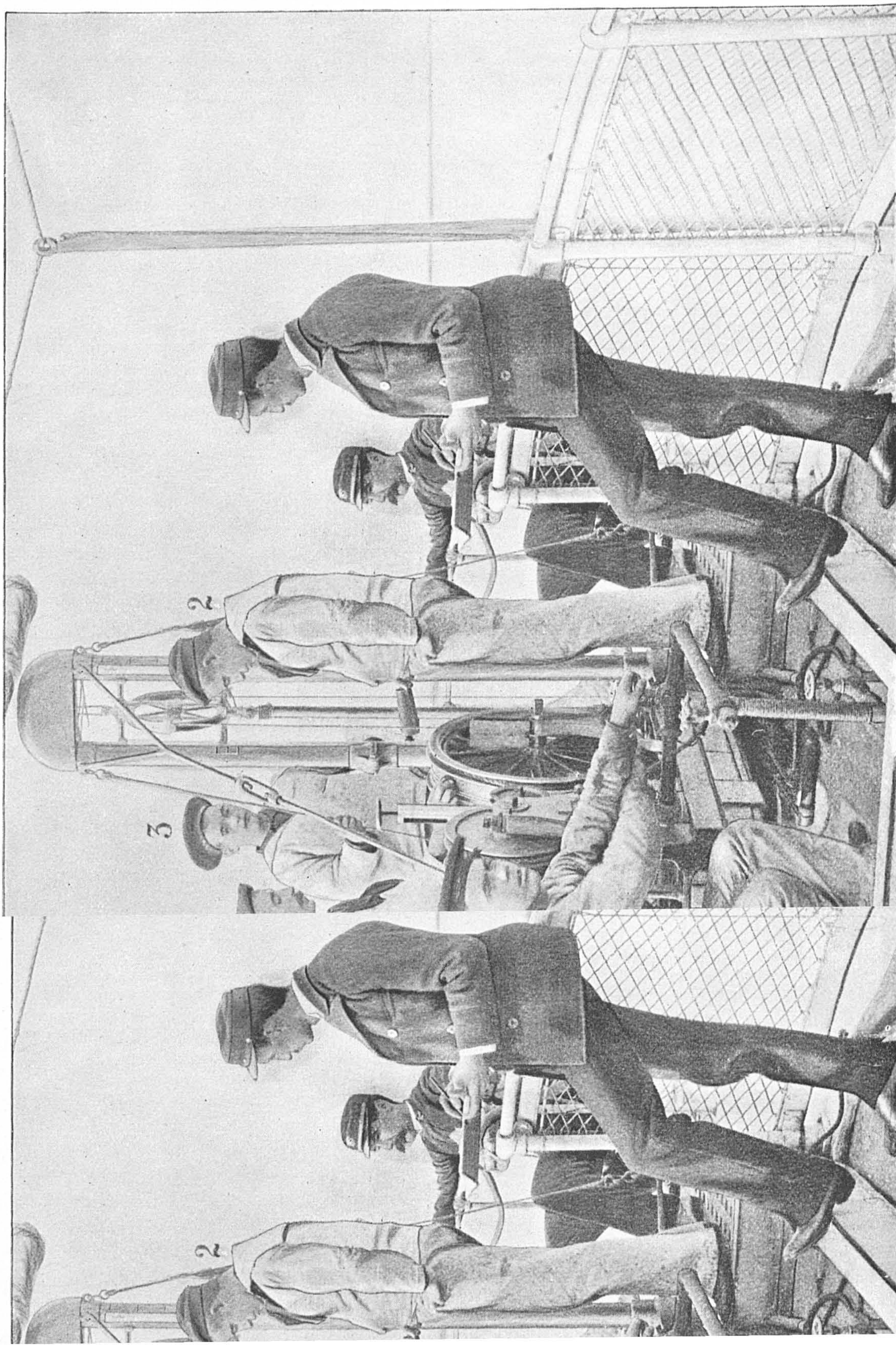
The crew of the Sigsbee sounding machine is composed of three seamen and a fireman, numbered 1, 2, 3, and 4; the officer of the deck and a recorder. Their stations and duties are as follows:

PREPARING TO SOUND WITH THE SIGSBEE MACHINE.

When ordered to man the sounding machine (plate XXXIX), No. 3 bends the stray line to the sounding rod, No. 4 places the sinker in the mounting rack on the left of the machine forward of the grating, the former then hooks the bail over the tumbler of the rod, lifts the shot from the rack, and swings it to the after end of the machine, when No. 2, who has shipped the right crank, heaves in the slack line until the sinker is suspended beneath the swivel pulley, where it is held by engaging the pawl on the ratchet wheel.

No. 1 wipes the V groove on the reel, and when dry and free from oil adjusts the friction rope and attends it.

PLATE XL.



STATIONS AT THE SIGSBEE SOUNDING MACHINE—WIRE COMING UP.

SIGSBEE SOUNDING MACHINE—WIRE COMING UP.

STATIONS—WIRE GOING DOWN.

The officer of the deck having taken his station on the grating to the right and abaft the machine, directs the sinker to be lowered a fathom below the surface of the water, the auxiliary lead bent to the stray line, the thermometer clamped a fathom above it, and the water-specimen cup a fathom above the latter, having first satisfied himself that the instruments are in perfect order. When everything is in readiness he directs the pawl to be thrown back, the crank unshipped, and gives the order to lower away.

No. 1, standing forward of the machine and facing it, attends the friction rope and makes the sounding as quickly as possible, having due regard for the safety of the apparatus. As soon as the sinker reaches bottom, and No. 2 has shipped his crank, No. 1 throws off the friction rope, ships the left crank, and assists in heaving the specimen cup clear of the bottom.

No. 2, on the right of the machine and facing it, attends the auxiliary brake in case of accident to the friction rope, or if the reel becomes unmanageable from any cause. As soon as the sinker strikes the bottom he ships the crank, heaves in a few fathoms of wire, and, when it is ascertained that the sinker is detached, he unships the crank, adjusts the dynamometer staff under the accumulator pulley, and assists in putting on the belt.

No. 3, seated on the grating to the left and abaft the machine, attends the swivel pulley, and, if the wire is accidentally slackened by the sinker unexpectedly striking bottom, grasps the bight and pulls it aft, taking up a fathom or more, which is often sufficient to prevent kinking or flying off the reel. When the sinker is down, he feels the wire to see whether it is detached, then assists No. 2 in adjusting the dynamometer staff.

No. 4 stands forward and to the left of the machine until he wishes to prepare the engine for reeling in, when he moves about it, as occasion requires, keeping out of the way of No. 1.

In case the sinker fails to detach, the officer or No. 3 pulls the bight of the wire aft from the machine, then lets it go, repeating the operation several times if necessary; and, if it still fails to detach, Nos. 1 and 2 ship the cranks and heave the sinker clear of the bottom, then carefully land it again, when the manipulation of the wire is repeated.

The sinker should not be landed on the bottom abruptly when trying to detach it, for, as a rule, the trouble results from its having sunk deeply into the soft ooze.

STATIONS—WIRE COMING UP.

No. 1 stands on the left of the machine abreast of the reel (plate XL), and, with sponge or rag, oils the wire as it comes in. When the stray line is sighted, and the reeling engine stopped, he throws the pawl into action, ships the crank, and assists in reeling it in by hand.

No. 2, standing on the right of the machine, guides the wire smoothly on the reel, reports defective splices, nips, or kinks, and attends the auxiliary brake in case of accident to the belt. When the stray line is sighted he ships the crank and heaves it in by hand; then assists No. 4 to remove the belt from the reel.

No. 3, standing or sitting on the grating to the left and abaft the machine, attends the swivel pulley leading the wire fairly into its score. He warns No. 4 to stop the reeling engine if he discovers anything unusual or suspicious on the wire as it is coming in, also when he sights the stray line. He unclamps the water-specimen cup and thermometer, unbends the auxiliary lead, hitches the end of the stray line to the fair-leader, and unships the dynamometer staff. He also delivers the bottom specimen to a naturalist in the laboratory, washes the specimen cup, and returns it to its place near the sounding machine.

No. 4, stationed forward of machine, adjusts the belt, attends the belt-tightener, and runs the reeling engine. Fixing his eye upon the dynamometer scale, he reels the wire in as rapidly as possible, keeping within the prescribed tension; and it requires a dexterous manipulation of the throttle to regulate the speed according to the rapidly varying strains. He reduces the speed of the reeling engine at 200 turns, and again at 100, to avoid jumping the thermometer and specimen cup out of the water, and, stopping when the stray line is sighted, he loosens the belt-tightener, throws off the belt, wipes up the oil about the engine, and prepares it for the next cast.

The crew examine the stray line and its splice, the surface wire on the reel, and all parts of the sounding machine, which they wipe carefully; the bearings are oiled, deck around the machine cleaned up, and everything put in place.

STATION AND DUTIES OF THE RECORDER.

He takes his place at the right of the machine where he can best observe the readings of the register. He keeps a record of everything connected with the sounding, filling the blanks in the record book, and making such further entries as the occasion requires. Having assured himself that the recording watch agrees with the ship's clock, he will note:

1. The date, day of the month, and year.
2. The serial number of the sounding.
3. The machine to be used, Sigsbee or Tanner.
4. The reel used, Sigsbee, Navy, or Tanner.
5. The kind of sinker used: A deep-sea lead, giving its weight; a 35-pound or 60-pound shot.
6. Reading of the patent log, when it is hauled in after the vessel stops to sound.
7. Hour, minute, and second, the sinker starts down.
8. The minutes and seconds for each 100 turns of wire, as shown by the register.
9. The exact time the sinker strikes bottom.
10. The number of turns of wire out when the sinker reaches bottom.
11. Correction to be added to the number of turns to get the depth in fathoms.
12. Depth in fathoms.
13. Time of starting to reel in the wire.
14. If the patent log is put over, note the time and read it when vessel reaches her course.
15. Time for each 100 turns of wire coming in.
16. Time wire is all in.
17. Reading of deep-sea thermometer.
18. Maker's number of thermometer.
19. Thermometer correction.
20. Corrected temperature.
21. Reading of patent log when last turn of wire came in.
22. Character of bottom.
23. Note if water specimen was taken.
24. Any unusual occurrence, such as fouling, kinking, running off the reel, or parting the wire; slack turns; loss of the stray line; delay in detaching the sinker; injury to or loss of instruments; discovery of imperfect splices, or detention from any cause.

The speed of deep-sea sounding varies with the meteorological conditions, character of vessel, apparatus, personnel, and the purpose for which the soundings are required. Time will be gained if the deep-sea thermometer can be dispensed with, and a greater gain will follow by using a cup of less weight and cross-section where a small bottom specimen will suffice.

Table I is taken from the original record of sounding No. 424, Hawaiian cable survey, December 18, 1891, and shows the rate of descent and ascent of the wire for each 100 turns of the reel and must not be mistaken for fathoms. The time intervals were kept with the greatest care as a matter of record, not for the guidance or instruction of the operator at the friction rope, who was an expert and at liberty to take advantage of every favorable circumstance to accelerate the descent of the sinker. The conditions of wind and sea, while not perfect, were favorable for rapid work. A moderate northeast trade and small sea were accompanied by an occasional long, rolling swell from a recent gale.

A careful analysis of Table I shows:

1. That the time intervals were not seriously affected by wind or sea.

2. That the friction increased steadily with the length of wire out, retarding the descent of the sinker proportionately.

3. That the operator felt the sounding shot at intervals by slightly increasing the friction until satisfied that there was no slack wire between the reel and sinker.

4. That he maintained the friction approximately equal to the weight of submerged wire, as the reel stopped promptly when bottom was reached. We know this because it required but 2 minutes and 5 seconds to ship the cranks and heave the specimen cup clear of the bottom, adjust the belt, and commence reeling in.

5. That the prescribed limit of 120 pounds tension was closely followed while reeling in. The friction is observed to diminish as the wire comes up, but not with the regularity of the increase during its descent, for the following reason:

6. The sounding was made with stern to wind and sea, and the wire maintained in a vertical position without headway or stern board; but, as soon as the sinker reached bottom, the vessel began to turn, with one propeller moving slowly, her way through the water being slight for a couple of minutes, then gradually increasing until at 5 minutes she was on her course, dragging the wire transversely through the water 2 or 3 minutes until it trailed out astern, and from that time the friction decreased regularly until the 200 mark was reached, when the speed of the reeling engine was checked; again at 100 turns it was slowed still more to prevent the sounding cup, thermometer, etc., from jumping out of water, for by this time the vessel was steaming at the rate of 7 or 8 knots.

The patent log was put over at the 2,000 mark, and during the 14 minutes consumed in reeling in the remaining wire the vessel steamed 1.4 knots on her course.

Table II is compiled from the original records of six soundings, including No. 424, from which Table I was taken, and is intended to illustrate the mean speed and uniformity of the *Albatross'* soundings under normal conditions.

TABLE I.

Sounding wire.		
Going down.	No. of turns.	Coming up.
M. S.		*M. S.*
....	....	0 50
0 45	100	0 40
0 50	200	0 35
0 50	300	0 35
0 50	400	0 40
0 55	500	0 40
1 05	600	0 45
1 00	700	0 45
1 00	800	0 45
1 05	900	0 50
1 05	1,000	0 50
1 10	1,100	0 55
1 10	1,200	0 55
1 10	1,300	1 00
1 15	1,400	1 00
1 15	1,500	0 55
1 20	1,600	1 05
1 20	1,700	1 05
1 25	1,800	1 05
1 20	1,900	1 10
1 25	2,000	1 10
1 35	2,100	1 20
1 30	2,200	1 20
1 30	2,300	1 15
1 30	2,400	1 15
1 40	2,500	1 10
1 40	2,600	0 40
1 00	2,661	....

TABLE II.

Serial No.	Date.	Depth.	Fathoms per minute going down.	Time required to put on belt and start reeling in.	Fathoms per minute coming up.	Total detention for each fathom of depth.	Total time consumed in making the sounding.
		Fathoms.		*h. m. s.*		*h. m. s.*	*h. m. s.*
386	Dec. 14, 1891	2,696	85.6	0 1 45	112.3	0 0 1.27	0 57 15
392	Dec. 15, 1891	3,006	83.5	0 2 25	106.4	0 0 1.33	1 06 40
395	.....do......	3,030	75.7	0 2 00	92.5	0 0 1.49	1 15 00
401	Dec. 16, 1891	2,916	83.7	0 1 50	109	0 0 1.34	1 03 25
405	Dec. 17, 1891	3,034	83.8	0 3 20	82.3	0 0 1.51	1 16 20
424	Dec. 18, 1891	2,825	86.2	0 2 05	112.2	0 0 1.27	1 00 00
Mean	....	2,918	83.1	0 2 14	102.45	0 0 1.37	1 06 27

TAKING SERIAL TEMPERATURES.

