TREASURY DEPARTMENT

UNITED STATES COAST GUARD

BULLETIN No. 5

INTERNATIONAL ICE OBSERVATION

AND

ICE PATROL SERVICE

IN THE NORTH ATLANTIC OCEAN

FROM FEBRUARY TO JULY

1915

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INTERNATIONAL ICE OBSERVATION AND ICE PATROL SERVICE.

The International Ice Observation and Ice Patrol Service, first undertaken by the Coast Guard[1] in 1913 and continued in 1914, was resumed in 1915. The cutter *Seneca* performed the ice-observation duty alone during the months of February and March, and was joined by the *Miami* for the continuous ice patrol, which extended through the months of April, May, and June. By that time the ice was no longer a menace to navigation along the trans-Atlantic lanes and the patrol was discontinued for the season.

In many ways the season of 1915 resembled that of 1913, particularly as to the small amount of ice seen near the tail of Grand Bank. Owing to the prevalence of high easterly winds during the latter part of the season, icebergs were carried much farther west, after passing the tail of the bank, than is usually the case. With this exception, the observations accord with those of previous years, and even this exception is entirely compatible with and marks an extension of the previous current observations.

Scientific observations were continued during this season by observers detailed from the Bureau of Standards, Bureau of Fisheries, and Weather Bureau. The patrol vessels sent daily weather reports for transmission to the Weather Bureau for the purpose of assisting in the extension of the scope of that bureau.

DISSEMINATION OF ICE INFORMATION.

As in previous years, the Hydrographic Office of the United States Navy cooperated with the Coast Guard in the dissemination of ice information. Ice reports were sent daily, at 4 a. m., to the branch Hydrographic Office at New York, which was kept open beyond the statutory hours in order to give immediate publicity to this information by means of the telephone and telegraph. The messages were forwarded to the Hydrographic Office at Washington, where they were incorporated into the Daily Memorandum, which has a wide circulation in maritime sections.

[1] By act of Congress approved January 28, 1915, the Revenue-Cutter Service and Life-Saving Service were combined into the Coast Guard.

INSTRUCTIONS FOR ICE OBSERVATION.

TREASURY DEPARTMENT,
OFFICE OF THE SECRETARY,
Washington, February 1, 1915.

COMMANDING OFFICER COAST GUARD CUTTER "SENECA,"
Tompkinsville, N. Y.

SIR: 1. When the *Seneca* is in all respects ready for sea, she is detached from the New York Division and assigned to duty in connection with the International Ice Observation and Ice Patrol Service. You will, on February 15 instant, or as soon as possible thereafter, leave New York with the vessel under your command, proceed to the coast of Newfoundland and locate the ice fields and positions of the icebergs. You will then keep in touch with the ice situation, making such observations as practicable on the quantities of ice, its kind and extent, its drift, and obtain any other information that may seem to be of value.

2. The service to be performed is primarily the ascertainment of the locations and the progressive movement of the limiting lines of the regions in which icebergs and field ice exist in the vicinity of the Grand Bank of Newfoundland, and the dissemination of the information so ascertained for the guidance and warning of navigators; and, coordinately with these primary duties, in making such oceanographical and meteorological observations as will form a contribution toward the causes why the limiting lines assume their observed localities.

3. Observations at recorded times, extending from the surface to the bottom, should be made in well determined geographical positions throughout the patrolled region for determining:

(*a*) The temperature and salinity of the water by readings in series at definite intervals of depth.

(*b*) The direction and rate of movement of the waters in the different depths.

(*c*) The collection and preservation of samples of the waters of the ocean from ascertained depths.

(*d*) The repetition of these observations in the same localities when these localities are revisited.

4. At intervals of four hours, there should be recorded the reading of the barometer, the temperature of the air, the humidity, the direction and force of the wind, the percentage of cloudiness, and the state of the weather and the sea.

5. Scientists will be detailed to the *Seneca* as soon as practicable for the purpose of carrying on these observations, and, in addition, certain instruments will be forwarded to the *Seneca* at New York or Halifax. You will afford the scientists every facility for, and assistance in, making such observations and collecting such data as they may desire, bearing in mind the main duty of the *Seneca* is to keep track of the ice movements; and this practical work of the *Seneca* must not be subordinated to the work of scientific investigation. It should also be borne in mind, however, that the work of ice observation is highly important, and it is believed that most valuable data can be collected from these observations without in any way interfering with the primary duty of the *Seneca*. Until such time as the scientists above mentioned report on board, you will make and record such observations as your equipment will permit.

6. During the period of ice observation, the *Seneca* will be the only vessel employed on this duty and you will make such ports as you deem expedient for coal, water, and other supplies and in cases of emergency.

7. The experience of previous years has shown that a continuous ice patrol should be established about April 1 and should continue throughout the season of dangerous ice conditions. It is the intention of the department to detail an additional vessel for that purpose and to have the ice patrol commence on April 1 next, unless information should be received from you that, in your opinion, the constant patrol should commence at an earlier date. Instructions for the ice patrol will be issued when the additional vessel is detailed to that duty.

8. On your passage to the eastward, you will report your position daily to the department through coast naval radio stations as long as practicable and thereafter through Cape Sable, Camperdown, Sable Island, or Cape Race Marconi stations. If not practicable to send by any of these stations, you will relay through any vessel within reach. After locating the ice, you will discontinue reports to the department and will make these radio reports to the Hydrographic Office, New York City. These reports for the Hydrographic Office will be sent by you daily at 4 a. m., seventy-fifth meridian time, and addressed "Hydrographic, New York." The ice information to be sent to the Hydrographic Office at New York will be in as plain and concise English as practicable and will state the following, all numbers to be spelled out:

(*a*) Ice (berg or field).
(*b*) Date.
(*c*) Time (seventy-fifth meridian time).
(*d*) Latitude.
(*e*) Longitude.
(*f*) Other data as may be necessary.

When practicable, these ice reports will be sent via Cape Race Marconi station.

9. Ice information will be given at any time to any ship with which the *Seneca* can communicate. You will notify the Marconi radio stations through which you communicate that they are at liberty to forward a copy of your ice reports to the proper Canadian authorities.

10. While on ice-observation duty you will make reports in duplicate to the department from time to time as opportunity is afforded.

11. Mail, express, and freight matter for the *Seneca* will be addressed to Halifax, Nova Scotia, and you will make necessary arrangements with the proper authorities at that port for the delivery of the same.

12. The work of the *Seneca* on this duty will be of international character, and as the various maritime nations of the world have intrusted the management of the ice-observation and ice-patrol service to the United States, it is important that this work be done as thoroughly and satisfactorily as possible in order that the record of the United States (and the Coast Guard in particular) for efficiency shall be sustained.

Respectfully,

BYRON R. NEWTON,
Assistant Secretary.

INSTRUCTIONS FOR THE ICE PATROL.

TO THE COMMANDING OFFICERS OF COAST GUARD CUTTERS ON ICE PATROL, 1915.

TREASURY DEPARTMENT,
UNITED STATES COAST GUARD,
Washington, March 22, 1915.

1. The object of the patrol is to locate the icebergs and field ice nearest to the trans-Atlantic steamship lane. It will be the duty of patrol vessels to determine the southerly, easterly, and westerly limits of the ice and to keep in touch with these fields as they move to the southward, in order that radio messages may be sent out daily, giving the whereabouts of the ice, particularly the ice that may be in the immediate vicinity of the regular trans-Atlantic steamer lane.

2. The patrol will continue until the ice no longer constitutes a danger to navigation in the trans-Atlantic steamship lanes. The ice season is usually three months—April, May, and June.

3. While on this patrol the vessels will obtain fuel and other necessary supplies at Halifax, Nova Scotia. The two vessels will make alternate cruises of about 15 days in the ice region, the 15 days to be exclusive of time occupied in going to and from Halifax. The senior commanding officer will so regulate the movements of the vessels that on the fifteenth day after reaching the ice region the vessel on patrol will be relieved by the second vessel, if possible, at which time the first vessel will proceed to Halifax, replenish her coal supply, and return in time to relieve the other vessel at the end of the latter's 15-day cruise. It is important that the patrol be continuous, and the vessel on patrol must not leave her station until relieved by the other vessel, unless it is absolutely necessary to do so.

4. Having located the ice, the patrol vessel will send the following daily radiograms. All times in radiograms will be in seventy-fifth meridian time.

(*a*) At 6 p. m. (seventy-fifth meridian time) ice information will be sent broadcast for the benefit of vessels, using 600-meter wave length. This message will be sent three times with an interval of two minutes between each.

(*b*) At 6.15 p. m. (seventy-fifth meridian time) the same information will be sent broadcast three times in similar manner, using 300-meter wave length.

(*c*) At 4 a. m. (seventy-fifth meridian time) a radiogram will be sent to the branch Hydrographic Office, New York City, through

Cape Race radio station, defining the ice danger zone, its southern limits, or other definite ice news. The telegraphic address of the branch Hydrographic Office is "Hydrographic, New York." If unable to send via Cape Race send by most convenient route.

(*d*) Ice information will be given at any time to any ship with which the patrol vessel can communicate.

5. Ice information will be given in as plain concise English as practicable, and will state in the following order:

(*a*) Ice (berg or field).
(*b*) Date.
(*c*) Time (seventy-fifth meridian time).
(*d*) Latitude.
(*e*) Longitude.
(*f*) Other data as may be necessary.

6. Attention is called to Circular Letter No. 122, the provisions of which will be followed in radiograms sent to the Hydrographic Office. (See par. 5 (*c*) of this order.) In radiograms sent to vessels other than Coast Guard cutters the words "latitude" and "longitude" will not be omitted.

7. Each patrol vessel will keep a remark book in which will be entered all data and information concerning the ice that can be collected.

8. Each vessel on being relieved by the other vessel will deliver to the relieving vessel copies of all radiograms sent to or received from the Hydrographic Office during the cruise and copies of all instructions received from Headquarters by radio.

9. At the end of each cruise each vessel will forward to Headquarters a full report in triplicate. These reports should not include any matters of purely ship's business which do not relate to the ice patrol. Each vessel will send these reports direct to Headquarters and furnish a copy of such reports to the other vessel on patrol.

10. Each vessel will plot on tracing paper used in connection with H. O. Chart No. 955 the positions and extent of the ice as located from time to time. Such data will also be plotted on a duplicate tracing paper, and this duplicate will be delivered to the relieving vessel.

11. If in an emergency it becomes necessary for the junior commanding officer to communicate directly with Headquarters, in order to avoid delay, a copy of all such communications will be furnished to the senior commanding officer.

12. Upon the discontinuance of the ice patrol further instructions will be issued by Headquarters.

E. P. Bertholf,
Captain Commandant.

REPORTS OF VESSELS ON ICE OBSERVATION AND ICE PATROL.

ICE OBSERVATIONS.

During the months of February and March the *Seneca* encountered much stormy and thick weather in the vicinity of the Grand Banks and found very little ice. Comparatively few vessels gave any ice information, and on the whole the ice-observation duty was not productive of any important results. Radio communication was poor and the commanding officer of the *Seneca* was able to transmit only two ice reports during this period.

ICE PATROL REPORTS.

April 1 to April 14—First Cruise of the "Seneca," Capt. F. A. Levis.

The *Seneca* left Halifax on April 1 for the Grand Banks of Newfoundland to begin the continous ice patrol and to do such work in oceanography as might be carried on therewith.

Our course took the *Seneca* to the south of Sable Island and we made two stations for oceanography on Sable Island Bank. On the 4th we experienced a hard blow from the SE., shifting to the SW., with very heavy confused sea, which compelled us to lie to for 24 hours. At 8 a. m. 5th instant we were in lat. 42° 14′ N., long. 50° 43′ W., from which position we steamed north (true) through thick fog to the tail of the bank, where we lay to for the night.

On the 6th instant we sighted a medium-sized iceberg and found it to be aground in 38 fathoms of water in lat. 43° N., long. 50° 09′ W. We circled around it, keeping it about 200 yards on port beam, and we found that our continuous record of temperature of injection water showed 32° F. throughout the circle and that there was no change in temperature of water in approaching or departing from it. Leaving this berg at 10.30 a. m., we ran SE. (true) until we raised the temperature of surface water to 36° F. at 2 p. m. in lat. 42° 40′ N., long. 49° 40′ W. Several steamers to the southward of our position having reported clear weather and no ice visible, I was satisfied that there was no ice south of the grounded berg.

On the 7th, 8th, and 9th we searched to northward in the Labrador current, running parallels across from the bank to warmer water, until we reached lat. 44° 55′ N. On this parallel, on the 9th, we found a berg with three growlers in long. 49° 18′ W. and another berg in warm water in long. 47° 03′ W. From this berg we steered SW. (true) and, as we had had three days of fine, clear weather, I

was satisfied that there was no ice being carried southward by the Labrador Current below the forty-fifth parallel at this time.

On the 10th and 11th we searched to eastward of banks for ice during the daylight hours and lay to on the bank at night, taking several stations for oceanography. On the 12th it set in foggy and we anchored on the bank with hawser and kedge, in 32 fathoms of water, lat. 43° 25′ N., long. 49° 39′ W. On the 14th we shifted our berth about 10 miles to the westward, and, as the fog continued very thick, we remained at anchor until the morning of the 16th when we steamed to the westward to meet the *Miami*. After much difficulty in finding each other in the fog, we came together at 8 p. m. in lat. 44°, long. 51°, and I turned over the patrol work to the commanding officer of the *Miami*.

During the *Seneca's* cruise broadcast messages of warning were sent out as directed, and we received many reports from passing steamers stating that no ice was encountered to the southward of our position.

The small number of icebergs in the vicinity of the Grand Banks during the *Seneca's* cruise would seem to indicate that ice will not menace navigation this season to the degree that it did one year ago.

April 14 to May 4—First Cruise of the "Miami," First Lieut. B. H. Camden.

The *Miami* left Halifax on April 14 for the Grand Banks of Newfoundland to relieve the *Seneca*.

Arriving at 1.27 p. m. the 16th by dead reckoning, at the meeting point agreed upon the with *Seneca*, we stopped and notified the *Seneca* by wireless that we were at our destination. Some minutes later we received a message from the *Seneca* that she was at the latitude and longitude of the meeting point according to her dead reckoning. The fog at this time was very dense, so the *Miami's* whistle was blown rapidly in short blasts, but Capt. Levis radioed that they could not hear it. Then the *Seneca* was requested to stand by for a gun report and the 6-pounder was fired, but it was not audible to them. It was then agreed that the *Seneca* should hold her position and the *Miami* would endeavor to locate her, using the whistle, wireless, and gun as aids. We stood to the southward, firing the gun at half-hour intervals, notifying the *Seneca* before each shot was fired. Our fourth shot was heard and the *Seneca* then fired her 6-pounder, which was not heard, although she was to windward. She informed us that the report from our gun came to them from NNE. We accordingly stood SSW., and after running three miles stopped and fired. The *Seneca* also fired, the report being heard by us. The interval between the click of the wireless and the report of the gun showed her to be some 4 miles to the westward. We came up to her at 6.20 p. m. and I went on board to confer with Capt. Levis.

At 8.40 p. m., having received instructions and information relative to the patrol, we stood to the southward to try to locate the berg nearest the trans-Atlantic steamer lane, which had been sighted, aground on the southern end of the Bank, by the *Seneca* on the 6th instant.

On the 18th we sighted several growlers, evidently from the grounded iceberg which the southerly winds were breaking up. Some of them were of sufficient size to sink a ship if struck. At this time we were some 15 miles from the reported position of the berg. The sea being very heavy and the fog shutting in, we turned and stood to the northward for 10 miles and stopped and drifted. Dense fog almost continuous from time of leaving Halifax. During the night we found our drift, with the sounding machine, to be about north, true, at the rate of 1 knot per hour. Day ends with moderate gale, rough sea, and dense fog.

The following day, 19th, a strong south breeze was blowing. Rough sea. The fog was too dense to attempt to locate any icebergs, so we drifted with steam on engine. The temperature of the water rose, showing the influence of the constant southerly winds on the Gulf Stream in setting its waters across the Banks. Sighted French barkentine fisherman.

April 20th, moderate gale from south. Rough sea. Drifting. It being evident that it was going to be a most difficult task for the navigating officer to ascertain the position of the vessel from day to day on account of the time spent in drifting and the inability to obtain a horizon for observations, a small float carrying a striped target was constructed by the carpenter. The vessel was then headed, slow speed, away from the sun, with the latter bearing directly over the stern. The target was made fast to a number seven shot-line, which had been wound on a reel and dropped overboard and 400 yards of line run out as the target drifted astern. At this time the sun could be seen, very faintly, but visible enough for an observation. The navigating officer took a position 30 feet above the water and observed the angle between the sun and the lowest point (water line) of the target. Table 34, "Bowditch," shows the angle between the horizon and an object 400 yards distant from an observer whose elevation is 30 feet, to be 1° 21′. Subtracting this from the angle observed will give the altitude above the horizon. This was tested later, on a clear day, and the difference between two simultaneous observations of the sun by two officers, one using the target as a horizon, was three minutes, after deducting 1° 21′. Two observations, using first the horizon and then the target, taken by one officer in rapid succession, varied only one minute. This method should be of great value to any vessel in foggy weather, and particularly to those vessels in the Bering Sea, where frequently the sun can be seen but not the horizon.