In order to guard against the loss of instruments, a large and strong temperature wire is used. It is steel piano wire, No. 21 music, about 0.045 inch in diameter, or No. 17 American gauge; it is in a single length of 1,225 fathoms, wound on a Sigsbee reel, and kept in a reel box in readiness for use.

Serial temperatures when taken always follow a sounding, and if water specimens are required for specific gravities a specimen cup is clamped to the wire a fathom above each thermometer. An assistant examines the thermometers and water-specimen cups in the laboratory and places them in buckets or other convenient receptacles in readiness to be carried to the sounding machine.

Preparatory.—When the sounding is completed, No. 1 guides the stray line on the reel and secures the end to its own part, removes the left cap-square and assists in dismounting the sounding reel and mounting the temperature reel; then replaces the cap-square, secures the roller guide in place, runs the end of the stray line over the accumulator pulley and through the guide, and adjusts the friction rope.

No. 2 reels in the stray line, unships the crank, removes the register and right cap-square; assists in dismounting the sounding reel and mounting the temperature reel; then replaces the cap-square and register, assists in securing the roller guide and in reeving the end of the stray line. He ships the crank and lowers the sinker a fathom below the surface when ordered.

No. 3 brings the deep-sea thermometers and water-specimen cups, assists in shifting the reels and in removing the fair-leader and swivel pulley. He bends a deep-sea lead to the stray line for a sinker and suspends it by the pawl below the roller guide, where it hangs quietly until it is lowered beneath the surface preparatory to clamping on the first thermometer.

No. 4 removes the fair-leader and swivel pulley and assists in shifting the reels and replacing the cap-squares. A convenient method of mounting or dismounting a reel is to use a small watch tackle from the main boom. If the boom is not available, lash a handspike across the reel in line with its shaft and four men will readily lift it out of its bearings or replace it, as the case may be.

STATIONS—INSTRUMENTS GOING DOWN.

No. 1 attends the friction rope (plate XXXIX), following the same general rule as in sounding. He is given the stopping-places in succession, and should bring the wire to a stand without jarring the instruments or bringing unnecessary strain on the wire itself. When the last thermometer has been lowered to its place and the pawl brought into action, he removes the friction rope from the groove and prepares to oil the wire as it comes in.

No. 2 passes the thermometers to the recorder, who notes their numbers, then to the officer in charge. The water-specimen cups are passed directly to the officer. He then stands in readiness to use the auxiliary brake.

No. 3 receives the thermometers and water-specimen cups from the officer and clamps them to the wire, as directed in sounding. When the last thermometer has been lowered to its place, he brings the pawl into action. An interval of five minutes is allowed for the last instrument of the series to take the temperature.

No. 4 puts belt on, gets reeling engine in readiness, and ships ratchet crank on driving shaft, where it is allowed to remain to assist in bringing the instruments carefully to the point above the grating, where they are removed from the wire.

STATIONS—INSTRUMENTS COMING UP.

No. 1 oils the temperature wire as it is wound on reel (plate XL), and passes water-specimen cups to an assistant in the scientific department, who turns their contents into specially prepared bottles.

No. 2 guides the wire fairly on the reel, receives the thermometers from the officer in charge, holds them in position for the recorder to verify the reading, then engages the propeller spindle and places them, bulb down, in a bucket or other secure place.

No. 3 seats himself on the grating, watches the wire and reports the appearance of instruments at the surface, also when they are in position to be conveniently removed. He unclamps the water-specimen cups and thermometers, passing the former to No. 1 and the latter to the officer in charge. He reports if instruments fail to act through the fault of their mechanism, and when they are all in he unbends the sinker.

No. 4 attends the throttle and reels the wire in, starting and stopping carefully at the designated points to avoid jarring the thermometers. He watches the register for the designated number at which he is to stop, giving heed also to the warning of No. 3 that the instruments have reached the surface.

The officer in charge directs when the sinker is to be lowered into the water and the first thermometer clamped to the wire, for, unlike deep-sea sounding, it should not be lowered until the vessel is in position and at a stand.

He examines thermometers and water-specimen cups, as directed in sounding, and passes them to No. 3, observing that he does not fail to catch the bight of the wire over the clamp screw to prevent slipping. This is quickly done by first engaging the upper jaw and throwing the frame forward until the wire slips easily over the screw head, then bringing it back into position and engaging the lower jaw.

He receives the thermometers from No. 3 as he unclamps them from the wire, carefully reads the temperature with a reading lens, and passes them to No. 2, who holds them before the recorder's eye while he verifies the reading to degrees without the use of a lens.

It has been found in practice that the officer may occasionally make a mistake in the degrees when using the lens, but not in the decimals of a degree, to which he naturally gives the greatest consideration, while the recorder, observing without the lens, quite as naturally gives his first attention to degrees.

DUTIES OF THE RECORDER.

In observing serial temperatures the recorder takes his station at the right of the machine and—

1. Sees that the register is set at zero when the instruments first attached are at the water's edge.
2. He informs the operator at the friction rope where each thermometer of the series is to be attached to the wire.
3. He notes the maker's number of each thermometer before it is clamped to the temperature wire, in order to identify it beyond question when making the final corrections.
4. If water specimens are taken for specific gravities, he notes the fact, also the depths at which they were obtained.
5. He reports the expiration of the interval allowed by the officer in charge for the last thermometer of the series to take the temperature.
6. When the engineer starts to reel in he informs him where each instrument is attached.
7. He enters the officer's reading of each thermometer, calling back the figures distinctly, and verifies it by personal inspection, giving special regard to the degrees. If the readings disagree he calls the attention of the officer before he allows the thermometer to pass him.
8. He notes any apparent discrepancies in the temperatures and the failure of thermometers to act.
9. He enters the corrections in the appropriate column and notes the corrected temperatures.
10. He fills the blanks in the record book and makes such further entries as the occasion requires.

The following table, taken from the original record, illustrates the method of recording serial temperatures on board the *Albatross*. The observations followed a deep-sea sounding in which a depth of 2,022 fathoms was found, 42 minutes being required to complete it; 6 minutes were consumed in shifting the reels; 22 minutes in clamping the instruments to the temperature wire and veering 1,000 fathoms; 4 minutes were allowed for the last of the series to take the temperature, and 16 minutes were required to reel in and detach the thermometers.

Serial temperatures.

Turns.	Fathoms.	Maker's number.	Temperature.	Correction.	Corrected temperature.	Remarks.
			°	°	°	
946	Surface...	....	74	0	74	Apr. 18, 1891.
921	25	69473	65.4	0	65.4	Latitude 20° 47′ 15″ N.
896	50	54815	59.3	—0.3	59	Longitude 106° 15′ 30″ W.
848	100	61755	54.6	0	54.6	Sounding.
754	200	69485	50.2	—0.4	49.8	A. m. 5 h. 5 m.; up 5 h. 47 m.
659	300	66665	45	—0.2	44.8	Serial temperatures.
565	400	63919	42.2	0	42.2	5 h. 53 m.; down 6 h. 15 m.
470	500	66724	41	+0.1	41.1	6 h. 19 m.; up 6 h. 35 m.
377	600	63903	40	—0.2	39.8	Time sounding, 42 m.
281	700	69477	38.8	—0.1	38.7	Serial temperatures, 48 m.
188	800	69480	38	+0.1	38.1	Total, 1 h. 30 m.
94	900	51451	37.9	—0.3	37.6	D. S. ther. Negretti & Zambra.
Surface..	1,000	66735	37.2	—0.2	37	Fahr. scale.
Bottom..	2,022	66735	36	0	36	H. C. F., recorder.

The numbers in column of turns indicate where thermometers are to be attached to correspond to depths in column of fathoms. The serial temperature observations completed, the reels are changed again and the machine prepared for sounding.

A HAUL OF THE TRAWL.

The trawl follows sounding and serial temperatures in natural order, and while they were being taken the dredging boom would be rigged and topped up, the dredge rope shackled to trawl, and the latter hoisted to boom end in readiness to be swung out.

Trawling and dredging are conducted by the commanding officer in person. He determines the direction in which the trawl will be laid out and dragged, and has the dredging boom rigged on what will be the weather or working side. In preparing to cast the trawl he is influenced in his choice of the working side by attendant conditions:

1. It is necessary that the dredge rope shall trend clear of the ship's side while towing; hence the direction of the haul with reference to wind and current must be such that the vessel will either make a true course or drift to leeward away from the rope.

2. He will follow the predetermined line of investigation as closely as practicable, and whenever obliged to deviate from it will adopt a course that most nearly approximates to it.

3. The most perplexing obstacle in the way of following a fixed line is often due to the contour of the sea bottom. It is difficult to trawl successfully down a steep slope; hence it becomes necessary to take the line of equal depths or to turn about and drag the trawl directly up the incline.

4. The direction and force of wind and current with reference to the line of investigation and contour of the sea bottom bear directly upon the plan of operations and determine the working side upon which the dredging boom is to be rigged.

The former practice of backing while casting the trawl and dragging it has been abandoned on account of the limited control the commander had over the course, which was always against the wind; for the natural tendency of a screw steamer is to bring her stern to the wind when backing, and this tendency becomes a fixed habit whenever a trawl is dragging. On the other hand, the vessel is always under control when steaming ahead, and may work with the wind from a point on the bow to right astern, providing wind and current are in the same direction.

Starting ahead slowly, the trawl is swung out, lowered to the surface of the water, and towed until the frame assumes a horizontal position, and the trawl net, the pocket, the mud bag, and wing nets all trend aft and are seen to be clear.

When the vessel reaches her course under a speed of 2 to 3 knots, with the lee engine only working, the order is given to lower away. The first few fathoms should be veered with promptness and sufficient rapidity to insure sinking the trawl well below the propeller, after which the commanding officer will prescribe the rate at which it shall be veered and regulate the speed of the vessel. Under ordinary conditions it would be about 3 knots per hour, and the first 200 fathoms of dredge rope would be veered at the rate of about 30 fathoms per minute.

The engineer at the dredging engine calls out each 100 fathoms, the recorder notes the time and stands, watch in hand, ready to increase or check the rate of veering, which is never allowed to exceed the prescribed limit.

By the constant use of the dredging quadrant the commander knows the angle of the rope at all times during its descent and so regulates the speed of the vessel and rate of paying out that the sinking of the trawl is facilitated, at the same time guarding against its capsizing or the rope kinking, contingencies that inevitably follow too rapid veering of the latter or too low speed of vessel.

DREDGING TABLE No. 1.

Depth of water.	Speed of ship while lowering trawl.	Length of dredge rope required for a given depth of water.	Time required to veer each 100 fathoms of dredge rope.	Angle of dredge rope while lowering trawl.	Angle of dredge rope while dragging trawl.	Allowance of dredge rope for catenary curve.
Fathoms.	*Knots.*	*Fathoms.*	*Minutes.*	*Degrees.*	*Degrees.*	*Fathoms.*
100	3	200	3½	60	55	25
200	3	400	3½	60	55	44
400	3	700	3½	60	52	50
600	2¾	1,000	4	55	50	60
800	2½	1,200	4	50	44	90
1,000	2½	1,500	4	50	40	110
1,500	2¼	2,166	4	50	40	206
2,000	2	2,670	4	45	35	250
3,000	2	4,000	4	40	35	350

Absolute rules can not be laid down for lowering the beam trawl, as its rate of descent varies with the conditions, which are rarely the same during two successive casts and frequently change more than once in the same haul. Yet dredging table No. 1 shows approximately the method followed on board the *Albatross*, which, in the light of experience, is considered safe practice under normal conditions.

The angles in this table are from the vertical. The speed at which the trawl is dragged along the bottom is not given in the table. It is usually less than that in the column for lowering, but is so variable that the safest plan is to maintain the angle as nearly as possible by the use of the dredging quadrant, regulating the speed as required, regardless of the actual progress of the vessel through the water.

The scope of dredge rope is given for ordinary practice, yet for rapid dragging in comparatively shoal water three and even four times the depth is allowed.

The rate of 3½ minutes per 100 fathoms for veering the dredge rope has been maintained up to 2,000 fathoms or more, sometimes successfully, but it is running on the verge of the danger line where the slackening of the vessel's speed or other unexpected occurrence might result in kinking it, capsizing the trawl, or fouling the net. The dredge rope is to the beam trawl what the string is to the kite. Hence the necessity for keeping a continuous strain on it while it is going down; otherwise it will lose its balance and finally capsize, as would the kite with a slackened string.

The horizontal drag resulting from tension on the dredge rope and the mean track of the trawl from surface to bottom is shown by the following data from Table 1 (p. 391), where the depth is 3,000 fathoms and length of rope 4,000 fathoms. The time occupied in paying it out is 2 hours and 32 minutes, or 152 minutes, during which the ship moved through the water 6,375 fathoms, at a mean speed of 2.55 knots per hour, or 42 fathoms per minute. The rope was paid out at the mean rate of 26.3 fathoms per minute, with a resultant drag of 2,386 fathoms, a mean of 15.7 fathoms per minute had the trawl remained on the surface, but it sank at the mean rate of 19.7 fathoms per minute, increasing the drag 1,414 fathoms, or 9.3 fathoms per minute. Thus the total horizontal drag was 3,800 fathoms, or a mean of 25 fathoms per minute.

The margin between the speed of ship and rate of veering rope grows broader as greater depths are reached and the length of rope increases, for the weight of the latter accelerates the forward movement of the trawl and assists in steadying it.

A beam wind is most favorable for lowering and dragging it, as the vessel will then drift well clear of the dredge rope and the speed is easily regulated, either with the engines or by the use of sail. Hauls have been made in deep water under sail alone when the conditions were favorable, thus economizing fuel and saving wear and tear of machinery.