It was evident that the foggy weather on the Banks would continue as long as we had the wind from the southward, so it was decided to stand down into the Gulf Stream for clear weather, as nothing could be accomplished by drifting in the fog. Accordingly, we stood SSW. into a head sea, but the vessel made excellent weather of it. At 7 p. m. stopped and drifted.

At 5.30 a. m., 21st, started ahead slow on account of heavy sea and dense fog. Course SW. Passed off Bank about 7 p. m. Changed course to south. Fog lifting. At 11 p. m. stopped and drifted. Fog shutting in. Wind shifted from SW. to north at 9 p. m.

April 22.—Drifted until 5 a. m. Stood to eastward. At 9 a. m. moderate gale from NNE. Overcast with rain. Rough sea.

Standing to eastward at reduced speed for position of grounded iceberg. At 2 p. m. headed to the northward across tail of Bank, but could not sight the iceberg, although soundings showed us that we were within a short distance of the latitude and longitude of the position given. Stood NNE. Day ended with fresh northerly gale. Heavy, rough sea.

23d.—Steaming at half speed. Moderate gale from north. Overcast. Rough sea. Standing to northward for iceberg sighted by *Seneca* on 9th instant. Sighted several French barkentines during day. At 8 p. m. stopped and drifted.

At 4.30 a. m. on the 24th, sighted the iceberg sought. Heavy, rough sea. Strong northerly breeze. Stood over toward berg, passing it at a distance of 1½ miles. Noted its position and stood to eastward.

Wind and sea increasing. Under all sail to steady vessel. 7.20 a. m., hove to under mainsail and main trysail. Reduced speed to 40 revolutions. In afternoon blowing whole gale; heavy, driving snowstorm; hail. At 4 p. m. stopped engine and drifted. Vessel rolling deeply at times.

25th.—Drifting throughout day. Storm moderating somewhat at end of day. Heavy, rough sea. Overcast with rain and snow.

26th.—Moderate NW. breeze. Heavy sea. At 5 a. m. stood to eastward for position of third berg sighted by *Seneca*. Iceberg not sighted. Stood to nortnward. At dark sighted iceberg about 10 miles to northward. Stopped and drifted.

At daylight the following morning, 27th, stood up to iceberg, passing within about 400 yards for photographs. This berg was about 100 feet high by 400 feet square, and it was estimated that it contained about 1,000,000 tons of ice. Two small bergs were sighted several miles off to the eatward.

Several reports by passing vessels of icebergs sighted south of the Banks made it advisable to stand down near the steamer lane. Accordingly, the vessel was headed to the southward after rounding the berg at close range. A fourth berg was sighted. This berg was disintegrating. At 2.30 p. m. stood to southward. At 6.40 p. m. stopped engine and drifted.

April 28.—Under way at daylight. Stood down to southward for position of iceberg reported, and at 6.40 p. m. stopped, having arrived at the locality, to drift for the night. No ice in sight.

April 29.—Having received a report from a passing steamer of a berg sighted to southeastward in the steamer lane, stood down for it. Received a second report from another steamer giving approximately the same position of a number of growlers sighted. We were not able to locate either the ice reported by the first or second vessel. Stood back to the northward and westward for other icebergs reported. 6.50 p. m., stopped and drifted.

April 30.—Standing to westward; no ice in sight. Fine, clear weather.

May 1.—Fog and rain. Stood to position of iceberg, but could not locate it, as the fog was too dense. Stood to northward for other bergs and toward the Bank to enable the *Miami* to meet the *Seneca* at the appointed time and place.

No ice was sighted this day, although five bergs had been reported in this locality and our course was through the center of the field.

It is very probable that there were only two, or possibly three, icebergs, and that the other reports were of the same bergs, which had drifted, or the shift of their reported positions was due to the difference in the dead reckoning of the vessels reporting them, for observations could seldom be obtained on account of the fog. It being thick weather, the range of our visibility at the time was not over 1 or 2 miles. At 7 p. m. stopped and drifted. Several fishing vessels in sight.

May 2.—Underway 6 a. m. Stood up toward Thirty Fathom Bank and anchored in 33 fathoms to give the crew an opportunity to catch some fish. Remained at anchor the rest of the day on account of thick weather.

May 3.—At 4.20 a. m. underway and stood to northwestward. At 8.45 a. m. received radiogram from *Seneca* reporting her position. Stood WNW. for her.

May 1 to May 15—Second Cruise "Seneca."

The *Seneca* left Halifax on May 1, proceeding to the Grand Banks, and relieved the *Miami* of ice-patrol duty on May 3 at 6 p. m. in lat. 43° 41′ N., long. 53° 37′ W.

May 4 a thick fog set in and *Seneca* anchored on Grand Bank with kedge anchor. Received a report from S. S. *Neches* that she had sighted a piece of timber 126 feet long and 4 feet thick in lat. 41° 56′ N., long. 49° 40′ W.; thinking this might be the keel of a derelict, bottom up, I decided to search for it. In running to the southward we passed close to a dangerous growler in lat. 43° 28′ N., long. 49° 57′ W., on the 5th instant.

On the 8th we received a report from the S. S. *Noordam* that she had sighted at 5 p. m. a large berg, 170 feet high and 400 feet long, in lat. 42° 19′ N., long. 52° 00′ W. I immediately turned and ran for that position, arriving there early the next morning, only to encounter a dense fog bank. We stopped and drifted the remainder of the day and the following night. On the 10th the fog lifted and a berg was reported to the NW. of our position, but we soon discovered that the supposed berg was a bark under full sail. We spoke her and found her to be the British bark *Beeswing*, bound for St. John, New Brunswick, and that she had been in that vicinity for several days. It is probable that she was mistaken for an iceberg by the *Noordam*.

I then set the course of the *Seneca* to make East, true, in lat. 42° 30′ N., and we held this parallel during the 10th and 11th, drifting with steam at throttle during the night. It was foggy most of the time and our advance was slow.

On the 12th we sighted an iceberg in lat. 42° 45′ N., long. 48° 44′ W. It was 100 feet high and was rapidly breaking up, there being numerous growlers and very small pieces of ice to leeward. Surface water 200 yards from berg was 40° F. This berg was reported twice after it was sighted by the *Seneca*, and these reports showed it to be moving ESE., true, at the rate of 14 miles a day, the winds being fresh from NW. to W. The *Seneca* continued her course to the eastward until she reached the 48th meridian, then ran South, true, for 25 miles, turning West, true, on the parallel of 42° 20′ N.

At 8 p. m. on the 12th received radio from S. S. *Baron Polworth* reporting that she had sighted a derelict water-logged vessel in lat. 40° 34′ N., long. 50° 28′ W., at 2.50 p. m. that day. I set the course of the *Seneca* for the reported position, ordered steam on both boilers, and found the derelict at 4 p. m. on the 13th. She was the three-masted American schooner *Wm. Thos. Moore*, of Bethel, Del., lumber laden, with deck load gone, masts gone, water-logged, and sea-breaking across her waist. She was a very dangerous obstruction, as she lay directly in the track of eastbound vessels. The wind was fresh from the westward and together with heavy Gulf Stream swell, caused a rough sea which prevented the running of hawser on board that night. The *Seneca* drifted for the night and on the morning of the 14th it was necessary to heave to under slow speed in a fresh SW. gale. At 4 p. m. on the 14th the gale abated and we ran before it, finding the derelict again just before dark. On the morning of the 15th we started work of running hawser and shackling it to both anchor chains of derelict. Before we finished this work and hoisted our boat, it was blowing again in stiff rain squalls from WSW. and a heavy sea running. We succeeded in making fast the hawser and hoisted our boat safely, starting ahead with derelict in tow at 8 a. m. Derelict sheered badly and we were only able to make 2 to 3 knots per hour.

On the 18th *Miami* relieved the *Seneca* of ice-patrol duty in lat. 42° 58′ N., long. 55° 39′ W., and I set course for Halifax under two boilers.

The *Wm. Thos. Moore* was abandoned on April 5, 100 miles SE. of Cape Henry, therefore she drifted over 1,200 miles in 40 days.

The icebergs which threaten navigation along trans-Atlantic steamer lanes are few in number and small in size so far this season. There is practically no ice south of parallel 42, but some of the small bergs have worked their way well to the westward, two having been reported in lat. 41–56 N., long. 52–37 W., on the 10th instant. The *Seneca* passed this point on the 16th, clear weather, but saw nothing of them.

There is much ice to the northward, and the Canadian sealing fleet report that they have encountered more ice off the coast of Newfoundland than they have for many years previous to this season.

During the cruise Mr. Wells, scientist from Bureau of Standards, studied the nucleation of the atmosphere, taking measurements of several hundred coronas with his apparatus set up in lower wheel house. Mr. Thuras, scientist, Bureau of Standards, assisted in work relating to nucleation and measured the amount of moisture in fogs. He also obtained a continuous record of sea-water temperatures and determined its density at about 100 different points.

Mr. Wood, of the Weather Bureau, made the daily meteorological observations, and sent aloft kites on 11 occasions, taking air temperatures, atmospheric pressure, and humidity at elevations from 2,000 to 5,000 feet.

Mr. Nightingale, of the Bureau of Fisheries, took 14 stations for oceanography during the cruise.

MAY 16–JUNE 7—SECOND CRUISE OF "MIAMI."

The *Miami* sailed from Halifax at 7.30 a. m., May 16, and stood out of harbor and then to the eastward on a course passing about 25 miles to the northward of Sable Island; speed about 9 knots.

At 2.40 a. m., 17th, changed course to SE. by E. ½ E. Weather clear and fine. In communication with *Seneca*.

At 2 a. m., 18th, made *Seneca* ahead. Stopped and sent surfboat with mail and papers. 4.10, boat returned, and *Miami* steamed ahead on SE. course to position of reported iceberg. Weather clear and fine.

May 19.—Drifted until 7.50 a. m., then stood to southeastward until night. Overcast and foggy with rain. Passed position of iceberg reported on the 8th, but failed to sight same.

May 20.—Course SE. ½ E. No ice sighted, although our course crossed the locality of three icebergs reported on the 9th. Stopped and drifted at 6.35 p. m.

May 21.—3.30 a. m., ahead on SE. course. Speed 7 knots. Rough to moderate sea. No ice sighted or reported in danger zone.

May 22.—Course SE. until 8.55 a. m., when, having arrived at the eastern point of the danger zone, turned and stood to the northwestward. Continued on course throughout the day.

May 23.—Standing to westward. Overcast with rain and fog. Moderate sea.

May 24.—Standing to westward at slow speed. Foggy. Sea rough. At 10.40 a. m., headed north for tail of the Great Banks.

May 25.—Overcast and misty. Sea smooth. Standing to northward. No ice sighted or reported in danger zone. At 3.30 p. m., stopped near French fisherman to purchase fresh fish. 6 p. m., stopped and drifted for the night.

May 26.—Owing to the fact that no ice had been sighted or reported in the danger zone, it was decided that it would be advisable to steam across the Labrador current and through the dead-water area until the temperature of the water showed that the Gulf Stream had been reached. Accordingly, at 3.45 a. m. stood to eastward.

May 27.—Standing to eastward. Crossed Labrador current and dead-water area. Received three wireless reports of icebergs lying in the steamer lanes. Turned and stood to southward. 5 p. m., stopped and drifted on account of fog. Nothing sighted during the day.

May 28.—Standing to southward.

May 29.—Standing to southward and then to southwestward, shaping our course so as to intercept the bergs reported, in their easterly drift with the Gulf Stream. Approaching the locality of the icebergs reported, and finding no ice, we stopped and drifted for the night.

May 30.—7.50 a. m., underway and stood to the northward and eastward in search of icebergs. No ice in sight.

May 31.—Standing to eastward. At 8.20 a. m., being some 40 miles to the southward of the eastbound steamer lane, turned and stood to the northwestward, having failed to locate any of the bergs reported. Engine making 40 revolutions.

June 1.—Standing to the northwestward. Weather clear and fine. Sea smooth. At 3.35, received radiogram from Headquarters directing *Miami* to remove wreckage reported. Shaped course to westward. Speed, 8 knots.

June 2.—Standing to the westward. Clear, fine weather. At 6 p. m. received radio message from S. S. *Portland* that she had passed wreckage at 5 p. m. in lat. 40–40 N., long. 51–40 W. This wreckage being directly in the steamer lane we turned and stood for its reported position, arriving at our destination the following morning.

A diligent search, covering an area of more than 2,500 square miles, was made, but no wreckage was sighted, although several small pieces of wreckage were passed. The sea during the previous night was somewhat heavy, and it is possible that the wreckage disintegrated; also the weather was not clear and our range of visibility was small. At dark we stopped and drifted for the night.

June 4.—We made a final trip to the westward in search of the wreckage reported, and stood to the southwestward toward the position of wreckage received in another report. Passed several small pieces of timber. Stopped and drifted for the night.

June 5.—Continued course to the westward along the parallel of the reported position of wreckage. A. m. and meridian observations showed that a drift of over 25 miles to the northward had been made by the vessel since the observations taken the previous day. Estimating the same drift for the wreckage, we stood to the westward without standing to the southward. At night we stopped and drifted. No wreckage was sighted.

June 6.—Standing to westward for reported position of derelict. Weather overcast and drizzling rain.

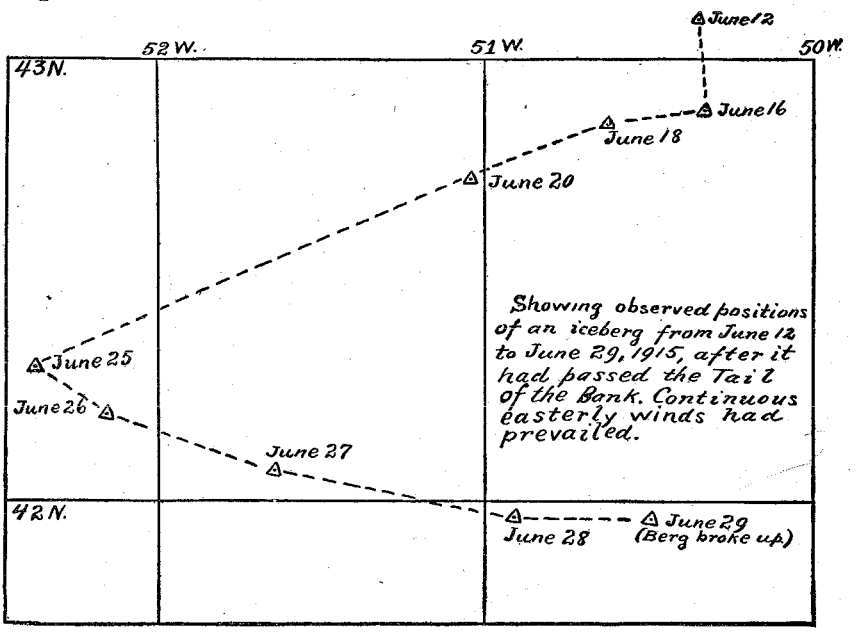
June 7.—Searching for derelict. In communication with *Seneca*. At meridian received radiogram from commanding officer of the *Seneca* releasing the *Miami* from further patrol duty and directing that this vessel proceed to Halifax and report her arrival and release from patrol duty to the captain commandant and await instructions. The message was acknowledged and the commanding officer of the *Seneca* was informed that the *Miami* would continue her search and set course for Halifax that night. Observations showed that the vessel had drifted over 20 miles to the southward since observations were taken the previous day. Weather overcast, cloudy and dense fog at end. Nothing was sighted. It will be seen from our previous experiences that the effects of the currents were most irregular, being, at times, diametrically opposite in directions with no apparent reasons.

June 10.—At 11.05 a. m. anchored off Halifax. In order to obtain data which would be of value to us while searching for icebergs, all vessels with whom communication was had were requested to furnish us with the following information: Latitude, longitude, true course, wind and sea, together with their statements as to whether they had sighted any ice or derelicts, or other obstructions to navigation. This data enabled us to plot their positions and course across the danger zone and to ascertain just what portions of this territory had been covered. A few vessels declined to give their positions and courses, while others, some of which were in sight, would make no reply to our request. Many vessels had no wireless outfit.

It would seem, from the ice reports received, that the field and heavy ice brought to the coast of Labrador and Newfoundland by the Labrador current has been carried to the westward before passing the northernmost points of the Great Bank of Newfoundland, and is prevented by the shoal water on the bank from coming any farther south.

June 5 to June 30—Third Cruise "Seneca."

The *Seneca* left Halifax on June 5 for the Grand Banks. On the 6th received a radio message from the *Miami* stating that she was searching for wreckage in the Gulf Stream in vicinity of lat. 40 N., long. 57 W.



On the 7th I conferred by radio with the commanding officer of *Miami* in regard to the ice conditions and was informed that the *Miami* had located no ice during her cruise. As conditions indicated that it would not be necessary to continue the ice patrol after July 1, I relieved the *Miami* by radio and released her from further ice-patrol duty, directing the commanding officer to proceed to Halifax and await orders.

On the 8th and 9th the *Seneca* steamed slowly through a thick fog anchoring on the Grand Bank at 8 p. m., 9th. On the 11th ran a line of soundings across the bank, coming to anchor at 4 p. m. in a dense fog near eastern edge of bank.

The *Seneca* cruised to the eastward of the Grand Bank on the 12th and 13th, but sighted no ice.

On the 16th sighted a medium-sized iceberg, in lat. 42–54 N., long. 50–20 W., which had been previously reported by the S. S. *Canadian*. We kept in touch with this berg until it broke up on June 29 in lat.

41–57 N., long. 50–30 W., during which time it drifted about 100 miles WSW., there reaching warmer water it turned back to the ESE. and finally disintegrated in a position about 60 miles south of where we first sighted it. This berg rolled over several times while we were watching it, and several growlers broke off each time it rolled. After rolling over, 20 to 30 minutes would elapse before it reached a state of equilibrium again. One of its faces presented a good target and I caused seven common shell, without bursting charge, to be fired into it from our 6-pounder guns. The ice was so rotten that the projectiles entered the ice and stuck there, plainly showing their bases in the holes they made. During the last two days of watching this berg it was rolling constantly, and finally on the 29th it separated into four pieces, and I was confident that it would melt so rapidly that it was no longer a menace to navigation. I append to this report a tracing, showing its set and drift.

I received reports showing that many of the bergs in the vicinity of Cape Race were drifting to the westward near the south shore of Newfoundland. During the entire cruise we experienced a strong set to the westward on the banks. The easterly set of the northern edge of the Gulf Stream was encountered in lat. 42–20 N., long. 51 W.

On the 29th an iceberg was reported by S. S. *Maryland* in lat. 43–49 N., long. 49–01 W. As we had a WNW. gale on the 29th and 30th, and had found no perceptible southerly set east of the bank, this berg undoubtedly was carried into the NE. branch of the Gulf Stream and would never reach the steamer lanes.

On the 30th I received orders by radio to discontinue the ice patrol, proceed to Halifax, and await orders.

The winds during the June cruise were mostly from the E. and NE.

Mr. Wood, of the United States Weather Bureau, and Mr. Thuras, of the Bureau of Standards, continued their observations of sea water and air temperatures, humidity, nucleation, and sea-water density, Mr. Wood making 15 successful flights with his kites.

SUMMARY OF OBSERVATIONS AND OPERATIONS, ICE PATROL, SEASON OF 1915.

REPORT OF CAPT. F. A. LEVIS, COMMANDING THE "SENECA," AND SENIOR OFFICER OF PATROL.

The ice-patrol season of 1915 differs from the season of 1914 in that much less ice found its way south to menace navigation in the trans-Atlantic steamer lanes, and also in the fact that of the few bergs which reached a position south of the forty-third parallel several were carried much farther to the westward than they were during the preceding season.

In 1914 there were no bergs seen or reported west of long. 51 W., while in 1915 there were three bergs west of the fifty-second meridian. During the season of 1915 the average point where the ice felt the influence of the Gulf Stream, turned and went to the northward and eastward, was about 3 degrees farther to the westward than it was in 1914.

One iceberg only, within our observation, turned directly to the eastward after drifting south of the forty-third parallel. On May 12th the *Seneca* found a large berg in lat. 42° 45′ N., long. 48° 44′ W., which was being set to ESE. at the rate of 15 miles per day. The *Seneca* had to leave this berg for the purpose of picking up the derelict schooner *William Thomas Moore*, which was reported to be exactly in the track of eastbound trans-Atlantic steamers, south of the tail of the Grand Bank, and her subsequent run to Halifax with this derelict in tow, prevented further following the course of this interesting iceberg; but I have no doubt that it was its remains which the U. S. cruiser *North Carolina* reported on June 13th in lat. 41° 33′ N., long. 41° 49′ W.

During the month of June the *Seneca* was either on the Grand Bank or near it for 23 days, and during that time the prevailing wind was from the eastward. A strong westerly current was experienced and water densities were the same as those found to the eastward of the bank. In April and May there was considerable southerly set to the eastward of the Grand Bank, but in June this current had practically disappeared and the Arctic water was running about WSW. over the bank. The axis of the cold water remained from 10 to 20 miles off the edge of the bank on its eastern and southern sides, but the direction of its set had changed. Cape Race station reported several bergs to the south and west of that place which proves that there was westerly set between the bank and the Newfoundland shore.

The ice conditions were so unfavorable off the coast of Newfoundland during April and May that the Canadian sealing fleet practically made no catch, and I attribute the fact that little of this ice came to the southward to the prevailing easterly winds. After an iceberg

reaches a position south of the forty-fourth parallel the wind determines its course entirely until it makes the Gulf Stream, when it is either carried to the N. E. or to the E., depending upon how far it penetrates the stream.

The set of the iceberg which the *Seneca* watched from June 16 to 29 (shown by sketch appended to my June report) is an example of a berg being driven to the westward by the combined action of wind and current. On June 25 the wind changed to the westward, and this berg having reached warmer water, lat. 42 18 N., long. 52 23 W., turned and began to drift to the ESE.

To the southwest of the Grand Bank narrow bands of warm and cold water were observed, and the northern edge of the Gulf Stream was farther north than it was directly south of the tail of the bank.

In February there was field ice at the eastern edge of the Grand Bank, but the *Seneca* had to answer a call for assistance from S. S. *Mongolian* and was consequently unable to ascertain its extent. We found that the *Mongolian* was leaking badly and needed a convoy to Halifax, and during the run of nearly 600 miles, at the request of the master, I kept the *Seneca* close on her quarter. We had much fog during this run and a rough, confused sea. The *Mongolian's* speed varied greatly on account of using steam for her pumps, and it required constant vigilance to hold our position. Radio messages kept me informed as to the leak, and under her own steam she safely reached Halifax, where she was docked and several new plates put in. Her damage was caused by hitting a rock off St. Johns, Newfoundland, after which the master made temporary repairs and put to sea, but the repair job did not hold tight.

The March cruise to the ice region was very stormy and thick, with sleet and snow squalls. A steamer, which refused to give her name, reported an iceberg in lat. 40° 25′ N., long. 47° 00′ W. The *Seneca*, however, located no iceberg south of parallel 43 and there was no field ice in the vicinity of the tail of the Grand Bank. There was a large berg reported in lat. 43° 24′ N., long. 49° 32′ W.

On April 4 we had a strong gale from the SE., shifting to SW., during which a heavy cross sea boarded the *Seneca* and tore the motor launch from its lashings, throwing it against the engine room skylight and ventilator, crushing in the latter. During April we encountered more fog than during any other month of the ice-patrol season, and after the blow on the 4th instant light southerly winds prevailed. On April 6 we found an iceberg aground in 38 fathoms of water on the tail of the bank in lat. 43° N., long. 50° 09′ W., and on the 9th another one aground in 67 fathoms in lat. 44° 55′ N., long. 49° 18′ W. We ran parallels to the eastward of the bank, but found only one berg to the eastward; that was in lat. 44° 55′ N., long. 47° 03′ W., in warm water and drifting to the northward and eastward. During April no ice was seen or reported to the *Seneca* south of parallel 43.

During May the *Seneca* received several reports of wreckage in the Gulf Stream, south of the tail of the Grand Bank, resulting from the storm of April 4 on the American coast, and we searched nearly a week for obstructions along the steamer tracks, finally picking up the derelict schooner *William Thomas Moore*, dismasted, seas breaking over her amidships, and deck cargo of lumber gone. This derelict was in the eastbound steamer lane and was a very dangerous obstruction. We towed it to Halifax, making, I believe, the longest

tow of a derelict on record—665 nautical miles. The owner and underwriters' agent came to Halifax and disposed of the hull and cargo below decks, which were in good condition, greatly to their advantage.

The *Miami* was searching for wreckage in the Gulf Stream when the *Seneca* relieved her, on June 7, and, as the ice conditions did not require her to return to the Grand Bank for another curise, she was released from ice-patrol duty.

During April and May the cold water on the banks and adjacent thereto was alive with murres, and there were petrels, fulmars, and gulls in abundance; but the murres all disappeared in June, leaving only petrels and a few large gulls. As a usual thing the icebergs were destitute of all bird life, but we did see half a dozen gulls perched upon the last berg of the season when we sighted it on June 16.

We caught plenty of cod and haddock whenever we lay to on the bank near the forty-fourth parallel, but fish were scarce near the tail of the bank.

The lower wheelhouse of the *Seneca* was used as a laboratory for the scientists on board. In it were installed the fog-corona measuring apparatus, fog liquid-content apparatus, mercurial barometer, barograph, and instruments for determining the density of sea water. The kite-flying machine was secured on the quarter deck. Mr. Wood, of the Weather Bureau, had no difficulty in sending the kites aloft, but sometimes could not land them on deck without damage, especially after the muslin had become wet from mist or drizzling rain. Several kites were lost; also one recording instrument, which sank before our lifeboat could reach it, the wire having parted when an attempt was made to haul it to the surface of the water.

As far as the ice-patrol duties of the vessel would permit, I gave the scientists every opportunity to pursue their investigations.

While on the Grand Bank and in the ice region, I usually either anchored at night or drifted with steam at throttle. At times it was necessary to lie to in the steamer lanes, where, owing to fog, we were an added peril to navigation.

Ice reports were sent out broadcast three time daily, and many special inquiries about ice conditions were answered. Of course, there is always a chance that a berg will reach the steamer tracks without being seen or reported, on account of prolonged periods of fog, but the presence of the ice-patrol vessels near the danger zone assures passing vessels that assistance is near by in case of disaster.

OCEAN CURRENTS AT THE SOUTHERN END OF THE GREAT BANK OF NEWFOUNDLAND.

By A. L. THURAS.[1]

INTRODUCTION.

The continuous record of surface temperatures made in 1914 had furnished data which, although insufficient in amount, nevertheless showed promise of locating ocean currents. The attempt was therefore made during 1915 to make temperature records of the greatest accuracy attainable, and to this work was added the measurement of salinity. A method attaining almost the precision of laboratory methods of density determination, but applicable at sea, made possible the simultaneous observation of three variables: (1) Actual surface temperatures; (2) actual densities in situ; (3) salinities.

From these data it was possible not only to locate bodies of water at different temperatures and salinities, but also to study their movements and the mechanism of mixing from month to month. If a sufficient number of measurements of these variables at different depths could be simultaneously made, data would be complete for a thoroughgoing study of the dynamics of ocean circulation in this complicated region.

The total area covered during 1915 was about 175,000 square miles. This area, although comparatively small, is nevertheless most important oceanographically. In this section the variations in temperature and salinity are the greatest and most extraordinary of those found anywhere in the North Atlantic. Here the cold fresh waters of the Arctic current meet and diffuse with the warm saline waters of the Gulf Stream, these two masses of water moving almost at right angles to each other at their junction. As the Labrador is the berg-carrying current, it becomes of immediate practical interest to know the location of this current and also the location of the Gulf Stream, which stops its flow southward, and the extent of their local variation from month to month. There seems to be no data which show definitely what becomes of the Labrador current after it comes into contact with the Gulf Stream. It has been thought that the Labrador current after passing Newfoundland is deflected westward over the bank of Newfoundland and flows southward along the eastern coast of the United States. Another theory is that this current, flowing SE. along the bank of Newfoundland, strikes the Gulf Stream, is buried, and proceeds beneath the latter after having literally pushed it to the SE.

[1] Delegated by Dr. S. W. Stratton, Director of the Bureau of Standards, to take scientific observations in connection with the international ice patrol of the North Atlantic Ocean by the U. S. Coast Guard cutter *Seneca*.

While the Coast Guard cutter *Seneca* was on ice-patrol duty an attempt was made to study and if possible locate these currents by the following methods: (1) Measurement of temperature; (2) determination of density and consequently salinity where the temperature is known; (3) movement of icebergs and wreckage; (4) current meter observations. The last method, being the most direct, would seem the best to use; however, the difficulties of operation under usual open ocean conditions are great, and, furthermore, the use of the current meter is limited to comparatively shallow water, as the vessel must be anchored.[1] Neither the Gulf Stream nor the Labrador current flows in shoal water at the southern end of the Newfoundland Banks, so the use of the current meters was not of value in locating these currents. However, measurements on the "tail" of the bank were valuable in showing that there was no definite current there.

In shallow water, near land, temperature observations may be exceedingly difficult to interpret, but in the open ocean, where the daily variation in temperature, aside from the movement of water, is never greater than 0.5° C. they are quite helpful in locating currents of widely different temperatures. The amount of salt in the water is a more reliable guide to the location of currents than is the temperature, as it is not subject to much local or seasonal variation, except by the active mixing of waters of different sources. Thus observations taken in the open ocean a month apart may show considerable change in temperature, but the salinities will agree very closely.

Density is very important in determining both the horizontal and vertical circulation of the water. When we consider density in situ in the ocean it becomes evident that density has an effect on circulation. The mere fact that the sea water is not equally heavy everywhere must be one of the chief causes of ocean currents. Density is a result of salinity and temperature and is therefore a temporary quality, changing as the water becomes colder or warmer. Knowing the density and corresponding temperature of the water, the salinity can be obtained. Salinity is defined as the number of grams of solids per kilogram of water. In this report densities reduced to 15° will be called salinities, as these reduced densities are directly proportional to the salt content.

Movements of icebergs, especially of the larger bergs which have no high flat sides to catch the wind, are good indications of the course of currents. Derelicts are also of value in tracing the course of currents if they are in such a condition as to be free from the effect of winds.

The observations during the 1915 ice patrol were made during the months of April, May, June, and July. The vessel left Halifax on the 1st of April, sailed to the southern part of the Great Bank of Newfoundland, cruised in this vicinity until the 16th, and then set course for Halifax, arriving there on the 20th of April. The vessel again left Halifax on the 1st of May, reached the Banks about the 3d, where she cruised about until the 12th. On the 12th we steamed SSW. into the Gulf Stream, where a derelict was found; by the 15th, the vessel, with the derelict in tow, got under way for Halifax, arriving there on the 21st. On the 5th of June we left Halifax, covering much

[1] Relative velocities have been obtained by simultaneous measurements at various depths with the vessel drifting. See The Ocean, Murray and Hjort.

the same territory on the Banks, and returned the 2d of July. On the 4th of July the vessel left Halifax and arrived at New York on the 7th of July.

DESCRIPTION OF METHODS.

The ocean temperatures were obtained by a recording thermometer. The general principle of the recorder is that of a Wheatstone Bridge. This bridge is balanced by means of a mechanism run by a small motor, which moves the slide wires in the ratio arms of the bridge. The regulation is effected by a galvanometer. When the galvanometer is deflected the actuating device moves a pen over the record until the galvanometer is balanced, thus recording the resistance of the thermometer. This recorder is made by the Leeds & Northrup Co., Philadelphia. The resistance thermometer consists of a coil of platinum wire wound on a brass tube, over which is soldered another tube. Its resistance is about 25 ohms at 0° C., and a change of 1° C, will change its resistance by 0.1 ohm. A change of 10 degrees is indicated on the record by 100 divisions, so that each division is equal to 0.1° C. These thermometers were constructed by the Bureau of Standards for this work.

The thermometer was placed in the condenser intake pipe for the circulating sea water about 6 feet from the outboard end. The sea water entered at a depth of 9 to 12 feet below the surface. The recorder was mounted on the outside of the engine room bulkhead and secured against rubber stoppers so that most of the vibration from the engine was eliminated. Great care had to be taken in balancing the galvanometer so that the center of gravity of the moving system was in a line through its supports. When this was accomplished the rolling and pitching of the ship did not change the position of the galvanometer pointer. Several times during the cruise it was necessary to rebalance the galvanometer. The results obtained by the recorder were checked frequently by a calibrated mercurial thermometer. In smooth weather the recorded temperatures were accurate to 0.05° C., but in rough weather it was necessary to reduce the period of the galvanometer, thus making it less sensitive. The maximum error arising from this reduction in sensitivity was never greater than 0.2° C. On the charts (Nos. 1, 2, and 4) the temperatures have been recorded to the nearest 0.5° C. and the errors of observation and recording are well within this value.

The density of the sea water was measured with a hydrometer and a small glass "bobbin." The hydrometer readings were not very accurate and quite difficult to take in a rough sea, so that they were discontinued.

The "bobbin" method of measuring densities depends upon the variation of density with temperature. Bobbin No. 4 (which was the only one necessary to use) floated in a liquid when its density reached 1.02295. All of the water tested had a density greater than this value. To make a test the sea water was poured into a bottle which was then placed in a copper cup heated electrically. When a temperature was reached such that the density of the water was below 1.02295, the bottle was removed from the cup, the bobbin inserted, and the liquid allowed to cool. The water was stirred constantly and when the bobbin just came to the surface the tempera-

ture was carefully noted. From a calibration of the bobbin the density at 15° C. was readily obtained by the use of curve, figure 1.

A sample of average sea water in which "bobbin" No. 4 will just float at a given temperature (plotted as abscissa) will have at 15° C.