If the vessel will not steer with the lee engine, as may happen under low speed, drag of trawl, and unused propeller, it should be stopped and the weather one used instead, as the drag will in a measure counteract the inclination of the vessel to fall off. The weather engine would be used habitually only for the possibility of the rope being caught in the propeller.

The requisite speed for lowering the trawl will be readily attained with the engines, but with fair wind and current the lowest speed might be too great for dragging after the trawl is landed on the bottom. In this case the engine may be stopped and the vessel allowed to drift, the rate being increased, if desirable, by the use of sail.

It has been found necessary in exceptional cases to slowly back an engine to retard the drift, and with an adverse wind and current it may be advisable to use both engines turning slowly rather than drive one at high speed.

The angle of dredge rope and the strain on it, shown by the accumulator scale, are watched very carefully after the trawl is landed, and increasing strain is noted. Should the increase be gradual and not excessive, it is an indication that the trawl is performing its function normally; but a sudden accession of 2,000 or 3,000 pounds signifies that the trawl has either encountered some obstruction, or buried itself in the soft ooze of the ocean bed.

Instant relief is afforded in either case, first from the dredging engine, which, having its friction clutch properly adjusted, allows the drum to reverse and the rope to run out until the strain is brought within the limit of safety, the vessel's headway being stopped in the meantime.

The rope is then hove short, the ship backing or steaming ahead slowly to relieve the strain, and in this manner she is placed directly over the trawl. If the trouble is due to its having caught on a ledge of rocks, or other ordinary obstruction, it can usually be cleared by steaming slowly in the opposite direction from which it was laid out. Should this maneuver fail after repeated trials, it is safe to conclude that the trawl has buried. In this case the rope is hove in to the limit of safety, and the vessel allowed to ride to it until the strain is partially relieved, then hove in again, the operation being repeated until it is worked out of its bed. Then steaming slowly ahead, a portion of the load is washed out through the meshes of the net, which is finally hove up.

If all efforts fail, as sometimes happens, a steadily increasing strain is put upon the rope by going ahead, or backing, until the bridle stops part and the trawl comes up tail first, or the rope is broken and the trawl and its attachments lost.

An overload of stones, clay, or tenacious mud is perhaps the most trying, for the net can not be relieved from its weight and must be hove up with the greatest care, consuming much valuable time and, not infrequently, parting stops or rope just as it reaches the surface.

The trawl is dragged from half an hour to an hour and a half in deep water and becomes more or less filled with ooze, making it very heavy, hence it should be hove up slowly at the start, and until a portion of it has strained out through the meshes of the net, the vessel retaining a little headway until the depth of water exceeds the length of submerged rope; otherwise the steady pull on it will soon tow the vessel, and as she begins to move through the water the trawl will remain stationary, possibly sinking more deeply into the soft bottom, and become overloaded, while fish and other free-swimming forms that have not yet found their way beyond the pocket may swim out of the mouth of the net.

The vessel should, under no circumstances, be allowed to shoot ahead and override the rope, or slacken it sufficiently to allow it to kink, as it is prone to do, or to leave a bight lying on the bottom, for it will have to be dragged transversely through the ooze, which is sometimes a serious matter. Should the engine be stopped after trawling to windward, and the vessel be allowed to fall off with the rope trending out from the weather side, as would seem, at first thought, the proper thing to do, she will soon have the wind abaft the beam, lying at right angles to her former course and directly athwart the rope. In this position the helm is ineffective, and the rope can be hove in only as fast as the vessel drifts, for as often as it is exceeded the rope will draw tightly under her bottom, whereas had she rounded to and stopped with the rope to leeward she would have gathered steerage way and held a course sufficiently high to clear it until she had nearly reached the trawl, when she could have steamed around it until the boom was again to windward. During boisterous weather it is advisable to keep a little headway until the trawl is up. In the event of the sea being too heavy to land it safely, the vessel may be brought stern to, as in sounding, while the last 100 fathoms are coming in. She will then be in the best possible position for handling it.

The speed at which a trawl should be hoisted varies with the character of service, the depth of water, and state of the sea, the first consideration being to secure the specimens in the best possible condition. A speed that is admissible in 100 or 200 fathoms would destroy a large portion of the haul if maintained from a depth of 2,000 fathoms, and a rate that would be practicable in smooth water would be destructive in a heavy sea. It has been customary on board the *Albatross* to start very slowly until the maximum strain is reached, then to run in about 25 fathoms per minute under ordinary conditions, increasing the speed according to circumstances, following in a general way the rule given in dredging Table No. 1, for lowering the trawl.

Dredging Table No. 2 is taken from the original records of six hauls of the beam trawl, and shows a fair average of the *Albatross's* work under ordinary conditions:

DREDGING TABLE NO. 2.

Serial Nos.	Depth of water.	Scope of dredge rope.	Time per 100 fathoms going down.		Time trawl was dragged on bottom.			Approximate distance trawl was dragged on bottom.	Time per 100 fathoms coming up.		L. B. T.=Large beam trawl. S. B. T.=Small beam trawl.	Load in trawl net.
Station.	*Fathoms.*	*Fathoms.*	*M.*	*S.*	*H.*	*M.*	*S.*	*Knots.*	*M.*	*S.*	*Beam trawl.*	
2565	2,069	3,000	3	42	1	18	30	3.0	3	06	L. B. T.	Light.
2566	2,620	4,000	3	54	2	12	00	2.0	3	59	L. B. T.	Ordinary.
2570	1,813	2,700	3	36	1	13	30	1.0	3	45	L. B. T.	Do.
2571	1,356	2,200	3	50	1	23	30	1.0	3	55	L. B. T.	Do.
2572	1,769	2,800	4	00	0	55	40	0.5	4	54	L. B. T.	Heavy.
2575	1,710	2,600	4	12	1	31	00	1.0	4	24	S. B. T.	Ordinary.

The scope of dredge rope is greater than is given in Table 1, and serves to illustrate some of the exceptions to the rule there given.

In No. 2565 the excess was allowed for the purpose of rapid towing, as will be seen by the distance it was dragged. It was the first station occupied in the immediate neighborhood and it was assumed that the depth was practically uniform, but the succeeding sounding showed that it had increased 551 fathoms and that the trawl had kept the bottom but a short time. The rapid rate at which it was hove up resulted from the light weight in the net at the start, which gave the impression that it was a waterhaul and no harm could come from recovering it rapidly. A variety of bottom forms found in the net was, however, sufficient evidence of its having been on the botton.

In the next haul, No. 2566, allowance was made for increasing depth, and the speed was reduced, the results showing that the calculations were sufficiently accurate to secure an excellent haul.

In the two following hauls a liberal allowance of rope was given on account of the uneven bottom and the results were normal, but in No. 2572 the trawl encountered an elevation into which it cut, penetrating the covering of ooze and bringing up an overload of gravel.

During the haul No. 2574 the trawl encountered an obstruction from which it could not be cleared and it was lost, hence the use of a small trawl at No. 2575. It was handled with care, and hove up slowly to avoid injury to delicate specimens, as the net was intended for shoal water and did not afford as much protection as those designed for deep-sea work.

To land the trawl on deck, hoist it to the boom end, when the bag will hang a little above water, put a strap around it and hoist it inboard with the boom tackle, either by hand or steam. If it is found to have a heavy load when it reaches the surface, suspend it for a moment, with the lead rope just out of water, ascertain its weight, then run it up to the boom end, or put a running bowline around it and take part of the weight with a tackle, and when it is up put a strap around it below the bowline and hoist it on board with the tackle, assisted by the after boom guy if necessary.

The critical moment in landing a heavily laden trawl is when the bag leaves the water, for if it was near the limit of safety when submerged its increased weight in air might greatly exceed it. In the event of the load being too great to warrant an attempt to land it, cut a slit in the net and allow a portion of its contents to escape. The small trawl net swings over the rail without the aid of strap and tackle.

To empty the trawl net, suspend it by the boom tackle, remove the mud bag, cast off the tail lashing, and allow the contents to run easily into the table sieve; wash the mud from the net with a hose, still holding it over the sieve that the specimens may fall into it, then lower it on deck; secure the contents of the wing nets by turning them inside out and rinsing them in a bucket of water; examine the trawl net, remove specimens that may adhere to it, repair rents, and prepare it for the next cast.

The mud in which the specimens are imbedded is washed from the table sieve with a steam hose, without nozzle, which affords an ample flow of water without force enough to injure the specimens. After they have been secured, the sieve should be thoroughly cleaned and the mud and water rinsed from the deck, in order to avoid the possibilty of mixing the hauls. A single specimen, even, out of place may throw discredit on the operations of a day.

The Blake deep-sea trawl is designed for use in great depths. It is operated practically the same as a beam trawl, over which it has the following advantages:

1. It has a lead rope on each side, and is right side up whichever way it lands. It may turn on its way down or while it is dragging without affecting the haul.

2. It may be lowered vertically until near the bottom, providing the pocket is properly lashed down and sufficient weight attached to tail of net to carry it down as rapidly as the frame will sink.

3. The course may be changed to any extent while lowering or dragging, providing the rope is not slackened.

The disadvantages compared with the beam trawl are:

1. The small sweep of lead rope.

2. A large volume of water rushes into the widely distended mouth during its ascent and injures the delicate specimens whenever they are unprotected by a covering of bottom soil in the bag. The facility with which it is operated and its certainty of action commend it for deep-water work, however, in spite of its faults.

The recorder keeps a full record of the haul, making the following entries:

1. The kind of trawl used.
2. Time of paying out each 100 fathoms of dredge rope.
3. Total length of dredge rope paid out.
4. Course and distance trawl is dragged on bottom.
5. Time the trawl is dragged.
6. Time required to heave up each 100 fathoms of dredge rope.
7. Load in trawl net—heavy, ordinary, or light.
8. General contents of the trawl net from his own observation, and such information as he can obtain from the naturalists.
9. Any matter of interest connected with the haul, as striking an obstruction, trawl burying in the bottom; loss or injury to rope, trawl, or other apparatus.

A haul of the dredge follows in case the trawl encounters foul ground or it is desired to collect mollusca or annelids that burrow in the bottom soil. It is operated in the same general manner as the Blake deep-sea trawl, and was formerly used instead of trawls for deep-sea work, but its scope is now confined to shoal water or moderate depths. The recorder keeps the same record as for a haul of the trawl.

A haul of the tangles follows if the bottom is too foul for the successful operation of trawl or dredge. The tangles are the simplest and most easily manipulated of all the various forms of apparatus for submarine collecting; they can be lowered vertically, if desired, more rapidly even than the dredge, and are expected to take their chances on the roughest bottom except they become locked under projecting rocks in such a manner that a reversal of direction is required to release them. A variety of forms are taken with the tangles, including starfish, sea-urchins, crinoids, corals, and even fishes of considerable size. The same record is kept as in trawling and dredging.

COLLECTING FROM INTERMEDIATE DEPTHS.

A haul of the Tanner intermediate tow net usually follows the trawl or dredge, as the possible change of depth would not affect its use unless observations are required near the bottom; then it follows the sounding. A description of the apparatus and its use will be found under the title of "Surface and intermediate collecting."

The recorder notes:

1. Time required to veer each 100 fathoms of rope.
2. The depth at which the net is towed.
3. The length of rope out and angle at which it is towed.
4. Time and distance the net is towed.
5. Time of descent of messenger.
6. Time each 100 fathoms of rope was hove up.
7. General account of the contents of lower and upper nets.
8. Anything of interest in connection with haul.

TRIAL LINES.

Cod and halibut trial lines are extensively used in the exploration of fishing banks. They are operated by the crew from the ship's rail as she drifts slowly over the ground; if she drifts too rapidly, as she is liable to do in boisterous weather, her stern is turned to the wind and the vessel is held in position with the propellers, as in sounding. The use of trial lines from the rail is practically limited to depths within 70 fathoms. The fishery expert takes charge of the catch, examines every specimen, and keeps a record of—

1. The numbers and species of fish taken.
2. Weight of each fish.
3. Their length and general dimensions.
4. Parasites found on them, external and internal.
5. Food-contents of stomach.
6. General physical condition of catch.
7. Relative abundance.
8. Bait and apparatus used.

He preserves a sufficient number of specimens from each station to show the general condition of the various species of fish, their food (as shown by contents of stomach), and examples of parasites which are found upon them.

The recorder notes the number of lines used in the trial, the numbers and species of fish taken, the duration of the trial, and any further information obtainable.

Fishing trials from the rail with the vessel underway are limited to fifteen minutes or half an hour, and if further examination is required it is customary to anchor and send the boats out, or leave them to continue the trial while the ship engages in other work in the vicinity.

THE USE OF TRAWL LINES.

Whenever an examination is extended beyond ordinary limits trawl lines containing from 300 to several thousand hooks are employed. They remain on the bottom from an hour to half a day, the shorter interval being sufficient for codfish and some other species, but not for halibut, which are slow at taking the hook. The set is repeated as often as occasion requires.

The vessel remains by the trawl line, or works in the vicinity, according to circumstances.

GILL NETS.

These nets are occasionally used at sea, and may properly be included in the occupation of a station, though usually employed near land. They may be allowed to drift with the current, or anchored at surface, bottom, or at intermediate depths.

THE RECOGNITION OF MARINE DEPOSITS.

Having long felt the need of some simple and practical suggestions for the recognition of the various kinds of sea bottom, I appealed, through the good offices of the United States Fish Commission, to Dr. John Murray, of Edinburgh, Scotland, requesting him to formulate such brief and practical rules as would enable the marine surveyor to recognize the general character of deposits encountered in deep-sea exploration. In response, he kindly contributed the following comprehensive description of the various marine deposits, and methods of distinguishing them:

The marine surveyor will render excellent service to science by carefully examining and preserving for future study the samples of marine deposits brought up from various depths and positions on the ocean's floor during sounding and dredging operations. Recent investigations with reference to the composition and distribution of deep-sea deposits have led to important generalizations in geology and physical geography. It may be stated generally that the marine deposits found in shallow and deep water near shore are for the most part made up of mineral particles and detrital matters washed down from the dry land or torn away from coasts by the action of waves and currents, and hence called *terrigenous deposits*.

On the other hand, marine deposits on the floor of the ocean at distances beyond 100 or 200 miles from land are for the most part made up of calcareous and siliceous shells, secreted by organisms in the surface waters, which have fallen to the bottom; the mineral particles and clayey matter associated with these shells appear likewise to have, for the most part, fallen from the surface and to have been derived from floating pumice and volcanic and other dust showers. These deposits are called *pelagic deposits*. There is a great variety in these two great classes of deposits, and in passing seaward there is a gradual transition from the one to the other class. In those regions of the ocean toward the Arctic and Antarctic which are affected by floating ice the line of demarkation is further complicated by continental rock fragments and minerals being carried far to sea and deposited on areas of the sea bed which would but for this circumstance be occupied by purely pelagic deposits. Phosphatic, glauconitic, and calcareous concretions are more or less characteristic of terrigenous deposits, while manganese nodules, sharks' teeth, earbones of cetaceans, cosmic dust (magnetic spherules containing nuclei of native iron and nickel), and zeolitic crystals are sometimes abundant in pelagic deposits.

In examining a sample of a marine deposit the surveyor should note its color and any evidence of stratification into different layers, as well as the size of any mineral or organic particles as observed by the naked eye. If a portion of a sample be shaken up in a bottle with abundance of water the larger organic and mineral particles can be separated from the amorphous clayey and calcareous matter by decantations. If, after the water is poured off the larger particles, they be treated with a little spirits of wine and then a match be applied, the spirits of wine will burn away and leave the particles dry, so that they may be easily examined with a loup or low power of the microscope. The calcareous particles are usually of a white color, and consist, for the most part, of Foraminifera (*Globigerina*) or Pteropod shells. The former are more or less roundish in form and the largest seldom over one-thirtieth of an inch in diameter. The Pteropod shells are larger but much thinner than the Foraminifera. In the very deepest deposits the Globigerinæ are all removed, apparently owing to the solvent power of the water through which they have fallen. At lesser depths the thinner Pteropods disappear from the deposits before the Globigerina; it is therefore important to note the presence or absence of these two classes of shells in deep-sea deposits. The siliceous organisms, such as Diatoms and Radiolarians, are recognized by their transparent appearance and sharp, clean-cut edges.

If a portion of a sample be treated with dilute hydrochloric acid (1 part acid to 10 parts water) all the calcareous particles may be removed, and the mineral particles can thus be more conveniently examined. By this process also a rough estimate may be formed of the quantity of carbonate of lime in the sample, and this is one of the most important points in classifying deposits. The particles of quartz and felspars making up the larger part of terrigenous deposits near land are usually rounded, or can be recognized by their fractures and transparent appearance. The volcanic particles in pelagic deposits are usually of a darker color, with the exception of the splintered fragments of pumice or volcanic glass. Particles of peroxide of manganese, so frequent in the red clays and other pelagic deposits, can at once be recognized by treating with a small quantity of pure hydrochloric acid in a white porcelain basin; the acid in a few moments dissolves the particles and passes away in a dark-colored stream.

In preserving samples for examination in the laboratory at home, the best method is to place the sample as procured in a glass bottle and to add a small quantity of spirits of wine.

The various kinds of marine deposits belonging to the two great classes have been named from the relative abundance and character of the organic or inorganic materials of which they are composed. The following is the nomenclature adopted by Dr. John Murray after an examination of the samples procured in various regions of the ocean by the *Challenger*, the *Tuscarora*, the *Albatross*, and other deep-sea expeditions:

	Materials	
I. Deep-sea deposits, beyond 100 fathoms.	Red clay; Radiolarian ooze; Diatom ooze; Globigerina ooze; Pteropod ooze.	1. Pelagic deposits, formed in deep water far removed from land.
	Blue mud; red mud; green mud; volcanic mud; coral mud.	2. Terrigenous deposits, formed in deep and shallow water close to land masses.
II. Shallow-water deposits, between low-water mark and 100 fathoms.	Sands, gravels, muds, etc.	
III. Littoral deposits, between high and low-water marks.	Sands, gravels, muds, etc.	

The term "ooze" is applied only to pelagic deposits made up chiefly of the remains of organisms, the term "clay" only to the red clay found in the deepest regions of the ocean, and the terms "mud" and "sand" only to terrigenous deposits.

It is unnecessary to enter into details as regards the shallow-water deposits, but the following notes on the deep-sea deposits, which term is applied to those from depths greater than 100 fathoms, may be appended:

A. Pelagic Deposits.

1. *Red clay.*—This deposit is spread over the greater depths of the ocean remote from land, and is the most widely distributed and probably the most characteristic of all deep-sea deposits. The *Challenger* took 70 samples in depths ranging from 2,225 to 3,950 fathoms, the average depth being 2,730 fathoms. The *Albatross* investigations have shown that this deposit is spread over a wide area in the northeastern Pacific. The amount of clayey matter and the color vary greatly in different samples, but red is the prevailing color, sometimes brick red, sometimes dark chocolate, sometimes bluish or gray. The immediate upper layer is thin, watery, and often has a lighter color than the deeper layers, which are much more dense.

The red clay is soft, plastic, and greasy to the touch. When dried it cakes into a hard, compact mass that can only be broken with the blow of a hammer. The hardened fragments assume a glazed appearance and characteristic shining streak when rubbed briskly with the finger nail or any hard, smooth body. In the greater depths carbonate of lime may be almost, if not entirely, absent, while in lesser depths it may rise to over 20 per cent, and is due principally to the remains of pelagic foraminifera, with a few coccoliths or rhabdoliths and other minute calcareous fragments. The remains of pelagic siliceous organisms are usually present, principally radiolarians and diatoms, along with sponge spicules and arenaceous foraminifera.

The principal mineral particles in a red clay are fragments of pumice and the mineral species usually found in its different varieties. There may be also fragments of basaltic glass, basalt, augite, andesite, and palagonite arising from the decomposition of the basic volcanic glasses. The peroxides of iron and manganese are found throughout the red clays in the form of minute grains or coatings. When deposited as concretions around organic remains and other nuclei, they form manganese nodules. In some red-clay areas thousands of sharks' teeth and earbones of cetaceans, more or less impregnated or coated with manganese, have been dredged, and zeolitic crystals of secondary formation (phillipsite) and cosmic spherules are sometimes met with.

The origin of the red clay has been the subject of much discussion. It is evidently not a residue or ash derived from the solution of calcareous organisms, as supposed by Wyville Thomson, but is derived from the decomposition of aluminous silicates and rocks spread over the floor of the ocean.

Average composition of the Challenger samples of red clay.

Carbonate of lime:		
Pelagic foraminifera	4.77	
Bottom-living foraminifera	.59	
Other organisms	1.34	
		6.70
Residue:		
Siliceous organisms	2.39	
Minerals	5.56	
Fine washings	85.35	
		93.30
		100

The term "fine washings" is used to indicate the amorphous clayey matter in a deposit left after treatment with dilute hydrochloric acid.

2. *Radiolarian ooze.*—This deposit resembles the red clay in most respects, but contains a much larger number of radiolarian shells, skeletons, and spicules, together with sponge spicules and frustules of diatoms. The *Challenger* samples ranged in depth from 2,350 to 4,475 fathoms, the average being 2,894 fathoms. There is usually only a trace of carbonate of lime, though it may rise to nearly 20 per cent, principally due to the remains of pelagic foraminifera, along with a few other calcareous fragments. Manganese nodules, palagonitic fragments, sharks' teeth, earbones of cetaceans, zeolitic crystals, and cosmic spherules have been found in nearly all the samples of radiolarian ooze.

Average composition of the Challenger samples of radiolarian ooze.

Carbonate of lime:		
Pelagic foraminifera	3.11	
Bottom-living foraminifera	.11	
Other organisms	.79	
		4.01
Residue:		
Siliceous organisms	54.44	
Minerals	1.67	
Fine washings	39.88	
		95.99
		100

3. *Diatom ooze.*—This deposit when wet has a yellowish straw or cream color. When dried it is nearly pure white, resembling flour. Near land it may assume a bluish tinge. The surface layers are thin and watery, but the deeper ones are more dense and coherent, breaking up into laminated fragments. It is soft and light to the touch when dried, taking the impress of the fingers and sticking to them like fine flour. Small samples appear quite homogeneous and uniform, but in all the *Challenger* soundings there were fragments of minerals and rocks, and gritty particles can generally be felt when the substance is passed between the fingers. The *Challenger* samples varied in depth from 600 to 1,975 fathoms, the average depth being 1,477 fathoms. The principal part of the deposit is made up of the dead frustules of diatoms, together with radiolarian remains, sponge spicules, and their fragments. The carbonate of lime varies from 2 to over 30 per cent, due principally to the dead shells of pelagic foraminifera. The mineral particles vary greatly in nature, size, and abundance, sometimes volcanic rocks and minerals, sometimes those of ancient and sedimentary formations predominating. This was to be expected, for all the *Challenger* samples lie within the region of floating ice in the southern hemisphere.

Average composition of the Challenger samples of diatom ooze.

Carbonate of lime:		
Pelagic foraminifera	18.21	
Bottom-living foraminifera	1.60	
Other organisms	3.15	
		22.96
Residue:		
Siliceous organisms	41.00	
Minerals	15.60	
Fine washings	20.44	
		77.04
		100

4. *Globigerina ooze.*—This deposit is white, milky yellow, rose, brown, or grayish, depending on the nature of the inorganic substances mixed with the foraminifera shells. The prevailing color is milky white or rose-color far from land, and dirty white, blue, or gray near land, when there is a considerable quantity of detrital matter from rivers in the deposit. It is fine-grained and homogeneous. In tropical regions many of the foraminifera are visible to the naked eye, while in temperate regions the form of the organisms is, as a rule, indistinguishable without the aid of a lens. When dried a globigerina ooze is usually pulverulent, but some specimens with a low percentage of carbonate of lime cohere slightly. The *Challenger* samples ranged in depth from 400 to 2,925 fathoms, the average depth being 2,002 fathoms. In addition to the pelagic foraminifera many other organisms contribute to the carbonate of lime in a globigerina ooze, some living in the surface waters, others at the bottom of the sea. Among the former are pelagic mollusks (pteropods and heteropods) and pelagic calcareous algæ (coccospheres and rhabdospheres with their broken parts, coccoliths and rhabdoliths), and among the latter are remains of mollusca, echinoderms, annelids, corals, polyzoa, and bottom-living foraminifera. The percentage of carbonate of lime varies from 30 to nearly 100 per cent, the estimated percentage due to the presence of the dead shells of pelagic foraminifera alone being usually

about 50 per cent of the whole deposit. The siliceous remains of radiolarians, diatoms, and sponge spicules are nearly always present, but usually in small quantity. In the purest samples of globigerina ooze mineral particles are exceedingly rare, and consist for the most part of a few minute fragments of feldspar, augite or hornblende, magnetite, volcanic glass, sometimes more or less altered, with which are associated a small quantity of clayey matter and the oxides of iron and manganese. In the less pure samples the mineral particles become more numerous, feldspar, augite, olivine, hornblende, and more rarely mica, bronzite, actinolite, chromite, glauconite, quartz, and cosmic dust being met with. The terms pulvinulina ooze, orbulina ooze, and biloculina ooze have arisen through a misconception, the samples examined having been passed through sieves and only the larger particles preserved. They are all really globigerina oozes.

Average composition of the Challenger samples of globigerina ooze.

Carbonate of lime:		
Pelagic foraminifera	53.10	
Bottom-living foraminifera	2.13	
Other organisms	9.24	
		64.47
Residue:		
Siliceous organisms	1.64	
Minerals	3.33	
Fine washings	30.56	
		35.53
		100

5. *Pteropod ooze.*—This deposit resembles the globigerina ooze in nearly all particulars, differing mainly in the greater abundance of the shells of pelagic mollusks (pteropods and heteropods principally), which sometimes makes up over 30 per cent of the deposit. In oceanic regions the deposit approaches in constitution a globigerina ooze, being, however, more friable and granular and less homogeneous and uniform from the presence of these larger shells, but the mineral particles are the same as in a globigerina ooze from the same region. Near the coast line the pteropod deposits resemble the terrigenous deposits in the large number of shore materials and organisms which enter into their composition, or fragments from coral reefs and calcareous organisms from shallow water may make up a large part of the deposit. The *Challenger* samples range in depth from 390 to 1,525 fathoms, the average depth being 1,044 fathoms. The percentage of carbonate of lime varies from over 50 to nearly 100 per cent, principally due to shells of pelagic foraminifera and pelagic mollusks. The remains of siliceous organisms are usually present in small quantity. Sometimes, however, they may make up nearly 20 per cent of the whole deposit. They are principally sponge spicules, radiolarians, diatoms, along with a few casts of foraminifera and arenaceous foraminifera. Mineral particles, principally magnetite, augite, feldspar, hornblende, etc., make up from about 1 to 10 per cent.

Average composition of the Challenger samples of pteropod ooze.

Carbonate of lime:		
Pelagic foraminifera	47.15	
Bottom-living foraminifera	3.15	
Other organisms	28.95	
		79.25
Residue:		
Siliceous organisms	2.89	
Minerals	2.85	
Fine washings	15.01	
		20.75
		100

B. TERRIGENOUS DEPOSITS.

6. *Blue mud.*—This name has been adopted for the deposits most frequently met with in the deeper waters surrounding continental land, and in all inclosed or partially inclosed seas more or less cut off from free communication with the open ocean. The materials of which the blue muds are principally composed are derived from the disintegration of continental land, and are very complex in character. When collected this deposit is blue or slate-colored, with an upper red or brown layer which had been in immediate contact with the water. The blue color is due to organic matter and sulphide of iron in a fine state of division, and these muds have, as a rule, when taken from the sounding tube, a smell of sulphuretted hydrogen.

The red or brown color of the thin watery upper layer is evidently due to the presence of ferric oxide or ferric hydrate, but as the deposit accumulates this oxide is transformed into sulphide and ferrous oxide in the presence of organic matter in the underlying layers. When dried the deposit becomes gray or brown, owing to the oxidation of the sulphide of iron. Sometimes the samples are homogeneous; at other times the aspect is heterogeneous, owing to the presence of large fragments of rocks and shells and small fragments of calcareous organisms. When wet the deposit may be plastic and behave like a true clay, but as a rule these muds may be described rather as earthy than as clayey. The *Challenger* samples ranged in depth from 125 to 2,800 fathoms, the average depth being 1,411 fathoms. The percentage of carbonate of lime varies from a mere trace to over 30 per cent, consisting mainly of pelagic and bottom-living foraminifera along with other calcareous fragments.