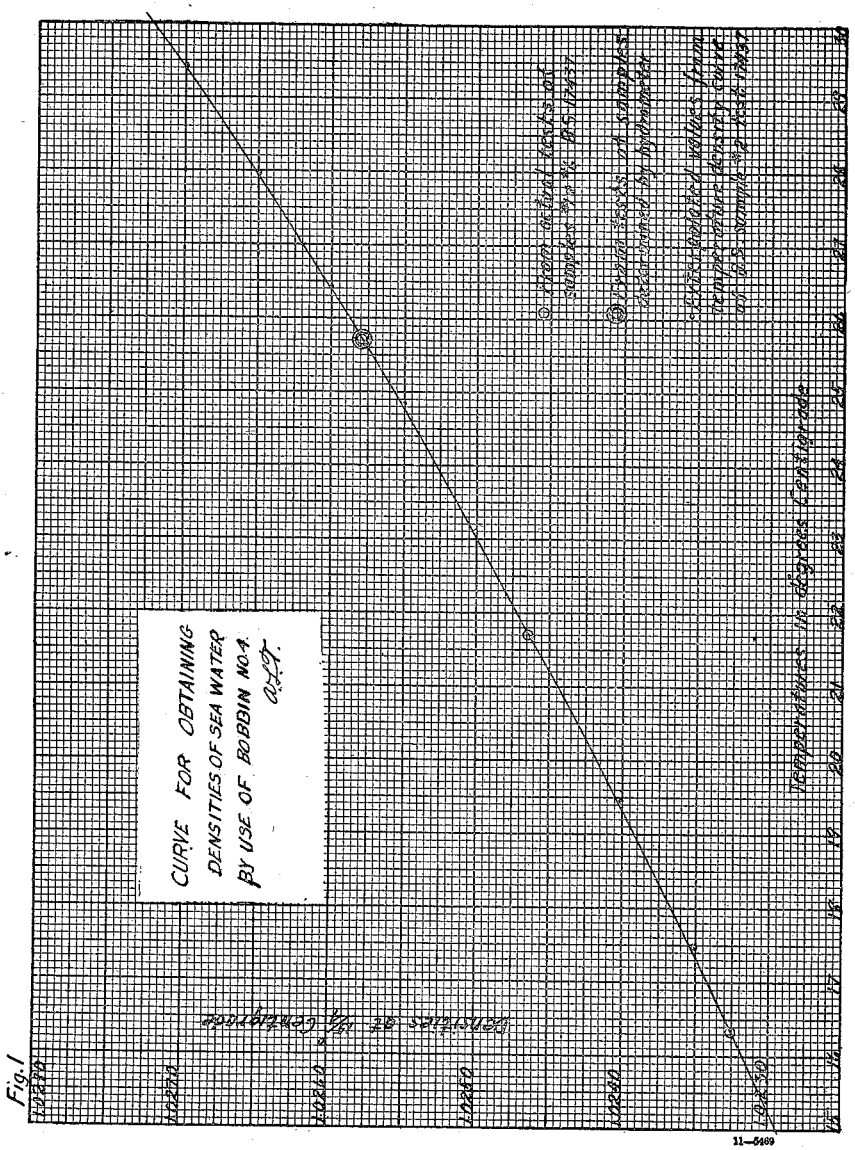


Figure 1.

the corresponding density (plotted as ordinate). For example, referring to the curve in figure 1, if the bobbin just floats in a sample when its temperature is 23°, the density of that sample reduced to 15° C. will be 1.0250. The densities were so uniform that a tem-

perature of 32° C. was the highest to which the water had to be heated. There was a little difficulty in keeping the bobbin free from air bubbles, so that just before the equilibrium temperature was reached the bobbin was taken out and carefully cleaned. The advantage of this method is its adaptability for use at sea; for when the density of the water is made equal to the density of the bobbin the latter remains in equilibrium independently of the motion of the vessel. Readings were correct to 0.3° C., and with special care the results were still better; 0.3° C. makes an error in the density of about ±0.00008.

The bobbin was carefully calibrated with two samples of sea water tested by the Bureau of Standards (test No. 17437, samples No. 1 and No. 6). Values beyond these two points were obtained by careful hydrometer readings with prepared solutions.

The calibration by samples No. 1 and No. 6 resulted as follows:

Density at 15° C.	Equilibrium temperature.	Density at 15° C.	Equilibrium temperature.
No. 1–1.02465	21.7	No. 6–1.02325	16.3
	21.7		16.2
	21.8		16.2
	21.6		16.3
	21.70		16.25

SUMMARY OF RESULTS.

With the exception of a few days, a continuous record of the ocean water temperature was obtained. About 250 density measurements were made from stations taken at various places. The current at 5 and 25 fathoms was measured at three stations on the "tail" of the Great Bank of Newfoundland.

Four Mercator charts have been used. One general chart (No. 4) shows the location of the area covered with reference to the surrounding land and sea bottom. This chart also contains the temperatures and densities from Halifax to New York. Of the other charts, two cover the area from longitude 47° W. to 57° W., from latitudes 40° N. to 45° N. Chart No. 2 contains temperatures, and No. 3, densities. The other chart, No. 1, covers the area from longitudes 57° W. to 67° W. and from latitudes 40° N. to 45° N. This chart has plotted upon it both temperatures and densities. Where the change in temperature was very rapid or erratic a note was made on the temperature chart referring to a curve which shows the rate and characteristics of the change. About 25 of these curves are given. Also a few typical Gulf Stream and mixed water temperature curves are included. On the April cruise, temperature records were taken on two parallel courses from the Newfoundland bank eastward. These have been plotted on one sheet, figure 3, with temperatures as ordinates and longitudes as abscissae. Temperatures and salinities below the surface at various stations in the vicinity of the bank refer to data obtained by Mr. H. W. Nightingale and kindly loaned by the Bureau of Fisheries.

APRIL CRUISE.

In April the course on the way to the banks lay between latitudes 43° N. and 44° N. The temperatures along this course were nearly constant, varying from 1 to 2.5°, until we came to longitude 55.30 W. where the temperature rose to 6°. This temperature was recorded up to longitude 53.40 W. where the temperature rose to 11°, increasing to 12.5° at longitude 52.40 W. This high temperature shows that water from the Gulf Stream had pressed up into this area well north of the tail of the Newfoundland bank. South along longitude 52° W. at latitude 43° N., bands of cold and warm water varying in temperature from 5° to 13° were passed through. This position is about 70 miles west of the southern end of the Newfoundland bank.

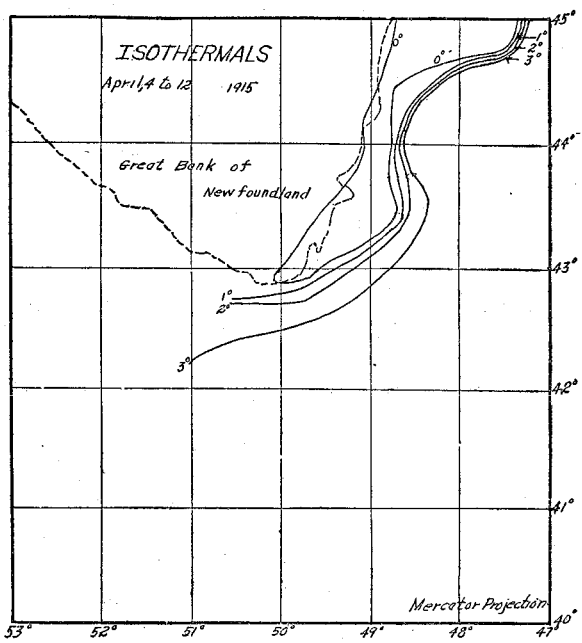


Figure 2.

Mixing of the Labrador current and Gulf Stream was evidently occurring here. From this position we followed the southern and eastern edges of the Newfoundland bank to latitude 45° N. The isothermals, figure 2, from 0 to 2° are quite close to the eastern and southern edges of the bank and cross it in places. At latitude 44° N. the isothermals are crowded in close to the banks gradually bending out farther north. From latitude 44° to 45° the isothermals are very crowded, but south of 44° N. the isothermals spread out. Just south of 44° N., at about longitude 48° W., a station was taken by Mr. Nightindale and on examining the data, the salinities were found to increase quite rapidly just below the surface, showing that there is water just east of the Labrador current that is more salty than that of this current. This saline body of water, which is thought to be a branch of the Gulf Stream, is probably the cause of the constriction

of the Labrador current at latitude 44° N. and also of the crowding together of the isothermals northward.

The curves of figure 3 show the variation in temperature across the Labrador current at two latitudes. Referring to the curve for latitude

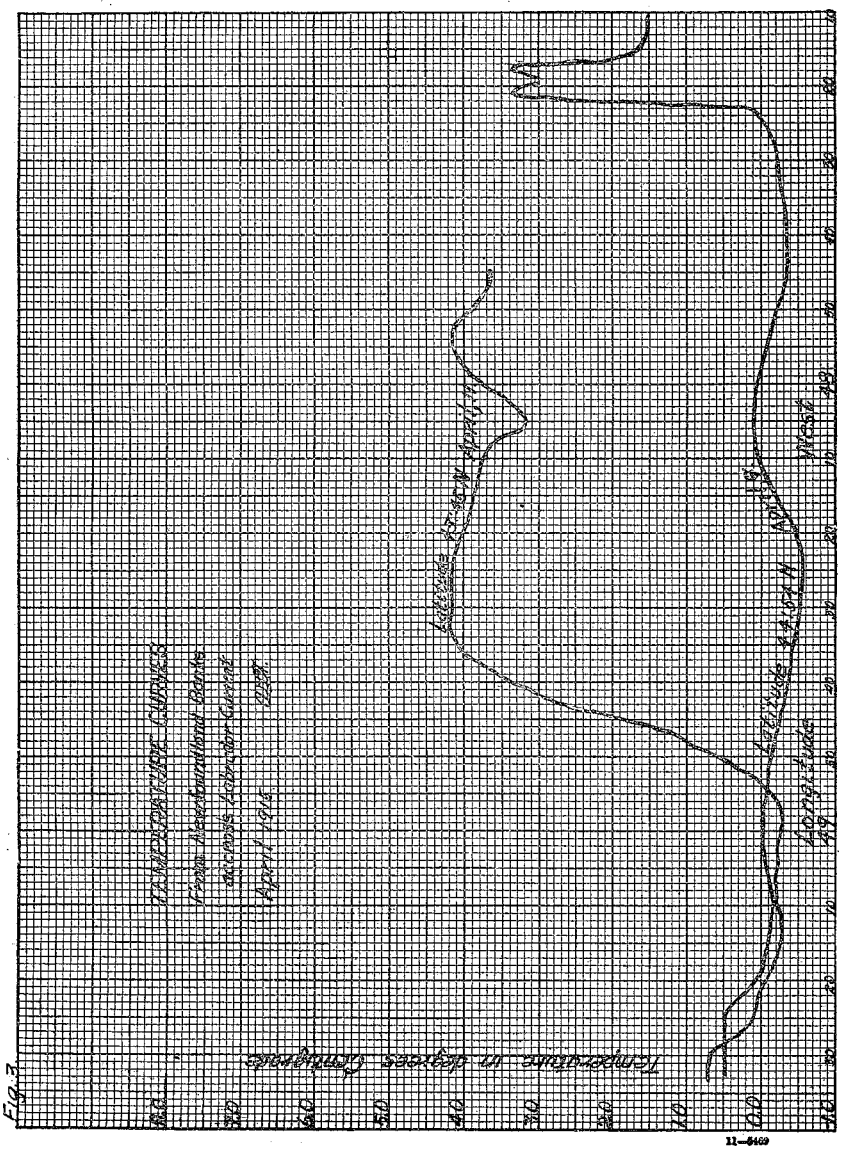


Figure 3.

44.54 N., the temperature on the bank, well within the 100 fathom line, was 0.5°; on reaching the edge of the bank the temperature dropped to 0.0°. At longitude 48.30 W., which is prabably the axis of the Labrador current, the temperature dropped to −0.5°. This is about 20 miles east of the 100 fathom line of the bank. The tem-

perature then gradually rose to 0.0° at about longitude 48° W., decreasing again to −0.4° at longitude 47.40 W. At longitude 47.20 W. the temperature rose abruptly to 3.4° C., dropping quickly again to 1.5° C. about 3 miles beyond. If the place where the abrupt rise in temperature occurs is the eastern edge of the Labrador current, then this current reached from the bank east about 65 miles at latitude 44.54 N. Farther south another record was obtained along latitude 43.45 N. (fig. 3). On the bank the temperature was 0.5° C., gradually decreasing to −0.3° at longitude 49.00 W., then rising quite rapidly to 4.2° at longitude 48.30 W., where it will be noted that the cold body of water (0.0 to −0.5°) is closer to the bank, being within about 25 miles of it. At the "tail" of the bank the cold water bends to the west. The temperature 15 or 20 miles south of the bank rose to 2° C., gradually increasing south of this to 3.8° C. at about latitude 42.15 N.

On the banks the temperatures, salinities, and densities were quite constant from the surface to the bottom. On the eastern edge the temperature was about 0°, increasing to 3° well in on the bank. From the surface to the bottom the maximum variation in density or salinity at six stations scattered over the southern end of the bank is less than 0.0004. The curves for salinity plotted against depths are almost vertical lines. The temperatures are also quite constant. This uniformtiy over the bank shows that there is probably no appreciable current there, and that the vertical and horizontal mixing due to differences of temperature and density has taken place quite completely.

From the 12th to the 16th of April the vessel was anchored on the banks at latitude 43.24 N. and longitude 49.50 W. The temperature on the 12th was 0° and on the 16th the temperature had risen to 3°. On figure 4 are plotted the winds for the month of April, as recorded by the ship's log, in terms of the Beaufort scale. The resultant velocities north and south and the resultant velocities east and west are shown on the same sheet plotted against time as a common abscissa. Each point on the curve represents the mean value for 12 hourly readings. From the 12th to the 16th, while the movement of the wind north and south was about zero, there was persistent movement from the east toward the west. Throughout this period there was fog, and the air temperature was from 3° to 4°; while the temperature previous to the 12th was 0°, with no fog. It therefore seems that the rise in temperature of the water is due to the actual movement of water from some warmer source. The cause of this movement is difficult to determine. It looks rather improbable that the east wind could have carried the warmer water, from east of the Labrador current, across the latter, to the bank.

Summary for April: The Labrador current water from −0.5° to 0.5° reached from on the Newfoundland bank about 65 miles east at latitude 45° N. Farther south the eastern edge of the cold water was closer to the bank. The isothermals north of latitude 44° N. swing out to the eastward and the temperature gradient is quite steep. South of 44° N. the isothermals spread out following the edge of the bank. At the southern end of the bank the cold water bends to the westward, and about 70 miles west of the bank it meets the warm Gulf Stream water, causing bands varying in temperature from 4° to 13°. West of the bank the Gulf Stream water was found

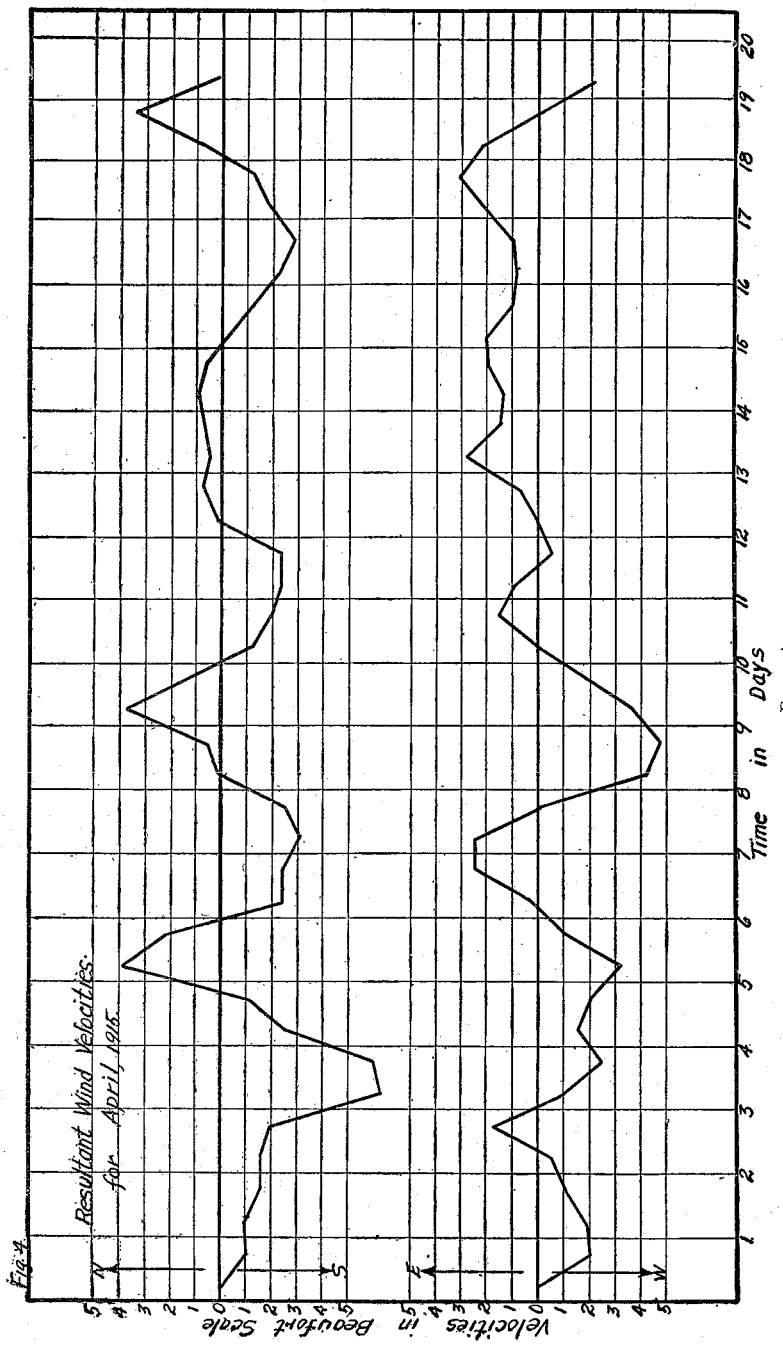


Fig. 4
Resultant Wind Velocities
for April 1916
N
S
E
W
Velocities in Beaufort Scale
Time in Days

Figure 4.

as far north as latitude 43.30 N. On the bank temperature, salinity, and density were quite constant from the surface to the bottom. While anchored on the southeastern edge of the bank, in a fog, the temperature rose 3° C. from the 12th to the 16th. The resultant wind during this period was from the east, and the air temperature was 3° to 4°, while previous to the 12th it was 0°.