The shells of pelagic species of foraminifera, which make up so large a part of a globigerina ooze, are not abundant nor universally distributed in the blue muds, the remains of shallow-water or bottom-living organisms predominating in many cases. The remains of siliceous organisms are usually present in small quantity, sometimes making up 15 per cent of the whole deposit, and consist of diatoms, radiolarians, sponge spicules, arenaceous foraminifera, and casts of the calcareous organisms in glauconite or some allied silicate. The mineral particles are mostly derived from the adjacent lands, and consist largely of the fragments and minerals of the various rocks forming the continents. The size of the mineral and rock particles varies much with the position; they are as a rule larger near the shore and smaller as the deep sea is approached, except in those regions affected by floating ice. More than half of the deposit is in many cases made up of the mineral particles, consisting largely of rounded grains of quartz, along with particles of older crystalline or schisto-crystalline rocks, quartzite, sandstones, and limestones. Among minerals, besides quartz, are orthoclase and plagioclase, green hornblende, augite, mica, epidote, etc.; glauconite can not be considered characteristic of blue muds, but is to be found in nearly all of them, though in limited quantity compared with the green muds.

Average composition of the Challenger samples of blue mud.

Carbonate of lime:		
Pelagic foraminifera	7.52	
Bottom-living foraminifera	1.75	
Other organisms	3.21	
		12.48
Residue:		
Siliceous organisms	3.27	
Minerals	22.48	
Fine washings	61.77	
		87.52
		100

7. *Red mud.*—Along the Brazilian coast of South America the terrigenous deposits offshore are different from the deposits found in similar positions along other continents in that they are all of a red-brown or red-brick color, apparently due to the large quantity of ocherous matter carried into the ocean by the Amazon, Orinoco, and other South American rivers, and distributed by oceanic currents along these coasts. Similar red deposits are formed in the Yellow Sea off the Chinese coast near the mouth of the Yang tse Kiang. Although organic matters are probably as abundant as in the deposits along other coasts, still they do not seem to be sufficient to reduce the whole of the peroxide of iron to the state of protoxide, nor does sulphide of iron accumulate here as in the blue muds.

It is a remarkable fact that there is no trace of the green-colored glauconitic casts of foraminifera and other calcareous organisms, nor of any of the glauconite grains which usually accompany these casts in other terrigenous deposits. There are a few spicules of siliceous sponges, but frustules of diatoms and the remains of radiolarians are exceedingly rare or wholly absent. In other respects this deposit resembles a blue mud. The *Challenger* samples varied in depth from 120 to 1,200 fathoms, the average depth being 623 fathoms. The percentage of carbonate of lime varies from 5 to 60 per cent, apparently depending more on proximity to the mouths of rivers than on depths. The shells of pelagic and bottom-living foraminifera are the most abundant of the calcareous organisms. The mineral particles range from 10 to 25 per cent, quartz being the most abundant.

Average composition of the Challenger samples of red mud.

Carbonate of lime:		
Pelagic foraminifera	13.44	
Bottom-living foraminifera	3.33	
Other organisms	15.51	
		32.28
Residue:		
Siliceous organisms	1	
Minerals	21.11	
Fine washings	45.61	
		67.72
		100

8. *Green mud and sand.*—In their composition, origin, and distribution these deposits resemble in many respects the blue and red muds. Their chief characteristic is the presence of a greater or less abundance of *glauconitic grains and glauconitic casts of the calcareous organisms.* These muds and sands are almost always developed along bold and exposed coasts, where no very large rivers pour their detrital matters into the sea. They contain, as a rule, many remains of calcareous organisms, mineral particles from the continental rocks, and a considerable quantity of clayey matter, although fine clayey or detrital matter appears always to be less abundant than in a characteristic blue mud. Along coasts where these deposits are laid down pelagic conditions appear to approach much nearer to the shores than where blue muds prevail, as, for instance, on the Agulhas Bank and off the Atlantic coast of the southern United States; to such an extent is this the case that, were it not for the presence of glauconite and the nature of the mineral particles, many of the green muds might equally well be called globigerina oozes.

The green sands differ from the green muds chiefly in being more granular in appearance, owing to the relatively small quantity of amorphous matter present, and are usually found in shallower water. The average depth of the *Challenger* samples of green mud is 513 fathoms, and of green sand 449 fathoms, the range of both classes being usually from 100 to 900 fathoms. The percentage of carbonate of lime varies to a great extent, the average being 25 in the muds and 50 in the sands, pelagic and bottom-living foraminifera being the principal constituents. The percentage of siliceous organisms may be as high as 50, usually higher in the muds than in the sands, and they are principally glauconitic casts of calcareous organisms along with diatoms, radiolarians, sponge spicules, and arenaceous foraminifera. The mineral particles usually make up a large part of the deposit, sometimes nearly 80 per cent, the grains of glauconite being the most characteristic, along with quartz, felspar, magnetite, hornblende, augite, etc., and fragments of continental rocks. In the green sands there are frequently nodules and small concretions of phosphate of lime.

Average composition of the Challenger samples of green mud and green sand.

	Green mud.		Green sand.	
Carbonate of lime:				
Pelagic foraminifera	14.59		21	
Bottom-living foraminifera	2.94		15	
Other organisms	7.99		13.78	
Residue:		25.52		49.78
Siliceous organisms	13.67		8	
Minerals	27.11		30	
Fine washings	33.70		12.22	
		74.48		50.22
		100		100

9. *Volcanic mud and sand.*—Around oceanic islands of volcanic origin the deposits consist in a large measure of the rocks and minerals arising from the disintegration of the volcanic rocks of the islands. Near shore, within the region of wave action, these are largely sands composed of volcanic material and the fragments of calcareous organisms which vary much in size. In deeper water, further from the islands, the mineral particles become less abundant and smaller, while pelagic organisms, such as foraminifera, and pteropod shells, coccoliths, and rhabdoliths, increase in number so that the deposit assumes the character of a mud in which there is a considerable quantity of clayey and calcareous matter, light gray, brown, or black in color, and of an earthy rather than a clayey character. These deposits may be found along any coast where volcanic rocks prevail, but they are characteristically developed around the volcanic islands of the great ocean basins. In general appearance and composition they present great variety, depending on position, depth, and the organic remains that take part in their formation, their chief characteristic being the relative abundance of volcanic materials.

The *Challenger* samples of volcanic mud range in depth from 260 to 2,800 fathoms, the average depth being 1,033 fathoms; the samples of volcanic sand range from 100 to 420 fathoms, the average depth being 243 fathoms. The amount of carbonate of lime varies greatly, sometimes rising to 70 per cent, principally due to the remains of pelagic and bottom-living foraminifera. Siliceous organisms are rare, always under 5 per cent, consisting of radiolaria, sponge spicules, diatoms, and arenaceous foraminifera; true glauconitic casts and grains are absent. The mineral particles make up a considerable portion of the deposit, sometimes rising to 80 per cent; the most characteristic are sanidine, plagioclases, augite, hornblende, rhombic pyroxenes, olivine, and magnetite. Among the lapilli the most frequent are those belonging to the basaltic and andesitic series of rocks, especially those belonging to the vitreous varieties, and they are often decomposed into palagonitic matter.

Average composition of the Challenger samples of volcanic mud and volcanic sand.

	Volcanic mud.		Volcanic sand.	
Carbonate of lime:				
Pelagic foraminifera	10.50		13	
Bottom-living foraminifera	2.82		3.80	
Other organisms	7.17		11.99	
		20.49		28.79
Residue:				
Siliceous organisms	1.82		1.40	
Minerals	40.82		60	
Fine washings	36.87		9.81	
		79.51		71.21
		100		100

10. *Coral mud and sand.*—Just as around volcanic islands the deposits are principally made up of the débris from volcanic rocks, so off coral islands and coral reefs the deposits are chiefly made up of the fragments of organisms living in the shallow waters and on the reefs, such as calcareous algæ, corals, mollusks, polyzoa, annelids, echinoderms, and foraminifera. These fragments form a coarse sand or gravel in the shallower waters, but beyond the limits of wave action there is a fine mud, consisting principally of triturated particles of calcareous matter. With greater depth and increasing distance from the land, pteropod and heteropod shells, as well as pelagic foraminifera, make up more and more of the deposit, till the coral muds and sands pass finally into a pteropod or globigerina ooze, in which reef fragments can with difficulty be recognized.

The *Challenger* samples of coral mud ranged in depth from 140 to 1,820 fathoms, the average being 740 fathoms. The samples of coral sand were all in depths less than 300 fathoms, the average being 176 fathoms. The percentage of carbonate of lime is very high, in some cases over 90 per cent, principally due to the remains of pelagic and bottom-living foraminifera, though the remains of other calcareous organisms derived from the reefs are much more abundant than in any of the other types of deep-sea deposits. Siliceous organisms are more abundant in the sands than in the muds, owing to the smaller quantity of minute clayey and calcareous amorphous matter, consisting of sponge spicules, diatoms, and radiolaria. Mineral particles are rare in both varieties, consisting of feldspar, augite, etc.

Average composition of the Challenger samples of coral mud and coral sand.

	Coral mud.		Coral sand.	
Carbonate of lime:				
Pelagic foraminifera	31.27		36.25	
Bottom-living foraminifera	14.64		20	
Other organisms	39.62		30.59	
		85.53		86.84
Residue:				
Siliceous organisms	1.36		5	
Minerals	1		3.75	
Fine washings	12.11		4.41	
		14.47		13.16
		100		100

LIBRARY.

The ship's library contains over 400 volumes, under the headings of natural history, scientific, publications of the U. S. Fish Commission, National Museum, and Smithsonian Institution, navigation and nautical astronomy, steam, history, biography, etc. It is the intention to provide such works as will be useful in all branches of investigation carried on by the vessel, text-books and professional works required by the officers, besides a few standard volumes of history and biography.

PREPARATION AND PRESERVATION OF SPECIMENS.

The methods followed on board the *Albatross* will be briefly described; and the location and arrangement of the laboratories with the facilities they offer for the work of the naturalist will be referred to again, more in detail, in order to give a better understanding of the descriptions that follow.

They are located near the middle body of the vessel, at the point of least motion, forward of and free from the heat of the furnaces and vibration of the engines, where the naturalist may safely leave specimens and apparatus lying on tables and about the decks at times when in other parts of the vessel they would require to be carefully secured.

The upper laboratory, in the deck house, 14 feet in length, 12 feet 6 inches wide, and 7 feet 3 inches high, has a large skylight overhead, two windows, and one door on each side, and a door communicating with the stateroom of the resident naturalist. A small chemical laboratory occupies one corner of the forward end, nearly the whole after bulkhead being covered by a book case in which an extensive professional library is kept, while in the center of the room stands a table about 5 feet square, around which four persons may seat themselves, each having at his right hand a tier of drawers conveniently arranged within frames which form the legs of the table.

A false cover, surrounded with a 3-inch ledge, water-tight, is used at sea to prevent specimens, etc., from sliding off in heavy weather; also to prevent the dripping of muddy water on deck. Over a lead-lined sink are faucets for water and alcohol, both leading from tanks, and above them, attached to the bulkhead, are two small aquaria, with water connections, used for the study of marine life. An ample supply of natural light and ventilation by day and an abundance of electric light at night combine to make it an admirable operating room.

The lower laboratory is on the main deck directly beneath the upper one, its only means of access being by a stairway leading down from that apartment. It occupies a space of 20 feet fore and aft, and extends entirely across the vessel. It receives light and natural ventilation from three large air ports on each side and two movable deck lights 12 inches in diameter; it has also the means of artificial ventilation and electric lights. The forward bulkhead is covered with specimen cases of sufficient capacity to hold the glass jars and bottles filled during an ordinary trip, and there are appropriate lockers for copper tanks in which the larger forms are preserved. Work tables are ranged along the sides, a chemical table with appropriate lockers and drawers on the after bulkhead, a photographic dark room with a large lead-lined sink and running water on the port side, and on the starboard side a medical dispensary.

The arrangement of the specimen case is simple and convenient. Its face is composed of a row of wire paneled doors about 2 feet 6 inches wide and 4 feet high, each having independent fastenings. Opening a door, from three to six sliding drawers, 2 feet 6 inches square and 6 inches high, are seen, one above the other, resting upon cleats. The drawers are filled with empty glass jars and bottles preparatory to a cruise; when required for use a drawer is withdrawn and is carried to the operating room, where it remains until the bottles are filled, when it is returned to its appropriate place in the case. Following this system the losses by breakage, even in the worst weather, are reduced to the minimum.

Copper tanks for alcoholic specimens are of three standard sizes—4, 8, and 16 gallons; special tanks are of any size or shape desired. They are carefully made of heavy material, thoroughly tinned inside, and closed with circular covers as large as the dimensions of the tanks will allow; they are without hinges, being secured by four thumbscrews, working through small projections placed at equal distances around the circumference of the covers. The joints are made on rubber gaskets. The tanks are furnished to the ship in wooden transporting cases having strong iron handles and hinges, the covers being secured by padlocks. The cases contain four 4-gallon, two 8-gallon, or one 16-gallon tank each, and, the tanks fitting snugly, it is only necessary to lock the cases to prepare them for shipment.

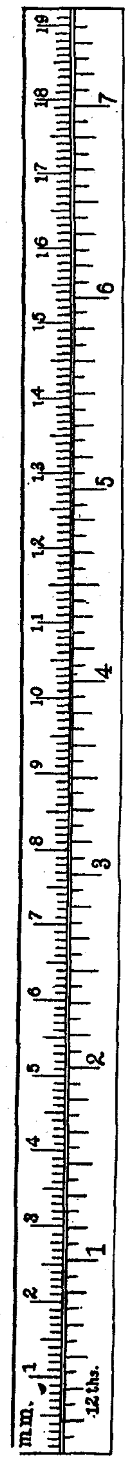
The laboratory storeroom is under the lower laboratory and can be entered only from the latter. Specimen cases of the laboratory are duplicated in the storeroom, which has also conveniently arranged lockers and bins for the safe carriage of alcohol in barrels or tanks and the storage of specimens of all descriptions, including the supplies and varied apparatus belonging to the scientific department. It is lighted by electricity, ventilated artificially, and, in case of fire, can be instantly closed from above and filled with steam. The storeroom receives little or no heat from the fireroom, as large coal bunkers lie between.

LABORATORY OUTFIT.

A complete schedule is considered unnecessary, but the following partial list of articles included in the scientific outfit will enable the reader to form a general idea of the appliances used in the laboratories of the *Albatross:*

Partial list of laboratory outfit.

Acids, picric, chromic, etc.
Alcohol, barrels and tanks.
Alum.
Antimony.
Anvil.
Arsenic.
Axes.
Bags, rubber.
Blast, sand.
Boxes, nests, assorted.
Boxes, small, assorted paper.
Bottles, glass, assorted.
Buckets.
Camera lucida.
Camera, photographic, with accessories.
Chisels, cold.
Chisels, mortising.
Clay for making casts.
Cloth, bolting, silk.
Cloth, cotton, cheese.
Cutters, wire.
Dippers, galvanized iron.
Dippers, galvanized iron, fine wire-cloth bottom.
Dishes, assorted, glass and earthenware.
Drills, twist, assorted.
Envelopes, letter and note.
Filter.
Forceps.
Gun, whale.
Hammers, blacksmith.
Hammers, riveting.
Hatchets.
Harpoons.
Hydrometer, glass, for alcohol.
Jars, glass, with corks, eight sizes.
Jars, fruit, glass, pint, quart, 2-quart.
Jars, butter, glass, 2-pound, 4-pound.
Knives, cartilage.
Knives, dissecting.
Knives, oyster.
Lamps, electric, hand, and submarine.
Lance, bomb.
Microscope, with accessories.
Nets, surface, silk bolting-cloth.
Nets, tub strainer, linen scrim.
Paper, English white tissue.
Paper, manila.
Paper, letter and note.
Paper, straw.
Pails, wooden.
Pans, large, galvanized iron.
Pans, marbleized, assorted.
Pistols, collecting.
Plaster, for models and casts.
Potash.
Presser, cork.
Rings, brass, surface net.
Rings, galvanized iron, surface net.
Rule, common 2-foot.
Rule, millimeter.
Rifle, .32 caliber.
Shotguns, 12 bore.
Shotguns, 10 bore.
Scissors.
Sieves, assorted.
Shears.
Shovels, common.
Spades, common.
Spades, trenching.
Still, copper.
Syringes, hypodermic.
Tanks, copper, alcoholic specimen.
Tools, carpenter's chest.
Tubs, wash, large size.
Vials, homeopathic, assorted.
Vise, bench.
Vise, hand.



CUT 76.—Comparative scale of linear measure, inches and millimeters.

THE METRIC SYSTEM.

The metric system is in general use by naturalists for the measurement of fish and other forms. A meter is the standard of linear measure. It is the ten-millionth part of a quadrant of the meridian, or 39.370 inches. A meter equals 10 decimeters, 100 centimeters, and 1,000 millimeters.

The accompanying scale of English inches and millimeters furnishes a convenient method of comparison and conversion, one into the other.

GENERAL REMARKS ON PRESERVATION OF SPECIMENS.

The data from which the following description of the methods of preserving specimens obtained by the collecting apparatus is compiled were kindly furnished by Messrs. James E. Benedict, of the Smithsonian Institution, and C. H. Townsend, resident naturalist of the *Albatross*. I have also quoted freely from Bulletin No. 39 of the National Museum.

The chief object of the deep-sea investigator is to obtain accurate information regarding life in the waters of the ocean and the physical conditions under which it exists, rather than the discovery of new and wonderful forms, each successful haul of trawl or dredge being made to do its part.

In operating the collecting apparatus and before it reaches the surface, the officers of the ship have given the station a serial number, located it astronomically, and recorded its physical conditions, the depth of water, character of the bottom, temperature of the air, surface, and bottom, specific gravity, currents, etc., and when the specimens are identified and described their names will ever after be linked with that particular station. Hence one's best work, or that of other investigators, will be discredited or worse by carelessness on the part of those having charge of the handling and preservation of specimens. A label giving a wrong station number, a trawl net not well shaken out and picked over, specimens carelessly left in the corners of the table sieve or on deck, where they may become mixed with the contents of a subsequent haul at another station, will falsify the record, perchance beyond the possibility of correction. If there is a doubt as to the station to which a specimen belongs, give it the date and any other available information, but no attempt should be made to supply a station number by guesswork. No label at all is better than a false record.

The contents of the trawl having been landed in the table sieve (plate XXXIV), the net should be carefully examined for hydroids, corals, or other delicate forms that are often found entangled in the meshes, clinging to the web, or caught on the frame, and in this seemingly accidental way valuable specimens may be taken in good condition that would be liable to serious damage if imbedded in the mud and general contents of a haul.

The fish found in the table sieve are picked out and placed in buckets or tubs of clean water; the invertebrates are assorted in a general way into pans, dishes, or sieves; the deck hose, without nozzle, is used to wash the mud through the grated bottom of the table sieve, care being taken not to injure the specimens. It is turned aside from time to time while the more delicate forms are picked from the surface of the mass or from the meshes of the sieve.

After the specimens resulting from the haul are gathered from net and sieve they are taken to the laboratory for assorting and preservation, a process usually quite simple, yet requiring experience and good judgment.

Alcohol is the preserving medium heretofore in general use. To insure its successful application, most specimens require to be first placed in a weak solution which, as it permeates the tissues, should be changed to stronger, thus completing the preserving process before they have time to soften and decay. An alcoholic mixture of 75 per cent is regarded as sufficient for the permanent preservation of well-cured specimens, although some require a stronger fluid, while others are equally well preserved in a weaker solution.

The necessity for a weak preliminary bath is illustrated in the case of a large fish of firm texture, which if thrown into strong, warm alcohol will quickly harden on the exterior, thus excluding the preserving fluid from the inner tissues and causing them to soften and decay. On the other hand, if it is subjected to a weak mixture of 35 to 50 per cent of cool alcohol, the fluid will penetrate the whole structure, after which the strength may be safely increased as desired.

The condition of alcoholic specimens collected in hot climates depends to a certain degree upon the temperature of the preservative when it is applied, a fact which has not always been given due consideration. The simple reduction of the alcoholic mixture by the addition of water raises its temperature from 10° to 20°, which, added to the constant heat of the surrounding atmosphere, greatly increases the difficulties attending the process of preservation.

Mr. James E. Benedict, when resident naturalist of the *Albatross*, adopted the plan of cooling alcoholic mixtures actually in use in the tropics by surrounding the tanks with ice, and as a further precaution he placed very delicate specimens in the cold room while they were absorbing the preservative, the cooling process being attended with excellent results.

TO PRESERVE FISH.

Wash them in clean water, and if more than half a pound in weight make an incision on the right side, just above the middle of the belly, to admit alcohol freely into the body cavity—the position of the cut leaves the left side intact in case a drawing or photograph should be required—then lay them out in dishes or pans of weak alcohol. After soaking a sufficient time, use the hypodermic syringe freely, if the body cavity has not been cut, injecting 95 per cent alcohol; then wipe carefully, wrap them in cheese-cloth, and pack them in jars or tanks containing alcohol of sufficient strength to maintain it permanently at 75 per cent. The soft and spongy tissues of deep-sea fish are rapidly permeated by the preserving fluid, and if full-strength alcohol is injected into the intestinal canal and body cavity it will rarely be necessary to make an incision.

Specimens designed for exhibition should be hardened slowly and retained in a natural position during the process, which may easily be done by securing them to a woven-wire screen of about half an inch mesh, seizing soft pine blocks under the expanded fins. In the preparation of specimens for this purpose it is well to remember that the nearer the temperature of the alcoholic solution approaches to 40° F. (the point at which decay of animal tissue is arrested) the weaker the first bath may be made, 25 per cent or even less being allowable, thus advantageously prolonging the hardening process, which in any event can not be delayed more than a few hours.

In placing specimens in jars or bottles while they are flexible, care should be taken that the receptacles are large enough to permit of their removal after the hardening process is complete, otherwise one or the other will be injured, and it is needless to say an experienced person will invariably sacrifice the jar.

It is common practice to use, for the first bath, old alcohol that has become too weak for other purposes.

THE PRESERVATION OF CRUSTACEA.

To preserve crabs, kill them in a dish of weak alcohol, placing a few in at a time lest they tear each others legs off in their struggles. When they become quiet, place them on separate pieces of cheese-cloth, backs down, fold the legs as naturally as possible, wrap them up, and tie the packages with soft twine. If any of the legs have become detached, as sometimes happens, place them in their natural position and wrap them up with the specimen. Inject large crabs with 95 per cent alcohol.

Wrappings may be dispensed with if desired in the case of small crabs, and it is always admissible when only a single specimen is placed in a bottle, yet it is good practice and but little trouble to wrap them in tissue paper, and if they are prepared in this manner the receptacle may be filled with specimens and 80 per cent alcohol turned upon them.

The various species of shrimp and all the coarser crustaceans may be treated practically the same as the crabs; only the larger forms require injecting.

THE PRESERVATION OF MOLLUSCA.

All mollusks may be preserved in alcohol, although it is unnecessary in the case of shells that are to be cleaned and dried. The animals may be killed with weak alcohol or hot water, and the soft parts removed with hooks or forceps.

Ascidians, octopods, and all of the naked soft-bodied mollusks are preserved in alcohol, first receiving a weak bath, the larger forms only requiring to be injected. Specimens of this class should be separately wrapped in cheese-cloth and protected from contact with the metal of the tank or each other by a liberal distribution of excelsior, tissue paper, or other suitable material. The tanks should not be more than half filled until the alcoholic solution permeating the mass has reached a strength of 75 per cent; they may then be filled, providing the specimens will not be injured by their own weight.

THE PRESERVATION OF ECHINODERMS.

Starfish and sea-urchins may be preserved in alcohol or dried; in either case a weak alcohol bath is desirable, as it expels a disproportionate amount of water, improves the condition of the specimens, and shortens the process of drying should they be preserved in that manner.

The tanks may be entirely filled with the ordinary hard-shelled sea-urchins, using 95 per cent alcohol, but the soft-shelled species require a cheese-cloth wrapping and excelsior protection in the tanks. Hard and firm starfish, like most of the deep-sea species, may be removed from the first bath, piled one upon the other to make convenient packages, wrapped in cheese-cloth, and placed in tanks with 75 per cent alcohol, where they will keep indefinitely.

The shoal-water species are usually soft, thickly covered with slime, and much distorted when they reach the laboratory. In this case place them in water while yet alive, and as soon as they have filled out transfer them quickly to weak alcohol and adjust their arms during the process of hardening. If they are to be dried, place them in a solution of arsenate of soda for a few minutes after they are removed from the first bath to protect them from the attacks of insects. If they are to be preserved in alcohol, remove the slime with a brush, make them up in packages wrapped with cheese-cloth, and treat them as deep-sea starfish. They are sometimes dipped in hot water in preparation for drying, but the alcohol bath is to be preferred.

Holothurians should be kept in a weak bath three or four hours, then injected, wrapped in cheese cloth, placed in tanks containing 90 per cent alcohol, and protected from pressure by excelsior.

Crinoids, actinians, small corals, etc., may be treated in the manner above described for starfish and holothurians. Large corals, too bulky to be preserved in alcohol, are cured with great difficulty on board ship, yet they may be safely and conveniently transported by first hanging them up until the water is drained from them, the process being accelerated by spraying the specimen with old alcohol, then packed in common salt, using a barrel or box as most convenient, taking care to pack the salt snugly around the branches to give them proper support.

The coral should be surrounded with a sufficient quantity of the preservative to absorb all of its moisture without forming brine. If salt is not available, clean, dry sand may be substituted, providing it is excluded from the delicate septa by wrapping the specimen in cheese-cloth or other suitable material. Large sponges may be prepared and transported in the same manner.

Other invertebrates are usually preserved in alcoholic mixtures, although some may be dried. Jelly-fish should be hardened in a saturated solution of picric acid, subjected to a preliminary bath in weak alcohol, wrapped separately in cheese-cloth, placed in alcohol of 90 per cent, and surrounded with excelsior to protect them from pressure. Another simple and effective method of protecting delicate, soft-bodied forms from undue pressure in tanks is to place them in thin wooden packing-boxes, in which holes are cut to allow free circulation of alcohol.

THE COLLECTION AND PRESERVATION OF MINUTE FORMS.

Our remarks have thus far been confined to forms of sufficient size to be readily seen and picked out singly from the mass in the table sieve, yet there are in every successful haul of dredge or trawl a multitude of minute invertebrates demanding the careful attention of the collector.

The process of washing the mud from the specimens through the meshes of the table sieve into the tub strainer (plate XXXIV) has already been described. When it has been relieved of its contents the strainer bags will contain more or less mud, foraminifera, shells, and other light matter, while the heavier material has settled to the bottom of the tub, the final disposal of which depends upon the time the collector is able to devote to it.

A very satisfactory examination may be made by first turning the contents of the strainer bags, four or five quarts at a time, into a small tub partially filled with water, stirring the contents with a rapid, whirling motion until the soft, light forms float to the surface, when it is strained into another tub through a 20-mesh sieve, the contents of the latter being placed in a pan of water, repeating the operation until all the mud in the tub strainer has been washed. The water and sediment thus collected in the small tubs and pans are then agitated and strained as before until the residue, composed of minute animal forms, free from mud, is placed on a 40-mesh sieve, and the latter set an inch or more above the mesh into a dish of weak alcohol, partially floating the specimens, where it is allowed to remain half an hour, then transferred to a stronger solution for an hour, when the mass may be placed in bottles or jars with 80 per cent alcohol. The receptacles should be kept at hand for a day or two and occasionally turned over to loosen the mass and insure its being properly cured, after which it may be packed away with safety.

Jars or bottles should not be more than one-third filled with material of this character, which may be said to include shrimp, all kinds of minute crustacea, worms, and, in fact, all forms, surface and deep-sea, that are liable to mat down in the jar. Striking objects or very delicate forms should be put separately into vials.

Foraminifera may be preserved by drying or in alcohol; in the latter case place it in jars with 95 per cent alcohol, turning it over occasionally for a day or two. The jar should not be more than half full of material. If to be dried, place in weak alcohol for a few hours, stirring the mass frequently, then spread it in pans or trays to dry.

Surface and intermediate collecting, including apparatus and methods, have been described on page 369 to the point where the specimens are removed from the nets to buckets or pans of water. The latter is then strained through a sieve of 40 mesh, which, with the specimens retained on it, is placed in a dish containing a saturated solution of picric acid for half an hour, when the larger and more striking specimens may be picked out and the remainder placed in bottles or jars containing 80 per cent alcohol.