MAY CRUISE.

Most of the time during May was spent in cruising around the southern end of the bank where the Labrador current meets the Gulf Stream. The isothermals and isohalines have been drawn from the surface observations on charts No. 2 and No. 3, on the assumption that conditions remained constant from the 3d to the 17th. Although for rather long distances no observations were obtained, these curves show, in a general way, the distribution of temperatures and salinities. The black circles show the actual observations.

Referring to figure 5, the 0° isothermal follows along the eastern edge of the bank, bending to the westward at the southern end. The 2° isothermal also follows the bank, but spreads out more at the southern end, swinging up close to the bank along its western side. The 4° isothermal at the southern end of the bank bends first eastward then southward almost to the Gulf Stream, where the temperature gradient is very steep. The isothermals from 0° to 4° probably locate the Labrador water. Well within the Gulf Stream the temperature was about 18° C., and this isothermal is shown at latitude 41° N. Isothermals 10°, 12°, 14°, and 16° show the edge of the Gulf Stream, and they form a rather steep gradient all along, and especially SE. of the bank. Just south of the bank these isothermals are deflected southward, due probably to the pressure caused by the Labrador current. Isothermals 6° and 8° are mainly of the Gulf Stream which has been cooled by coming in contact and mixing with the cold Larbador current west of the bank. In the area between isothermals 8° and 10° four stations were taken. One station in the eastern part, near the steep isothermals of 2°, 4°, 6°, and 8° showed a low salinity onthe surface and rather high salinity below the surface. Another station just a little NW. of this gave a rather high salinity on the surface and a much higher salinity just below the surface. At another station in about the middle of this area the salinity was uniformly high from the surface down. To the southwest, in the area covered by isothermals for 10°, 12°, 14°, and 16°, the salinity was uniformly high down to 50 fathoms. The temperatures were also high; in fact the temperatures increased below the surface. In this area then the water is mixed, being principally Gulf Stream water at a dpeth of 50 fathoms and slightly fresher on the surface. In the eastern part of the above area the surface water approaches the freshness of the Labrador current.

In the eastern part of the area inclosed by isothermals of 2° and 4° the salinities also increased rapidly down to a depth of 50 fathoms, below this depth the salinities were irregular, tending to become equal at about 400 fathoms. The temperatures were also irregular. From the surface to a depth of 50 fathoms the temperature decreased. From 50 to 200 fathoms the temperature increased. From 200 to 400 fathoms the temperature gradually decreased.

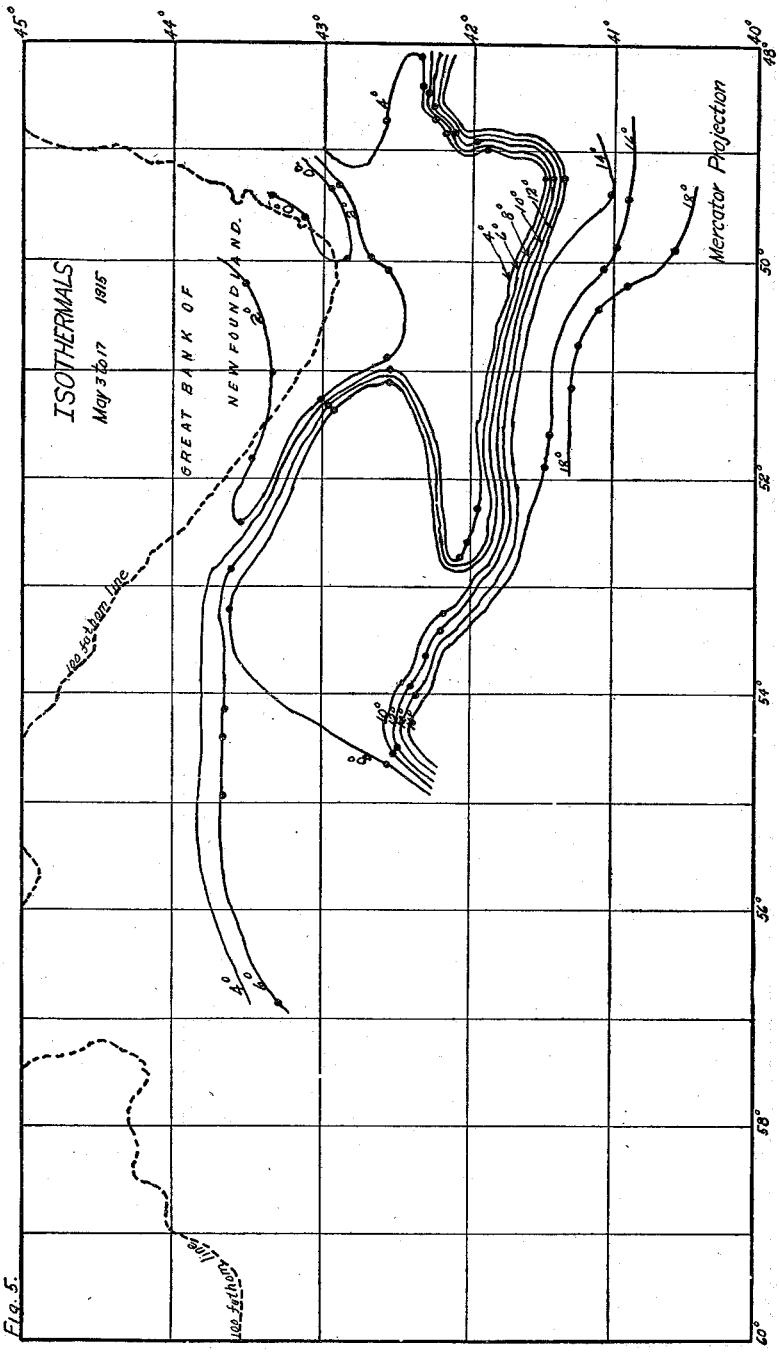

ISOTHERMALS
May 3 to 17 1915
GREAT BANK OF
NEW FOUNDLAND.
Mercator Projection
ice fathom line
ice fathom line
45°
44°
43°
42°
41°
40°
48°
50°
52°
54°
56°
58°
60°
4°
6°
8°
10°
12°
14°
16°
18°

Figure 5.

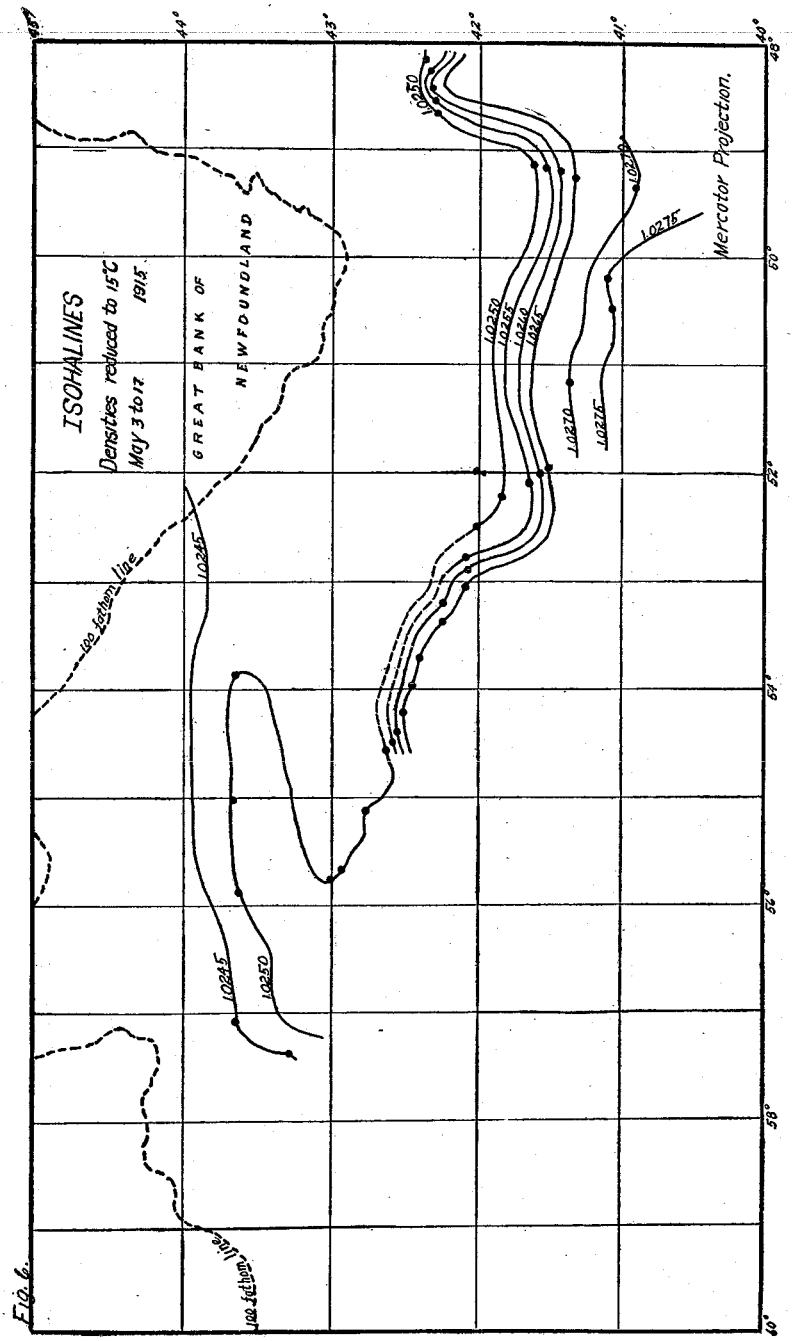

ISOHALINES
Densities reduced to 15°C
May 3 to 17 1915
GREAT BANK OF NEWFOUNDLAND
Mercator Projection.
100 fathom line
1.0245
1.0250
1.0255
1.0260
1.0265
1.0270
1.0275
45°
44°
43°
42°
41°
40°
48°
50°
52°
54°
56°
58°
60°
Fig. 6.

Figure 6.

The surface isohalines for the May cruise are plotted in figure 6. They are given in densities, reduced to 15° C., by steps of 0.0005. The lines for densities above 1.0250 are similar to the isothermals for the same period. The Labrador water has a density between 1.0245 and 1.0249, the Gulf Stream a density of about 1.0270, reduced to 15° C. The salinities of the two streams are therefore quite different.

The important thing shown by this chart is that the Labrador current spreads out quite a distance south and west of the bank. At longitude 53° W. the isohaline for 1.0250 has been shown by a dotted line, as no density measurements were made in the area to the NE. This isohaline probably bends upward similarly to the 8° isothermal. In their general depression southward at the tail of the bank, the isohalines and isothermals display a marked similarity.

At position 49.08 W. and 41.55 N. on the 6th of May the temperature of the water was 10.5°. On May 12 we again passed very close to this same area and the temperature was 4° C. This position is quite close to the steep Gulf Stream isothermals and the change in temperature is probably due to the movement of the water caused by the winds. Previous to the 6th the resultant movement of the winds was decidedly from the east toward the west. Figure 7 shows a resultant wind of about No. 5 Beaufort Scale persisting from the 1st to the 6th. This wind has undoubtedly carried the warm Gulf Stream water westward to this position. From the 6th to the 12th the resultant wind was from west to east with a slight southerly component. The result of these winds seem to be a movement of the warm water back again with the colder Labrador current following.

On the course SSW. into the Gulf Stream a series of surface densities and temperatures were obtained to determine if the densities in situ of the Labrador current and Gulf Stream were the same or not. Graphically in figure 8, the three variables, temperature, density in situ, and density reduced to 15° C. (or salinity), are plotted in trilinear coordinates. Stations 35 to 37 are in the Labrador current, 39 and 40 are in mixed water between the two currents, and 41 to 46 are positions in the Gulf Stream. The total distance from 35 to 46 is about 70 miles. Neglecting the observation at station 43, which probably is in error, we find the density in situ of both the Labrador current and Gulf Stream very nearly equal to 1.0269, while the temperature difference is about 14° C. and the difference in salinity about 0.0025. Thus we see that, although the Labrador current has a much lower salinity than the Gulf Stream, nevertheless its lower temperature counteracts this effect, causing their respectivity densities in situ to be very nearly equal. The slightly higher densities of 39 and 40 may indicate that the rate of thermal conduction is slightly more rapid than the rate of diffusion.

The densities in situ coming out of the Gulf Stream are shown in figure 9. Referring to the course into and out of the Gulf Stream on Chart No. 2 it will be seen that the course out of the Gulf Stream was well SW. of the bank where the Labrador current deflects the Gulf Stream southward. The distance from Station 51 to 65 is 140 miles. Station 51 to 54 was in the Gulf Stream, 55 to 58 in the Labrador current water, and the other stations were in bands of cold and warm water between the two currents. Again the densities in situ along this whole course did not change very much. The lower values of those stations in the Gulf Stream may be explained by the

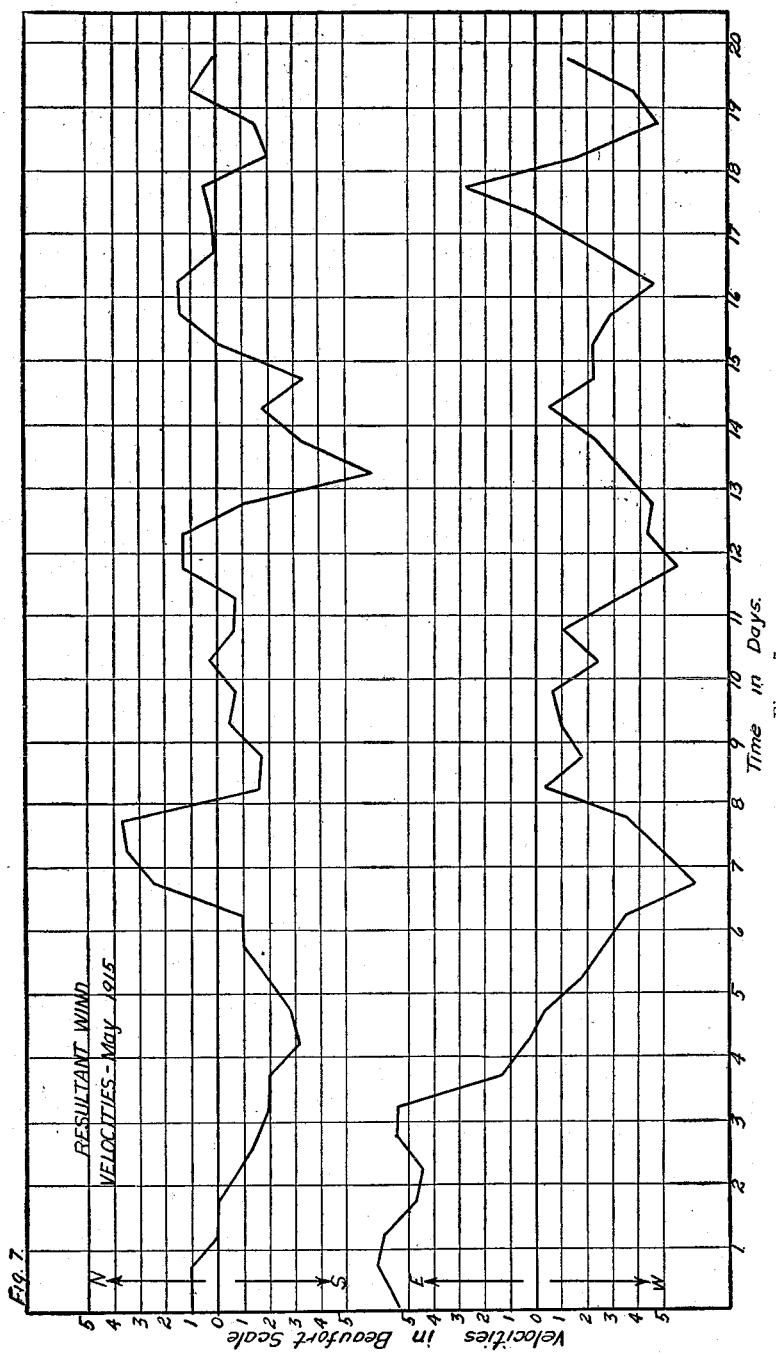


FIG. 7.
RESULTANT WIND
VELOCITIES - May 1915
N
S
E
W
Velocities in Beaufort Scale
Time in Days.

Figure 7.

fact that they were well within the Gulf Stream and consequently as the mixed water which is more sluggish in its movements.