FORMALIN.

This liquid has recently been introduced as a preservative, and although it has not been in use long enough to thoroughly establish its value and limitations, it has already proved itself a useful adjunct and bids fair to rival alcohol for many purposes. It is cheaper than alcohol, is not inflammable or explosive, and is put up in 1-pound (about 1 pint) bottles of convenient form for transportation, a couple of bottles capable of making from 2 to 10 gallons of preservative being easily carried in a hand bag. Its great value for fieldwork is already acknowledged, and it is generally conceded by collectors that it is unexcelled as a medium for preserving soft-bodied forms.

Mr. James E. Benedict, of the Smithsonian Institution, has specimens of fish in a good state of preservation, both in texture and color, that were cured more than a year ago in a solution of 1 part of formalin to 40 parts of water.

Prof. B. W. Evermann, of the United States Fish Commission, has fish and other forms that have been preserved a year and a half in 3 parts of formalin to 40 parts of water, all in excellent condition.

Should there be a doubt as to the continued safety of formalin specimens cured in the field, alcohol may be added to the solution after they reach the laboratory, or they may be transferred to alcohol, the two preservatives seemingly working together to their mutual advantage. Formalin does not freeze, although the solution used as a preservative will; freezing may, however, be avoided by adding a sufficient quantity of alcohol.

LABELS.

The importance of properly labeling specimens has already been referred to and must be apparent to all collectors. The ship's name, date, and serial number of the station is usually considered sufficient, further information being recorded under the corresponding number in the naturalist's journal.

If labels with properly printed headings are not at hand it is better to write them with a soft lead pencil on unglazed paper rather than use ordinary ink, which is liable to fade in alcohol. A small metal label, on which the serial number is stamped, is used on board the *Albatross* for labeling deep-sea fish and other forms. There is a hole in one end through which the seizing is passed with which to attach it to the specimen. The serial number is usually sufficient identification, yet the addition of an initial letter, or other arbitrary symbol for each vessel, would enable one to place the specimen on sight without the necessity of referring to the records.

BRIEF DIRECTIONS AS TO COLLECTING BIRDS.

Guns.—The best gun for general collecting is a 12-gauge double-barreled shotgun, with 28 inch barrels. Each gun should be furnished with an auxiliary barrel, .32 caliber, for collecting small specimens. A .22-caliber breech-loading pistol, with 18-inch barrel, is much used on board the *Albatross*. A .32-caliber rifle will be found useful in collecting the larger birds.

Ammunition.—Only the best powder should be used, black powder for the 12-gauge, American wood powder, D grade, for .32 caliber, and E for .22 caliber. Shot for the 12-gauge gun, Nos. 4 and 3; for the auxiliary barrel and pistol, Nos. 12 and 8.

For skinning birds a pocket knife, or scalpel, a pair of sharp-pointed scissors, a pair of bone-cutters, and spring forceps are all the tools necessary. A needle and thread will be required if the skins are to be stuffed. Raw cotton is best for filling the skin. Arsenic is the best preservative, and the skin should be covered with it before stuffing or packing.

A game bag or fishing creel will be found convenient for carrying birds while collecting. The specimen when shot should be picked up by the feet, to prevent the blood from soiling the plumage; remove blood clots from the bill and shot-holes, sprinkle moist feathers with corn-meal, sand, or other absorbent, push a plug of cotton well down its throat, and place it, head down, in a cornucopia of thick brown paper, which may then be placed in the creel. These precautions are taken for the purpose of securing the specimen with its plumage in the best possible condition, free from blood or other liquids. To kill a wounded bird squeeze it under the wings with thumb and finger until it dies from suffocation. If the bird is of large size, hold it firmly by the feet, or between the knees, and plunge a knife into its breast, reaching the heart if possible, then hold it by the feet until the blood has drained from its mouth, when it may be prepared for transportation practically as above described for small birds. Specimens should be skinned as soon as possible, though in cold weather or when ice is plentiful it may be delayed a reasonable time.

Birds were skinned on board the *Albatross* on the operating table in the upper laboratory; in the center of the table was placed a box of arsenic and a small brush, a box of corn-meal, or other absorbent, and a basin of water. At the side of each operator were skinning tools, a roll of cotton, a towel, sponge, needle and thread, labels, pencil, and a ball of twine.

Few measurements were taken as a rule, except in the case of a new species or some peculiarity in form. The coloring of bills, legs, feet, etc., was noted. The girth of the specimen was taken by wrapping a strip of paper around the body over the wings, and pinning it like a band, then slipping it off toward the tail and using it as a guide in stuffing the skin in order to retain the original size of the bird.

The process of skinning was much the same as that in general use among collectors, and may be briefly described as follows: Make an incision through the skin from the breast-bone to the anus, taking care not to soil the feathers or mutilate the sexual organs. Separate the skin on one side to the knee, expose the thigh, thrust the knee up on the abdomen, and loosen the skin around it until you can, with scissors or knife, separate the joint and muscles. Repeat the operation on the other side; loosen the skin about the base of the tail, and cut through the vertebræ at the last joint, taking care not to sever the bases of the quills; invert the skin and loosen it from the body. Loosen the skin from the first bone of the wings, and cut through the middle of it, or separate it from the body through the joint and draw the skin over the neck until the skull is exposed.

Detach the delicate membrane of the ear from its cavity in the skull without cutting or tearing it; then, by means of the thumbnails, loosen the skin from other parts of the head up to the eyes, taking care not to lacerate the balls. Scoop out the eyes, and, by making one cut on each side of the head, through the small bone connecting the base of the lower jaw with the skull, another across the roof of the mouth behind the base of the upper mandible and between the jaws of the lower, and a fourth through the skull behind the orbits and parallel to the roof of the mouth, you will have freed the skull from all accompanying brain and muscle. Should anything still remain remove it separately. In making the first two cuts do not sever the small bone extending from the base of the upper mandible to the base of the lower jawbone. Invert the skin of the head to the base of the bill, and clean off all the muscle and fat from the head and skin of the neck. Corn-meal should be used freely between the skin and carcass during the process of skinning. Skin the wings down to the wrist joints, detaching the roots of the larger feathers with the thumb or finger nails, removing the muscles from the bones but leaving the latter; or, make an incision on the under side along the bone, removing the flesh through the opening thus made. The latter method is preferable with large birds.

Skin the legs down to the lower joint of the thigh, remove the flesh from the bone, remove the muscle and fat, including the oil gland, from the base of the tail, but do not cut the roots of the feathers. To prevent stretching during the process of skinning, handle the skin as close as possible to the point of adhesion, a stretched skin being unsatisfactory in every respect; keep the feathers separate from the fleshy parts to prevent soiling the plumage and apply a suitable absorbent whenever a bloody or fatty surface is exposed.

Woodpeckers, ducks, etc., have the head so much larger than the neck that it is impossible to skin over it; in such cases cut the neck off before the skull is reached, turn the skin right side out, make an incision from the top of the head down to the base of the skull, and skin the head through the opening; stitch the incision together either before or after the specimen has been stuffed. Some birds have very tender skins that adhere to the rump or lower part of the back so closely that it is difficult to separate them; in such cases a little delay in skinning will facilitate the operation.

Birds having a white plumage very compact on the lower parts may be skinned through an incision along the side just under the wing, or on the back.

To poison the skin turn it wrongside out, lay it in the box containing the poison, and apply arsenic freely with brush, or other convenient method, taking care that it reaches every part of the head, particularly the base of the bill, about the wing, and leg bones and the base of the tail. After the poisoning is completed shake the skin over the box to detach loose powder.

The essential points in cleaning a bird skin are to never let the blood dry on the feathers; always use the absorbent immediately after washing, freeing it from the feathers before it dries.

To stuff a bird skin, fill the holes from which the eyeballs were removed with well rounded and elastic wads of cotton immediately after the skin is poisoned and while it is reversed; then form a roll of cotton around a knitting needle or other slender steel wire and insert it into the neck until the end can be grasped through the bill; withdraw the wire and push the end of the roll back from the mouth, so that when it is closed the cotton will not be exposed. If preferred, the end of the roll may be pushed into the skull cavity instead of the throat and the latter filled through the mouth; the latter method is preferable when the natural pose of the head is at a considerable angle with the neck. Next make up a soft oval wad or roll of cotton the size of the natural body, insert one end beneath the neck roll, which is raised and held up for the purpose, then work the wad into place by carefully pulling the skin over, taking a stitch or two to close the incision. The leg bones of large and medium-sized birds should be wrapped with cotton in order to fill out the thighs to their proper shape.

Birds with long necks or tender skins should have the stuffing wrapped around wires or sticks to strengthen them; if sticks are used the blunt anterior ends may be forced into the cavity of the skull; if wire is used it should be sharpened at both ends, one being forced through the anterior part of the head, the other through the root of the tail.

To shape or make up a specimen, lay it on its back on a thin sheet of raw cotton sufficiently large to inclose the skin when wrapped around it; fluff up the feathers under the wings, place the thumb and finger beneath them and gently press the sides together, as one would squeeze a wounded bird to kill it. When the body has thus been brought to its natural shape, bring the wings up against the sides in their normal position, allowing the side feathers to lay over them, and adjust the wing tips beneath the tail; lay the feet in a natural position, adjust the tail feathers and plumage wherever required, then roll carefully in the cotton in such a manner as to assist in retaining the contour previously given to the specimen. See that the bill is properly closed, either by a turn of a seizing, a stitch through the nostrils and around the lower mandible, or by twisting the cotton envelope around it. It is good practice to close the bill as soon as the neck has been stuffed.

The sex of a specimen should be determined by dissection, and when the generative organs have been destroyed by shot, or otherwise, omit the sex mark and substitute a query. If the organs are uninjured the sex may be readily ascertained, after the specimen is skinned, by making an incision in the side near the vertebræ and exposing the inner surface of the small of the back, where they will be found attached nearly on a line with the last ribs. The testicles of the male will be recognized as two spheroidal or ellipsoidal whitish bodies, varying with the season and species from the size of a pin head to that of a hazelnut. The ovaries of the female, consisting of a flattened mass of spheres, variable in size with the season, will be found in the same region. A magnifying glass is useful in determining the sex of very small birds, particularly the young, in which the organs are but partially developed.

To prepare rough skeletons of birds, remove the skin and clean the bones, taking care to avoid injuring the delicate parts. The tools required are simply a knife and a pair of scissors.

The following points require special attention: Birds' wings terminate in very small, pointed bones, corresponding to the thumb of mammals, hidden in a tuft of feathers on the bend of the wing, which it is well to leave undisturbed, as well as the two or three outermost wing feathers, so as to avoid the risk of removing any of these small bones with the skin. Other parts requiring attention are the slender points on the under side of the neck vertebræ, those projecting backward from the ribs, and the last bone of the tail; if the tendons of the legs, wings, under side of the neck, and along the sides of the back, become ossified, as they sometimes do, it is not advisable to tear them off. In some birds the neck and back can be left untouched, as the muscles will dry up and a thin coat of arsenical soap will serve to keep out the insects which would otherwise attack these places. The hyoid bones, which support the tongue and are attached to the windpipe, should be saved, as also the windpipe itself whenever, as in many ducks, it has bony structures developed in part of its length.

In many birds, especially birds of prey, there is a ring of bones surrounding the pupil of the eye, hence it is safer not to remove the eyeball, but to simply puncture it to allow the escape of the fluid contents. The brain should be carefully removed.

Cormorants have a small bone attached to the back of the skull, and in auks and many similar birds there is a small bone at the elbow. Sometimes there is a little bone at the hinder angle of the lower jaw, so that it is a good rule not to trim a bird's skull too closely. A favorite method of collecting small birds for skeletonizing is to make an incision in the lower part of the abdomen and place them in 30 per cent alcohol.

NOTES ON SKINNING AND PRESERVING SKINS OF MAMMALS.

To skin small mammals a median line incision from the lower neck to the tail, through which the body is removed, is sufficient, while for large ones branch incisions along the inner surfaces of the legs to the feet are usually necessary. Leg bones are detached close to the body, and the skull separated from the neck, the tail bones are removed, the leg bones thoroughly cleaned of flesh, and the eyes and brain removed from the skull.

The brain is best removed through the large foramen, with a wire hook. In skinning the head care is taken not to injure the lips and eyelids, and the skull, after being cleaned, is kept separate from the skin. The skins of mammals of all sizes are thoroughly cleaned of flesh, and in small specimens the raw sides are dusted with arsenic, lightly filled with cotton, carefully shaped, and laid away to dry.

The skins of large mammals are disposed of on shipboard to the best advantage by salting thoroughly on the flesh side and rolling into a tight bundle and stowing in a barrel, with plenty of damp salt to cover it. If many such skins are to be cared for, they are placed as soon as cleaned in a barrel of very strong brine, which sets the hair on both sides, and keeps them pliable for the taxidermist who finally receives them.

The division of small mammals includes everything up to the size of the fox. Deer and bear skins are salted and air-dried. Thick-skinned animals, such as seals, are kept in damp salt or brine. All skins require prompt treatment in the tropics and should be examined occasionally in all climates.

PREPARATION OF ROUGH SKELETONS.

In the preparation of rough skeletons of mammals it is important to know the correct name of every animal and whenever it is unknown its skin should be taken off and kept as a means of identification. If an animal is shot, some of its bones are liable to be broken and such may be allowed to pass, but when it has been beaten to death, fracturing skull and limb bones generally, the animal had better be thrown away at once. If the skull alone is broken, select if possible another of the same size and send both with the body, and when convenient send with a broken leg another of the same size, but on no account throw away the fractured limb.

If an animal is rare, the skin should be carefully taken off and preserved; otherwise remove it roughly and disembowel the specimen, taking care not to cut into the breast-bone, especially the disk-shaped piece of cartilage in which it ends. Animals destined for skeletons should on no account be split up the breast as though they were being dressed for market.

Detach the legs from the body and remove the flesh, taking care in so doing not to remove the collar bone or kneepan with the meat. In the cat family the collar-bone is very small, and lies loose in the flesh, between the shoulder blade and front end of the breast-bone. The collar-bone of weasels is very minute and difficult to find, but climbing and burrowing animals usually have this bone well developed, uniting the shoulder-blade with the breast-bone. Deer, antelope, and seals have no collar-bone.