During this month a water-logged derelict was found well within the Gulf Stream, and as it was mostly submerged the winds had probably little direct effect on its movements. This derelict was abandoned on April 4, 1915, in latitude 36.17 N., longitude 74.01 W., about 110 miles SE. of Cape Henry in a water-logged condition under a single reefed mainsail, and rudder lashed amidships. It was reported on April 10 at 9.30 a. m., in latitude 37.22 N., longitude 66.10 W., with mainmast burned through and part of a deck load of lumber amidships; therefore, from this position on it should give a good indication of the movement of the surface water. It was found by the *Seneca* on May 13 at 4 p. m. in latitude 40.43 N. and longitude

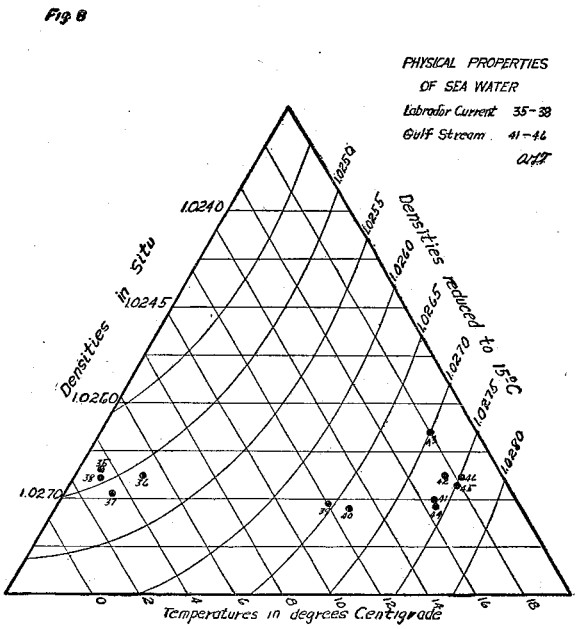


Figure 8.

50.27 W. From 9.30 a. m. on the 10th of April to 4 p. m. on the 13th of May the derelict had drifted 750 nautical miles, which gives an average velocity of 0.94 mile per hour. Its direction was east by north. From 4 p. m. on the 13th to 8.30 a. m. on the 15th the derelict drifted 32 miles, which gives an average velocity of 1.6 miles per hour. Its direction had changed to NE. On examination of the winds for May we see that there is a decided movement toward the NE. during this period. It seems quite reasonable, therefore, to assume that this increase in velocity and change in direction is due to the winds. The effect of persistent winds on currents, or at least on surface currents, must be quite large.

Summary for May: The isothermals of 0° and 2° follow quite closely the edge of the Newfoundland Bank. The 4° isothermal bends to the southward almost to the Gulf Stream. The edge of

the Gulf Stream is shown by the crowding of the isothermals 10°, 12°, 14°, and 16°, being especially noticeable SE. of the bank. Southwest of the bank the 6° and 8° isothermals bend well to the north and are also mainly Gulf Stream water, as the salinity is high. Both the isothermals and isohalines are deflected at the southern end of the bank, due probably to the pressure of colder water from the north. Under the surface the salinities increase very rapidly. Close to the region of crowded Gulf Stream isothermals a change in temperature of 6.5° in six days is probably accounted for by the movement of the water caused by persistent winds. Densities in situ in the Labrador current and Gulf Stream were found to be very nearly equal where they meet. The mean velocity of the surface

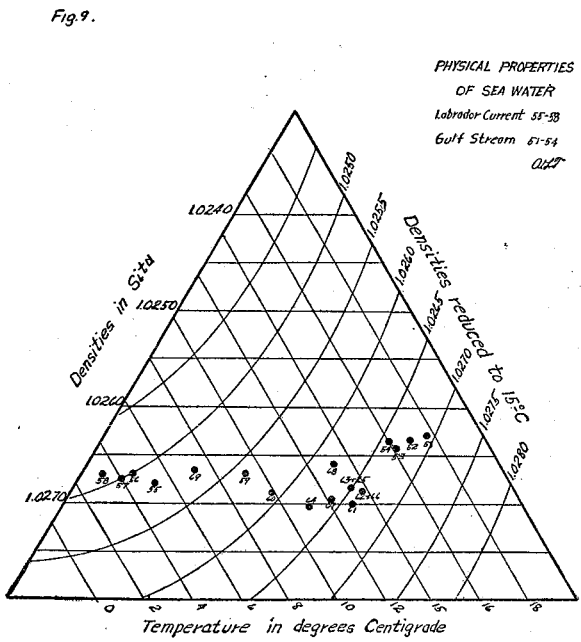


Figure 9.

waters of the Gulf Stream SW. of the Great Bank of Newfoundland for 33 days was 0.9 mile per hour, direction a little north of east. With decided southwesterly winds the average velocity for 19 hours was 1.6 miles per hour in a northeasterly direction.

JUNE CRUISE.

During the June cruise more observations were obtained in the area SW. of the bank where the Labrador current mixes with the Gulf Stream, but the temperatures were so variable that it was not possible to continue the isothermals through this area. In this area the temperatures within two or three days of each other changed by as much as 4° in almost the same location. On examination of the winds we find a northerly movement from the 6th to the 11th, which is probably the cause of the high temperature of 15° on the

afternoon of the 8th, where later on in the month the temperatures were only 6° to 9°. From the 11th to the 26th the movement of the winds are southeasterly. On an examination of the isothermals and isohalines the effect produced by this continued southeasterly movement will be noticed.

The isothermals in June (fig. 10) have changed considerably from those of May. The 0° and 2° isothermals are absent, while the 4° and 6° isothermals follow the eastern edge of the bank. West of the bank the isothermals of 10°, 12°, 14°, and 16° bend to latitude 43 N. At the "tail" of the bank they deflect southward and again bend northward just east of the Labrador current. Thus the Labrador current is hemmed in on all three sides.

The isohalines (fig. 11) have also followed the general direction of the isothermals, showing that the Gulf Stream has pressed the fresher water farther to the north and also northwest, making it impossible for the Labrador current to flow by on the west.

During this month the movement of the Labrador current and Gulf Stream SW. of the bank was noted by the movement of an iceberg which had been carried down by the Labrador current and westward around the southern end of the bank. This berg drifted as far west as longitude 53 W. latitude 42.12 N., which is the farthest west that any berg drifted during the season. Moreover, a peculiar condition was noticed here in the remarkable freshness of the water while the temperature was as high as 10°. This water had apparently warmed up without directly mixing with the Gulf Stream. It is to be regretted that we were unable to obtain any undersurface temperatures and salinites at this place. At longitude 53.05 W., on the 27th, the berg began to drift to the eastward at the rate of 1.3 miles per hour. The drift of the berg was watched for two days and during this whole period the surface water was relatively fresh, showing that it was not in the Gulf Stream water, which has a much higher salinity. The winds during this easterly drift were toward the NE. during the first part and toward the SE. during the last part. Previous to this period, as noted in fig. 12, the winds from the 11th to the 25th were from the NE. It seems quite probable, therefore, that from the 11th to the 25th the Labrador current was strengthened and consequently moved far to the SW., overflowing the northern edge of the Gulf Stream and forming a surface layer of fresher water. If by conduction this fresh cold water was warmed by the Gulf Stream below, then it would become lighter and have no tendency of mixing with the heavier understrata of the Gulf Stream.

On the 25th, as the wind movements shifted toward the NE. and SE., the surface layers of the Labrador current lost their velocity westward and the Gulf Stream began to carry this water eastward. An examination of the simultaneous salinities and temperatures and therefore densities in situ in this area seem to corroborate the statement in regard to the fresher and lighter surface water. In this area the salinities averaged about 1.0247, which is what we found in the Labrador current in April and May. However, in April and May the temperatures were about 0° and the density in situ was 1.0269 (fig. 13). In June the temperatures averaged about 8°, which gives a density in situ of 1.0260. The adjacent Gulf Stream had a density of about 1.0269. It therefore seems that if the Labrador current

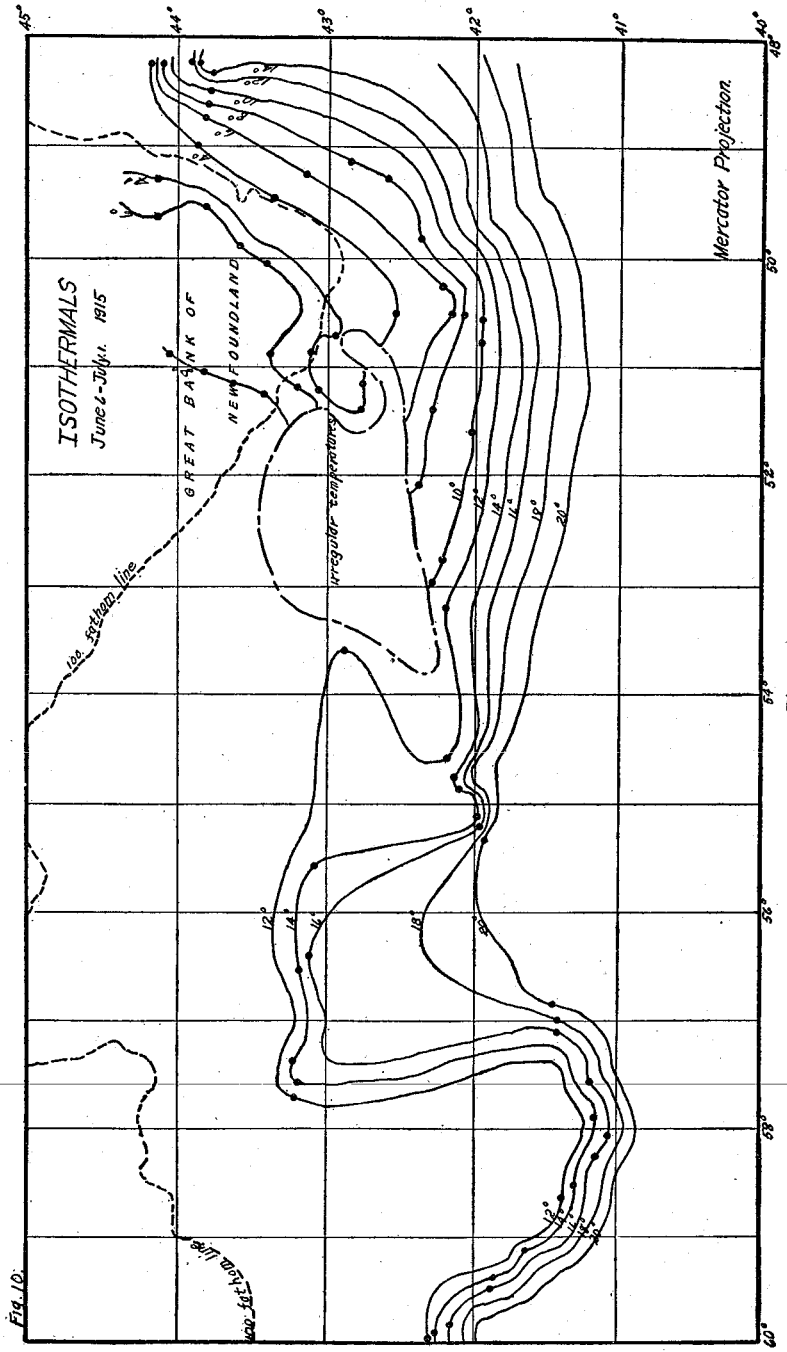

ISOTHERMALS
June 6-July 1. 1915
GREAT BANK OF NEWFOUNDLAND
Mercator Projection
ice system line
irregular temperatures
45°
44°
43°
42°
41°
40°
48°
56°
52°
64°
36°
68°
60°
10°
12°
14°
16°
18°
20°

Figure 10.

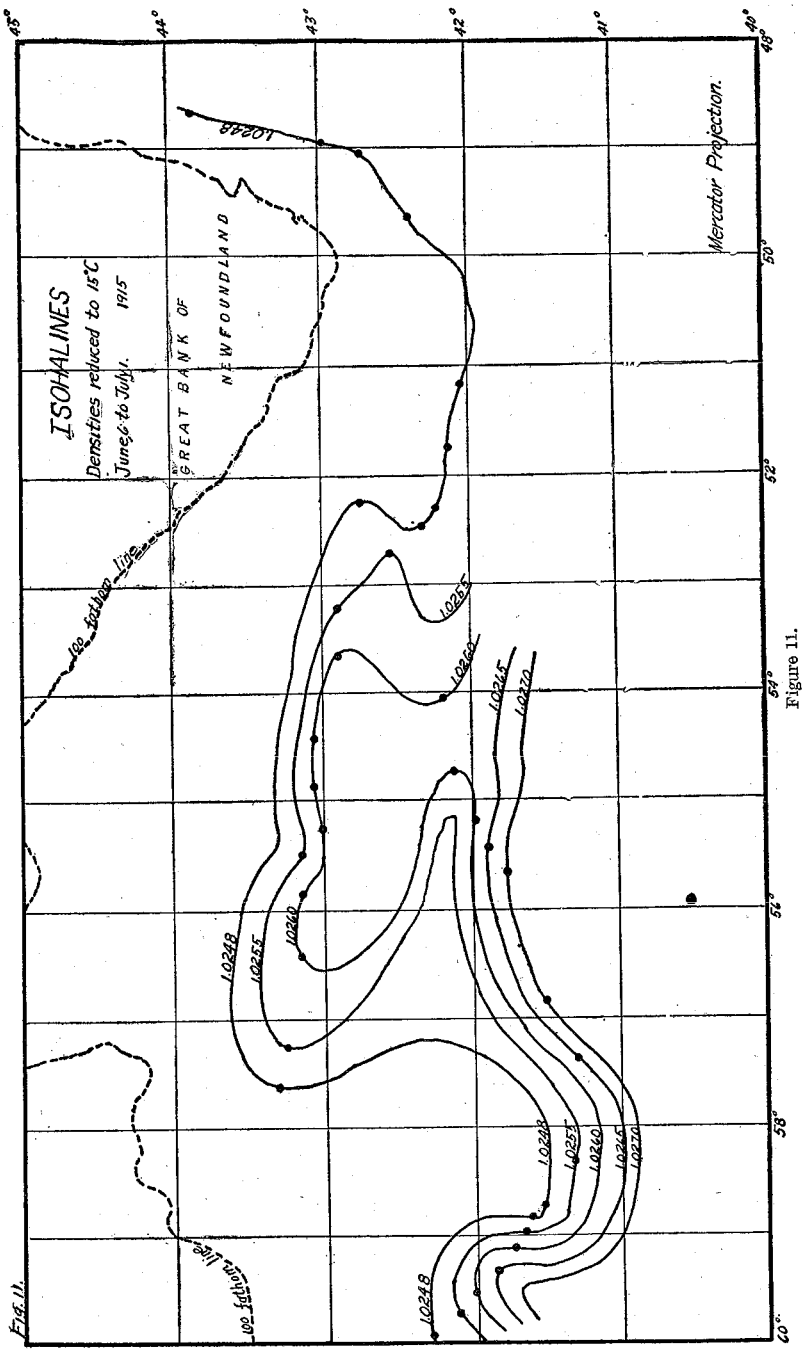

ISOHALINES
Densities reduced to 15°C
June 6 to July 1. 1915
GREAT BANK OF NEWFOUNDLAND
Mercator Projection.
100 fathom line
Fig. 11.
1.0248
1.0255
1.0260
1.0265
1.0270
45°
44°
43°
42°
41°
40°
48°
50°
52°
54°
56°
58°
60°

Figure 11.

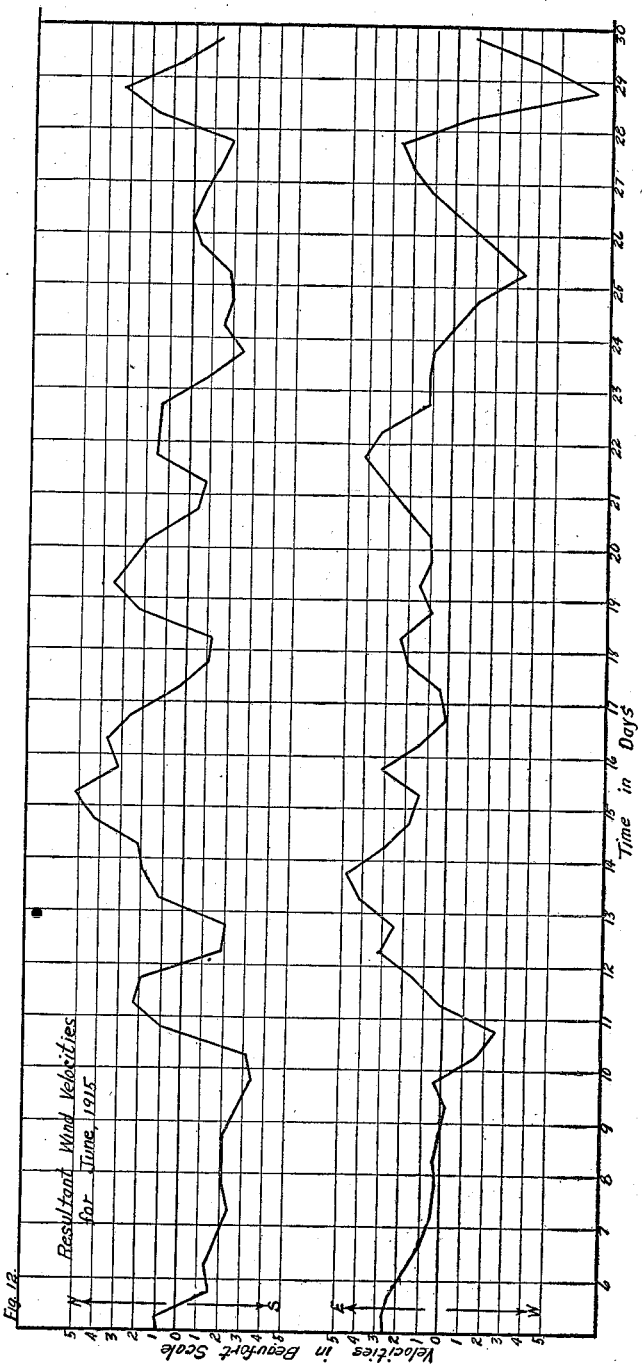


Fig. 12.
Resultant Wind Velocities for June, 1915
N
S
E
W
Velocities in Beaufort Scale
Time in Days

Figure 12.

water is carried (by winds) onto the Gulf Stream and is warmed, it will become lighter and tend to float on the surface of the latter.

If ever the effect of dilution caused by the fresh water melting from icebergs could be used to detect the proximity of ice, surely a berg

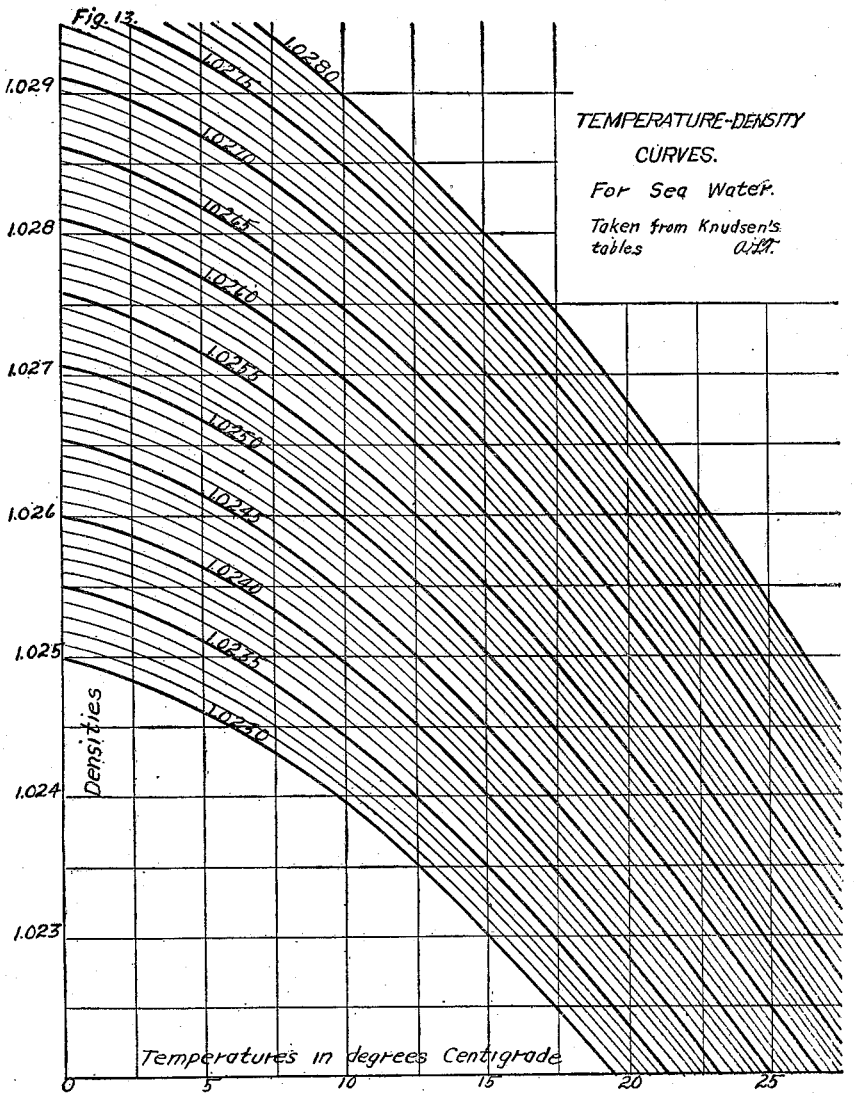


Figure 13.

in this area at such a high temperature should give an indication. A series of densities reduced to 15° C. were taken around the berg referred to above and no dilution on approaching it could be detected. Around another berg, at latitude 42.43 N. and longitude 51.05 W., the

following densities were obtained (the last figure is of relative significance, even if not absolutely correct):

Densities reduced to 15° C.:	Remarks.
1.02458	Berg 10 miles away.
1.02453	Berg 2 miles away.
1.02450 1.02453 1.02448 1.02453 1.02448	Densities taken at approximately equal intervals on approaching berg.
1.02456	Berg 200 yards away.
1.02453	Berg 200 yards away.

The proximity of icebergs at greater distances than a few hundred yards could not be determined by either temperature or density measurements.

While anchored on the bank, current measurements were made with two Ekman meters at three stations which are located on the temperature charts. The readings were taken from the side of the vessel a little forward of the beam where the rise and fall of the ship was the least. I do not know the extent of the error caused by the motion of the vessel but it was probably small, as most of the readings were taken in a calm and smooth sea. The vessel did not swing appreciably.

At station No. 1, on June 15, measurements were taken at 5 and at 25 fathoms from 10 a. m. till 7 p. m. There was a No. 4 breeze blowing most of the time and the state of the sea was moderate, so that the results should not be too much depended upon. The measurements at 25 fathoms are plotted in vectors on the velocity sheet, figure 14a. Referring to this sheet, a decided tide effect is indicated by the clockwise rotation of the vectors. The velocity seems to be stronger in the SE. quadrant and this might indicate a current flowing SE. However, the direction of the wind three or four days previous to the 15th was from the east, which would seem to oppose this flow.

On the 19th of June, at station No. 2, velocities and directions were obtained at depths of 5 and 25 fathoms, see figures 14b and 14c. The weather conditions were very good for current observations; the sea was smooth [1] and the wind low.

The weather conditions at station No. 3, on the 21st and 22d, were also as good as could be expected, the sea being smooth most of the time. Both at 5 and 25 fathoms the clockwise rotation of the vectors, see figures 14d and 14e, was again noted, making a complete rotation in about 14 hours. At 5 fathoms the velocities in the northerly direction were quite small while those in the southerly direction were large. At 25 fathoms the northerly and southerly velocities were small while those easterly and westerly were large. The vessel lay to the wind and did not swing appreciably.

Where there was a rapid or erratic change in temperature a tracing of the curve was made. These records (curve No. 1 to No. 25) show the rate of change of the temperature on passing from one body of water to another of different density. To give an idea of the most rapid changes, the following curves are discussed:

[1] Smooth=as recorded in ship's log.

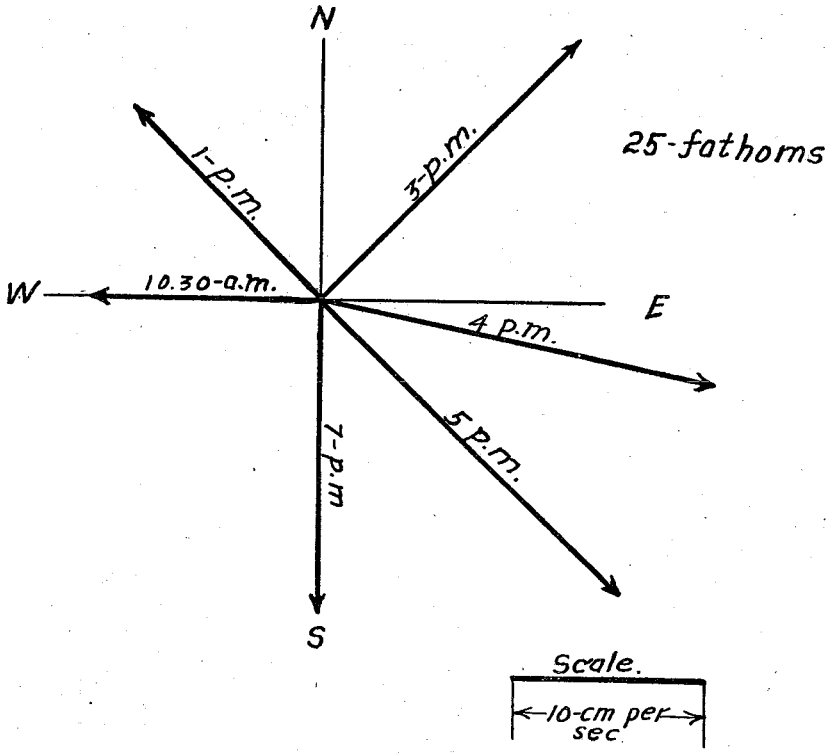


Figure 14a.

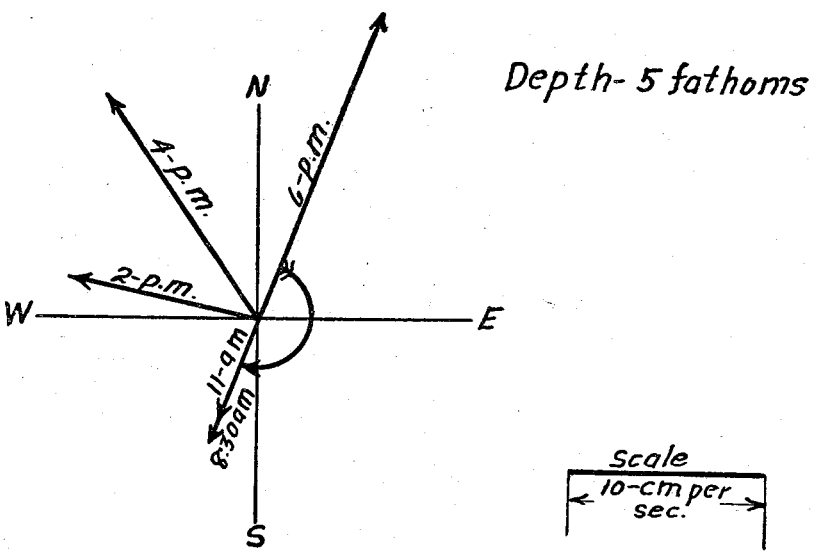


Figure 14b.

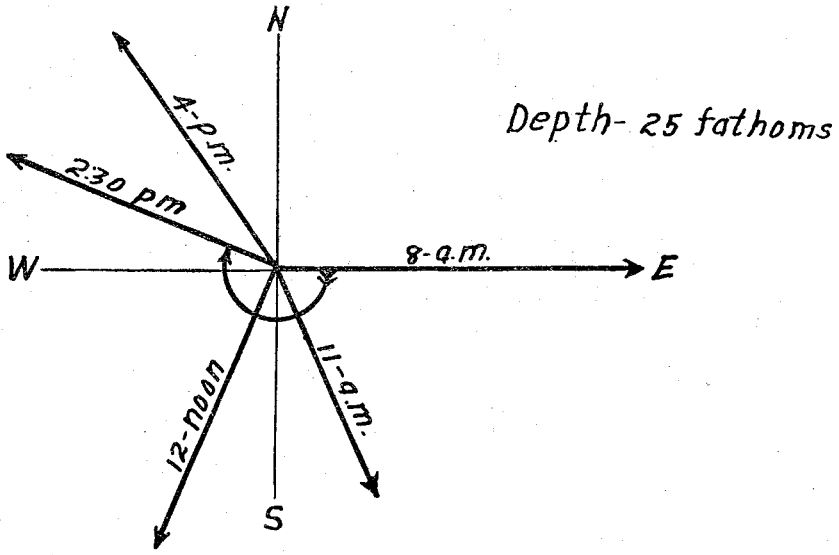


Figure 14c.

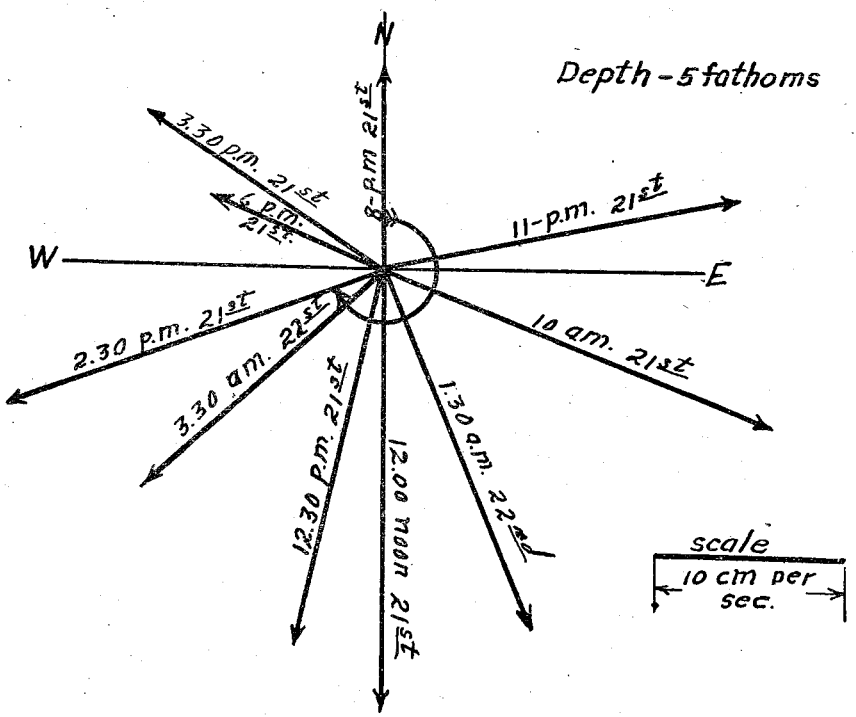


Figure 14d.

At curve No. 11 the temperature rose from 4.0° to 12.0° C. in about 1.3 nautical miles. Curve No. 12 shows the rate of change as we go from cold water into the Gulf Stream; the temperature rose from 5.0° to 11.0° C. in one-half mile. Coming out of the Gulf Stream we probably left it at an angle as the temperature dropped irregularly from 13.0° to 4.0° C. in 5 miles. Curve No. 4 shows a temperature rise of 6° in 0.25 mile. At curve No. 16 the temperature rose very rapidly, taking less than 1.2 of a minute, which is 0.05 of a mile or less than 300 feet to rise from 7° to 10°. Also at No. 23 the temperature changed 4° in less than 1,000 feet.

Summary for June: Considerable change had taken place since May; the Gulf Stream water had pressed farther north hemming in

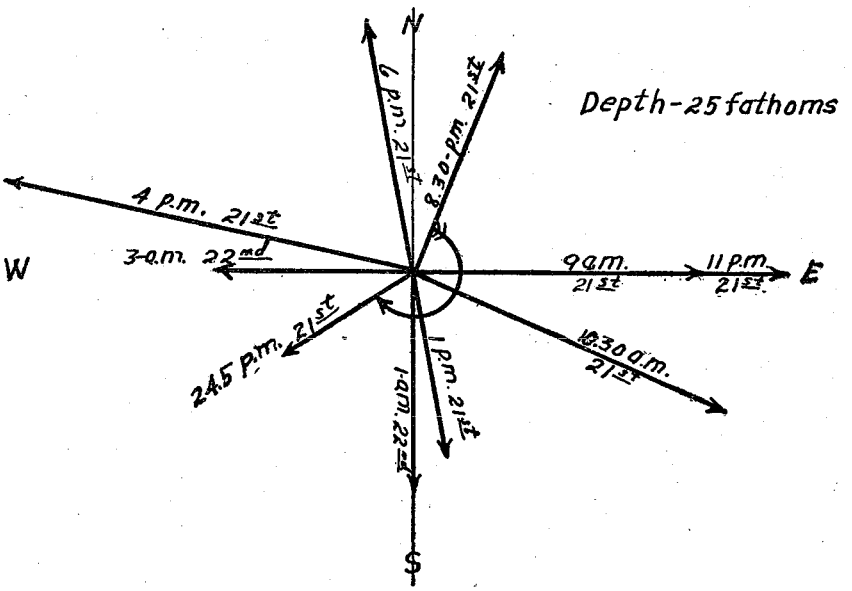


Figure 14e.

the Labrador current water and had also spread out toward the northwest. Due probably to the persistent NE. winds the Labrador current water was found quite far west of the southern end of the bank, and it seems that this fresh water had flowed onto the Gulf Stream and assumed the velocity of the latter after the NE. wind had lost its force.

The mean velocity of the surface water of the Gulf Stream, as shown by the drift of a derelict, was 0.9 of a mile per hour in an easterly direction. With persistent winds in the general direction of the stream the velocity was found to be about 1.6 miles per hour. Current meter measurements on the "tail" of the bank showed a definite tide effect, the maximum velocity being about 20 centimeters per second, repeating about every 14 hours.

CONCLUSIONS.

Large and rapid changes in the currents are constantly taking place due to differences of temperature and of salinity, to winds, tides, and other causes. Even with the mass of data taken it is extremely difficult to draw any accurate conclusions, as the area in the vicinity of the southern end of the Grand Bank is so complicated. However, the following general statements might be made:

1. The main body of the Gulf Stream has a rather steady flow eastward, the northern edge tends to press northward west of the Great Bank of Newfoundland, and is depressed southward at the southern end of the bank.

2. The Labrador current is more sluggish in its motion and hence largely affected by winds. At the southern end of the bank it spreads out, losing most of its velocity and seems to discontinue as a definite current. The extent of the Labrador current water to the westward and southward of the bank is variable; with persistent NE. and E. winds it may move quite far to the westward.

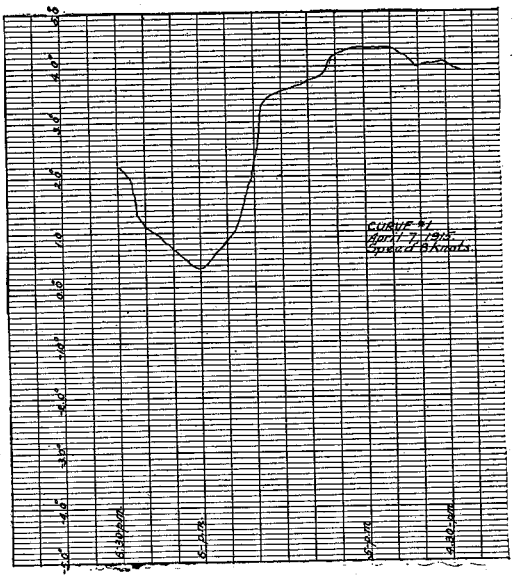
3. There seems to be no tendency of the Labrador current to flow under the Gulf Stream as the densities in situ of the two streams are nearly equal; in fact the Labrador current in June actually seems to have flowed onto the Gulf Stream.