In small quadrupeds it will usually be unnecessary to detach the legs, but if convenience in roughing out or packing renders this desirable, cut the collar-bone loose from the breast-bone and leave it fastened to the shoulder-blade.

The legs being finished, disjoint and clean the skull. Be careful in removing the eyes not to thrust the point of the knife through the thin portion of the skull back of them, and in deer, antelope, or other ruminants take care not to break through the thin bone back of the upper teeth; also be careful not to cut off any projections of bone.

In cleaning the ribs, avoid cutting the cartilages joining them to the breast-bone, and, when the tail is reached, look out for a few little bones projecting downwards from the first few vertebræ. Fold the legs snugly along the body, or, if they have been detached, tie them together with the skull on the under side, as much as possible within the chest cavity; also turn down the tail and tie it upon itself. If there are any loose bones or splinters from a broken bone tie them up in a rag and fasten them to one of the long bones. Hang the skeleton up to dry, avoiding the hot sun or the heat of a fire if possible.

In the case of small skeletons that are likely to be some time in transit, it is desirable to give a thin coat of arsenical soap or other insect poison to preserve them from attack. The breast-bones of large animals should also be poisoned.

Embracing the upper part of the windpipe and connecting it with the base of the skull is a series of bones known as the hyoid apparatus, which should be carefully saved. There are usually small bones, termed sesamoids, imbedded in the tendons, where they play over the under sides of the toes, and on this account the tendons should never be cut off close to the bone.

There are often one or two small bones on the back lower portion of the thigh-bone; these should be left in place. In preparing the skeletons of rabbits, particular attention should be given to the shoulder-blade, as this has a slender projection at the lower end, which extends some distance backward.

The male organ of many quadrupeds, as the raccoon, is provided with a bone. As it is difficult to say when this may or may not be present, it should always be looked for, and when found left attached to the hip bones.

The *skeletons of porpoises, blackfish, etc.*, are very easily prepared, but one or two points, such as the slender cheek-bones and the pelvic-bones, or rudimentary hind limbs, require special care. The pelvic-bones are so small and so deeply imbedded in the flesh that they are too often thrown away. It frequently happens that the last rib lies loose in the flesh, with its upper end several inches from the back-bone. This should always be looked for. There are no bones in the sides of the tail or flukes nor in the back fin, and they can be cut off close to the body and thrown away. The hyoid is largely developed in most cetaceans, and will be found firmly attached to the base of the skull.

The tools required for making rough skeletons are a knife, scissors, and a few steel scrapers.

To rough out a turtle it is usually necessary to remove the under shell, although some species may be roughed out without detaching it. In sea turtles and a few others the plastron can be cut loose by taking a little time to the operation, but in the more solidly built tortoises and most fresh-water turtles it is necessary to saw through the bone. The interior of the body being exposed, it is a comparatively easy matter to cut away the flesh. Usually this can be done without disjointing any of the legs, and it is better, especially in small specimens, to have them attached to the body. Do not cut into any bones, as they are frequently soft and easily damaged.

Snakes require very little care in their preparation after the skin has been removed, but in the larger serpents rudimentary hind legs are present and should be carefully preserved. Externally the legs appear as two little claws situated on either side of the vent; internally they are slender bones, about an inch and a half in length, loosely attached to the ribs.

Do not try to skin through the mouth, but make a long cut on the under side and skin either way from it.

Fishes vary so much in structure that definite instructions for preparing their skeletons can not be given, yet a few general remarks may be of service. Most species have two rows of ribs. Use the knife slowly and carefully, as the edge will often give notice of an unsuspected bone, especially about the head, where there is a chain of bones encircling the eye, and the eyeball itself is often a bony cup.

Occasionally there are two or three bones attached to the back part of the head, and a patch of flesh on the cheek is about all that can safely be removed. When the skeleton is hung up to dry, place bits of wood between the gills to allow free circulation of air.

Ordinarily it is better for the collector to preserve fishes in alcohol and not attempt to prepare skeletons. The same may be said regarding most small mammals, reptiles, and birds.

The naturalists of the *Albatross* found useful auxiliaries for the preparation of certain classes of small skeletons in the amphipod crustaceans commonly called "sea fleas," found in the shoal waters of nearly every sea and particularly abundant in Alaska. The specimen was first prepared by removing the skin and loose flesh, then tied in a small net and lowered over the ship's side, where it was allowed to hang just clear of the bottom. It would be discovered immediately and myriads of active little helpers would go to work, a few hours' time being all they required to clean the bones of every particle of flesh. They would eat bones and all if sufficient time was allowed them, but they like the soft parts best, and a little watchfulness on the part of the collector will insure a successful roughing out without injury to the skeleton.

In packing be sure that the skeleton is dry, particularly if it is a small one. In the case of a larger one it does not matter so much.

If it is the size of a deer, it should be disjointed, severing the back-bone just behind the ribs, in order to make a compact bundle. In larger specimens the back-bone may be cut into several sections, and the leg-bones separated at each joint. In the event of still smaller packages being required, the breast-bone may be separated from the ribs by cutting through the cartilage just below the end of each rib, when the latter may be detached from the back-bone, and thus dismantled a good-sized skeleton can be packed in a small box or barrel.

Straw, hay, or excelsior is the best packing material. Kelp, gulf weed, and all salt marsh or sea grasses should be avoided. In case of large skeletons salt may be sprinkled on the bones when it is impracticable to dry them, and the skeletons of seals, porpoises, etc., may be packed in salt.

The tag or label should be no larger than required; it should be sufficiently strong to withstand frequent handling, and a metal eyelet at one end will add much to its security. It should be legibly marked with the following data: The number, definite locality, date, year, month, and day; sex, using the ordinary signs ♂ for male and ♀ for female, and name of the collector. Other information is better given in the field book. The label should be tied with a square knot, to one leg, and the ends cut to not more than an inch in length; cotton sail-twine makes a safe and convenient seizing. Skins require drying before they are packed for shipment or placed in a storeroom, unless the latter is sufficiently warm and dry; it is not good practice to dry by artificial heat. Skins are liable to be attacked by insects about the bill, feet, shafts of wing, and tail feathers, etc., and any good insect poison may be used as a preventive.

The *field notes* of a collector should be full and explicit, as they determine largely the value of the specimen. They should be written in a book, on one side of the page, and should include observations on the habits, etc., of the various species, the localities they frequent, their food, and generally their life-history. He should catalogue his specimens, beginning with No. 1, numbering them serially as taken, in order to avoid duplication, making sure also that the numbers on label and catalogue correspond.

BLANK FORMS OF RECORDS.

The following blank forms of records kept on board the *Albatross* will be found useful not only as a basis for making similar forms, but as reminders of the valuable information that can be given, in tabulated form, on board of seagoing vessels by the expenditure of very little time and labor. It will be observed that some of the data are repeated on two or more forms. This method admits of the subdivision of reports, all complete in themselves, and made out on sheets of ordinary and convenient size.

Blank forms from the United States Hydrographic Office, and from other branches of the United States Government, are not included, as they are furnished to vessels by the Department requiring special information.

All hydrographic or other information obtained by the *Albatross* that is useful for making or correcting charts, or sailing directions, is furnished to the United States Hydrographic Office and United States Coast and Geodetic Survey.

Blank pages of sounding and dredging record book.

No .... Date ....
.... Machine. ...... Reel. ....
Turns .... Cor. + ... Depth ....
Shot or lead ....
Bottom ....
Bottom temperature ....
No. of thermometer .... Cor. ....
Corrected temperature ....
Air .... Surface .... Drift ....
Trawl or dredge ....

Sounding wire.		Turns.	Dredge rope.	
Down.	Up.		Down.	Up.
		0		
		100		
		200		
		300		
		400		
		500		
		600		
		700		
		800		
		900		
		1000		
		1100		
		1200		
		1300		
		1400		
		1500		
		1600		
		1700		
		1800		
		1900		
		2000		
		2100		
		2200		
		2300		
		2400		
		2500		
		2600		

Sounding wire.		Turns.	Dredge rope.	
Down.	Up.		Down.	Up.
		2700		
		2800		
		2900		
		3000		
		3100		
		3200		
		3300		
		3400		
		3500		
		3600		
		3700		
		3800		
		3900		
		4000		

SERIAL TEMPERATURES.

Depth.	Temp.	No. of ther.	Cor.	Cor. Temp.
25				
50				
100				
200				
300				
400				
500				
600				
700				
800				
900				
1000				

REMARKS.

Navigator's report—Summary of the movements of the Albatross for the year.

Date.	Movements.	Distance.	Object.
		Miles.	

The above table gives the number of days the vessel was at sea during the year; also the distance run and the object of each trip.

Record of hydrographic soundings.

Serial No.	Date.	Time of day.	Position.		Depth.	Character of bottom.	Temperature.			Instrument used.	Weight of sinker.
			Lat. N.	Long. W.			Air.	Surface.	Bottom.		
			° ′ ″	° ′ ″	*Fms.*		° F.	° F.	° F.		*Lbs.*

Record of temperatures and specific gravities.

Date.	Time of day.	Station.	Lat. N.	Long. W.	Depth.	Temperature of specimen when taken.	Temperature of air.	Temperature of specimen at time specific gravity was taken.	Specific gravity.	Specific gravity reduced to 15° C., with pure water at 4° C. as standard.
			° ′ ″	° ′ ″	*Fms.*	° F.	° F.	° C.		

Record of serial temperatures.

Date.	Serial No.	Position.		Depth (fathoms).	Character of bottom.	Temperature (degrees F.).														
		Lat. N.	Long. W.			Air.	Surface.	25 fathoms.	50 fathoms.	100 fathoms.	200 fathoms.	300 fathoms.	400 fathoms.	500 fathoms.	600 fathoms.	700 fathoms.	800 fathoms.	900 fathoms.	1,000 fathoms.	Bottom.
		° ′ ″	° ′ ″																	

Record of meteorological observations.

Date.	Position at meridian.		Barometer.		Temperature.						Weather.	Direction and force of winds.	Rainfall.
					Air: Dry bulb.		Air: Wet bulb.		Water at surface.				
	Lat. N.	Long. W.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.			
	° ′ ″	° ′ ″	°	°	°	°	°	°	°	°			

Meteorological and cruising record. North Pacific and Bering Sea.

Date.	Meridian position.		Distance run per log.	Barometer.		Temperature.						State of the weather.	Force and direction of winds.	Rainfall (approx).	State of sea.	Currents.	Strength in knots per hour.	Number of hours sealing weather.	Number of seals seen.
						Air.				Water at surface.									
						Dry bulb.		Wet bulb.											
	Lat. N.	Long. W.		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.								
	° ′ ″	° ″ ′	*Knots.*																

Record of Tanner intermediate tow-net stations.

Serial No.	Date.	Time.	Position.		Temperatures.			Depth.	Wind.		Drift.		Mean depth.	Remarks.
			Lat. N.	Long. W.	Air.	Surface.	Bottom.		Direction.	Force.	Towed at a depth.	Time towing.		
			° ′ ″	° ′ ″				*Fath.*			*Fath.*	*Min.*	*Fath.*	

Record of dredging and trawling stations.

ABBREVIATIONS USED IN THIS TABLE: m., mud; s., sand; g., gravel; co., coral; sh., shells; p., pebbles; sp., specks; c., clay; st., stones; r., rock, bk., black; wh., white; yl., yellow; gy., gray; bu., blue; dk., dark; lt., light; gn., green; br., brown; hrd., hard; sft., soft; fne., fine; crs., coarse; brk., broken; lrg., large; sml., small; rky., rocky; stk., sticky; oz., ooze; for., foraminifera; glob., globigerina, L. B. T., large beam-trawl, S. B. T., small beam-trawl; Tgl. bar, tangle-bar; Bl. dr., Blake dredge; Sh. dr., Ship's dredge.

Serial No.	Date	Time.	Position		Temperatures			Depth	Character of bottom.	Wind		Drift (mag.)		Instrument used
			Lat. N	Long W	Air.	Surface	Bottom.			Direction	Force.	Direction	Distance	
			° ′ ″	° ′ ″	°F.	°F.	°F.	*Fathoms.*					*Miles.*	

Record of trial line fishing for cod

Date	Serial No	Position		Depth	Nature of bottom.	Length of trial.	No. of lines used.	No of cod taken	Range in weight.	Average weight.	Range in length.	Average length	Bait used.
		Lat. N.	Long W.										
		° ″	° ′ ″	*Fathoms.*		*Min*			*Pounds*	*Pounds*	*Inches*	*Inches*	

Record of fishing stations.

Date	Serial No	Position.		Depth.	Character of bottom.	Bottom temp.	Instrument used	Length of time.	Food fishes taken.
		Lat. N.	Long. W.						
		° ′ ″	° ′ ″	*Fathoms*		°		*hrs. m*	

Record of fishing stations, Atlantic and Gulf Coasts.

Date.	Time.	Position.		Depth (fathoms).	Character of bottom.	Temperature.			Object of search.	Implement used.	Tilefish (*Lopholatilus chamæleonticeps*).	Hake (*Phycis tenuis*).	Whiting (*Merluccius bilinearis*).	Skate (*Raia* sp.).	Dogfish (*Mustelus canis*).	Codfish (*Gadus morrhua*).	Red grouper (*Epinephelus morio*).	Black bass (*Centropristes striatus*).	Red snapper (*Neomænis aya*).	Black grouper (*Garrupa nigrita*).	Haddock (*Melanogrammus æglifinus*).	Norway haddock (*Sebastes marinus*).	Miscellaneous.
		Lat. N	Long. W.			Air.	Surface.	Bottom.															
		° ′ ″	° ′ ″			°	°	°	General.	Hand-line.													

Record of animal life, driftwood, kelp, etc., observed from deck of Albatross at sea.

FROM PORT TOWNSEND, WASH., FOR UNALASKA, ALASKA.

Date.	Meridian position.		Mean temperature.		Fur-seals.	Whales	Auks.	Cormorants.	Ducks.	Gulls.	Goneys.	Guillemots.	Petrels.	Puffins.	Terns.	Drift-wood.	Kelp.	Remarks
	Lat. N.	Long. W.	Air. Dry bulb.	Water. Surface.														

LIST OF ILLUSTRATIONS.

PLATES.

TEXT-CUTS.