4. On the southern end of the Great Bank of Newfoundland temperatures and salinities were found to be uniform from the surface to the bottom. A tidal effect was noted on the bank with a maximum velocity of 20 cm. per second, repeating in direction about every 14 hours.

5. A comparison between the temperatures of 1914 and 1915, shows that the locations of the Labrador current and Gulf Stream at the southern end of the Great Bank of Newfoundland, in corresponding months, are not the same but vary considerably from year to year.

CHARACTERISTIC CURVES OF TEMPERATURE CHANGES.

Locations indicated on Charts Nos. 1 and 3.



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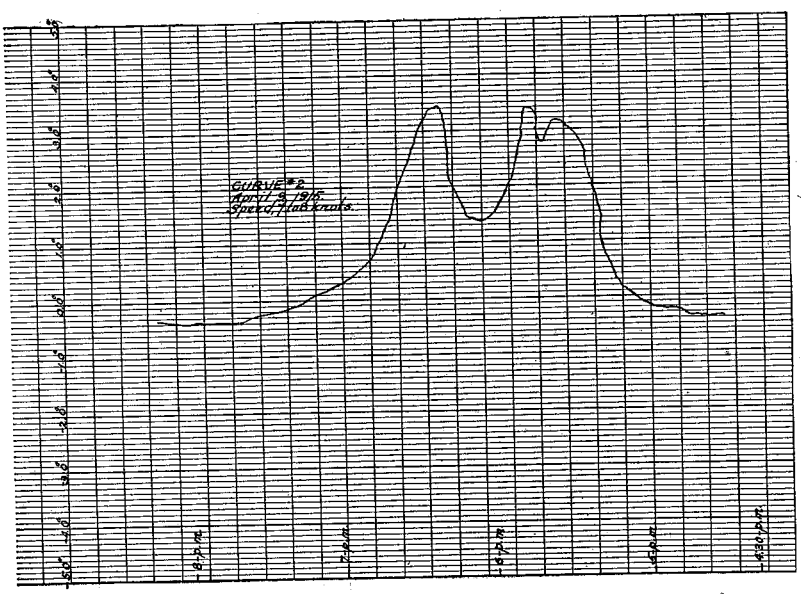

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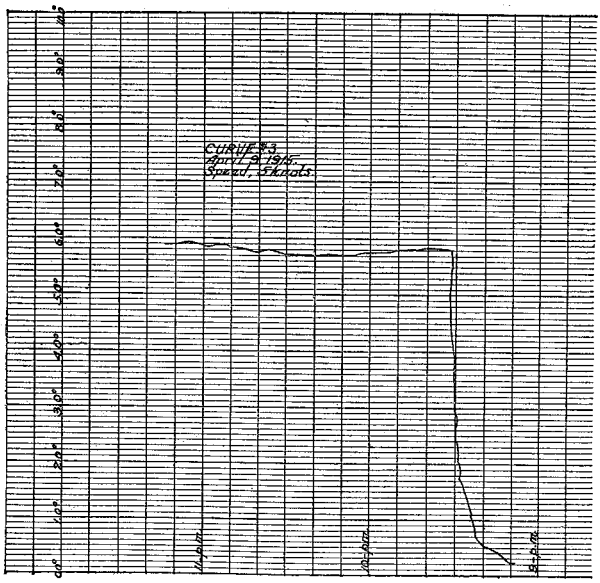

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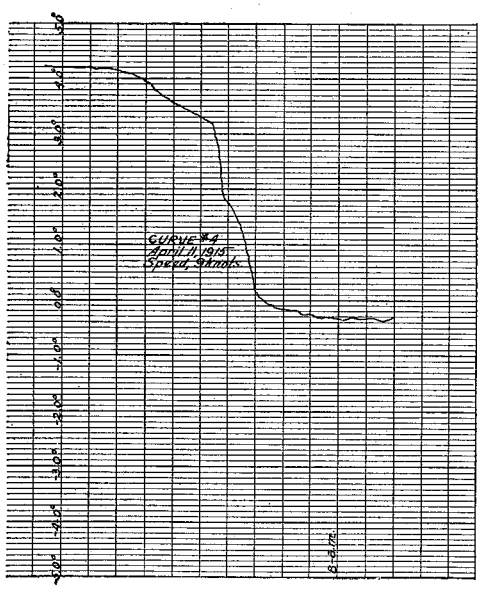

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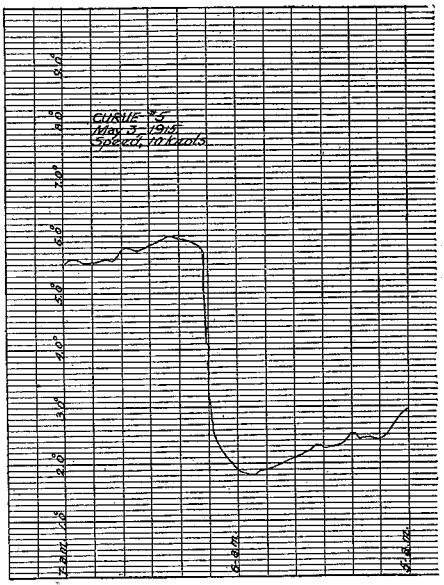

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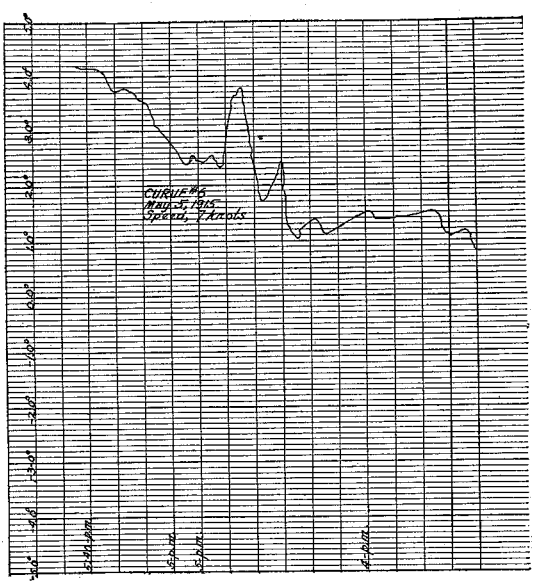

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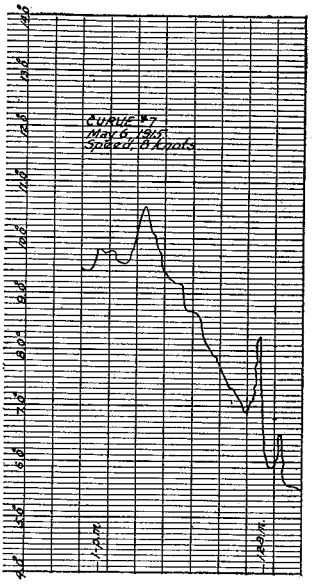

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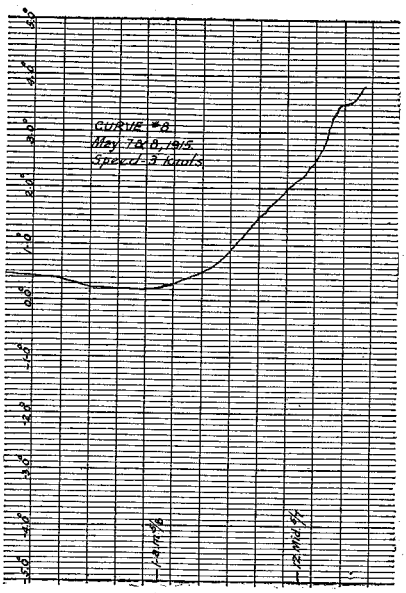

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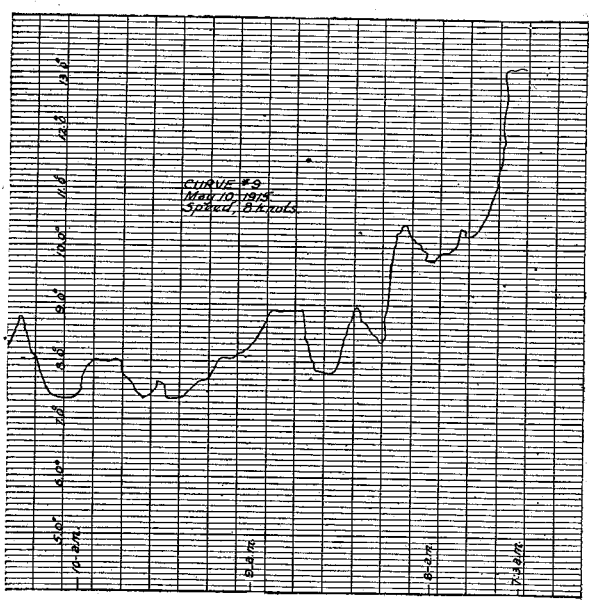

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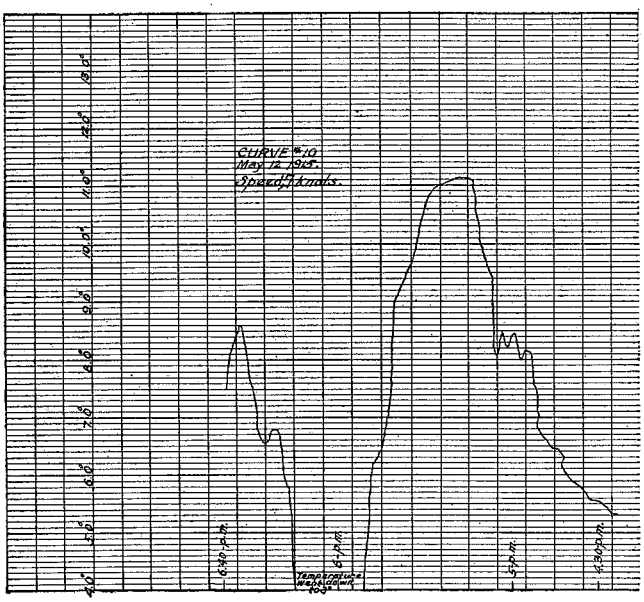

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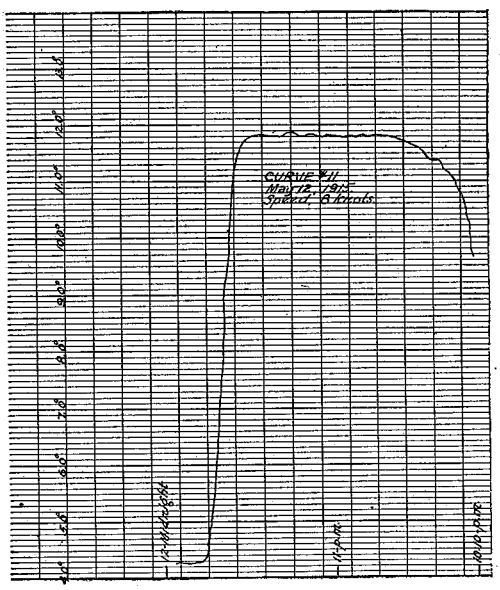

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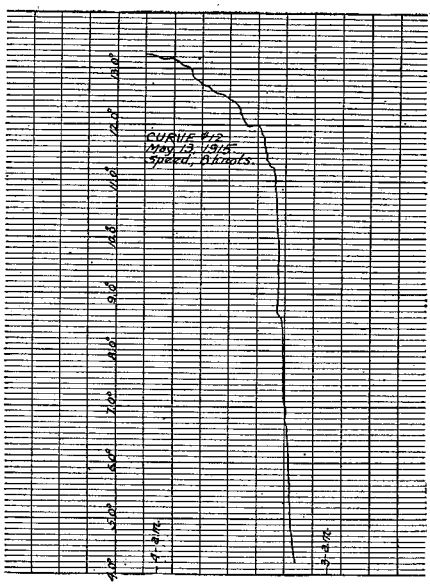

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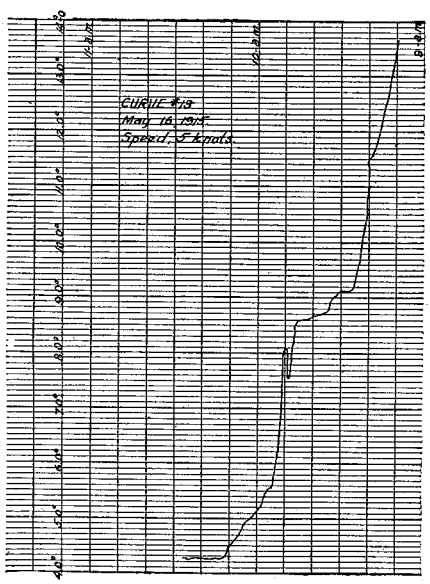

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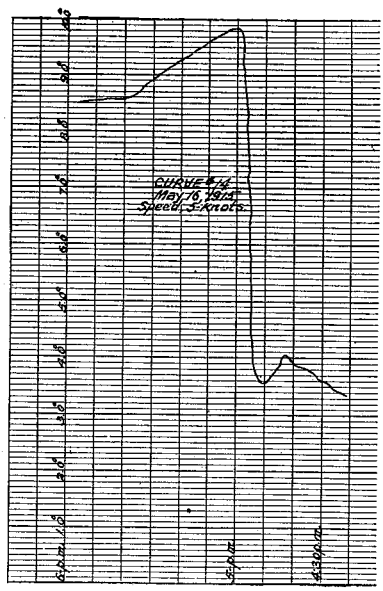

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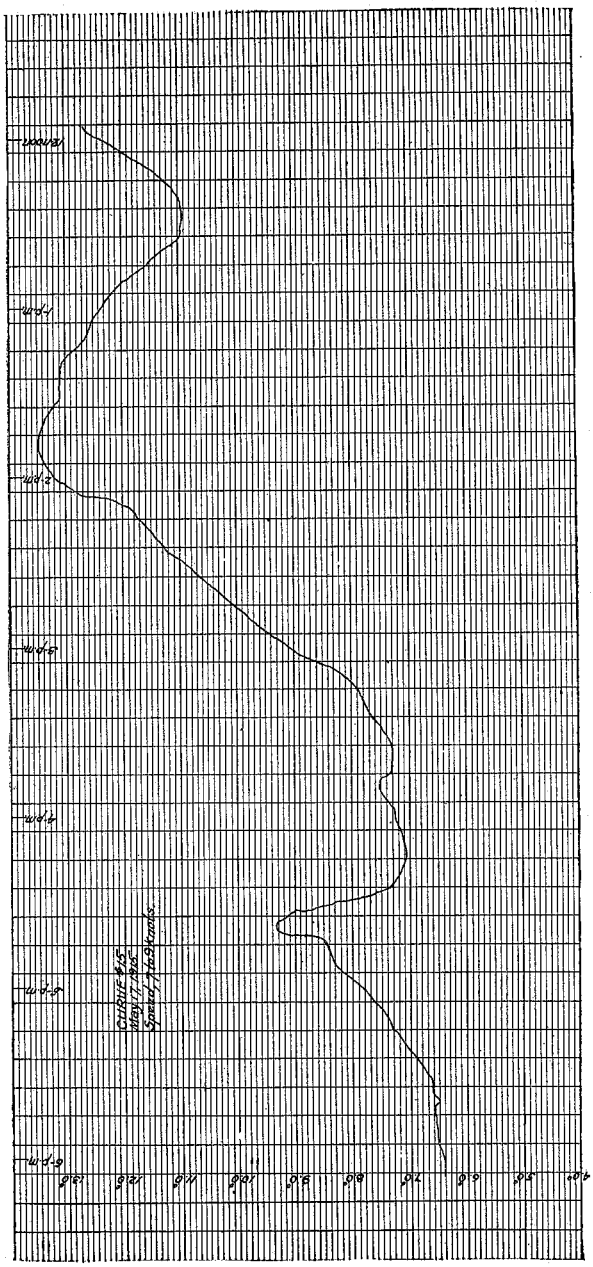
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Steering Pos.
Speed 12.8 knots
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7 p.m.
8 p.m.
9 p.m.
10 p.m.
11 p.m.
12 m.
1 a.m.
2 a.m.
3 a.m.
4 a.m.
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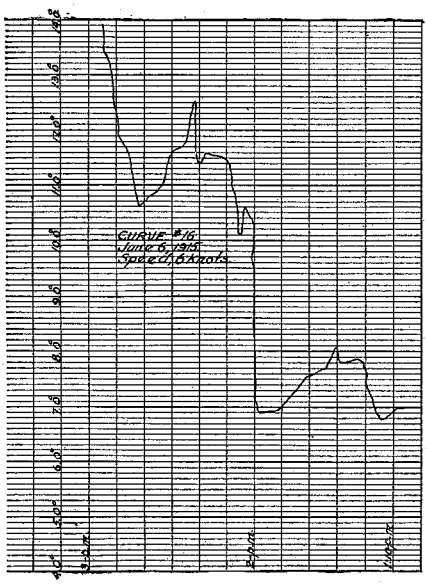
60°
50°
40°
30°
20°
10°

Curve 15.



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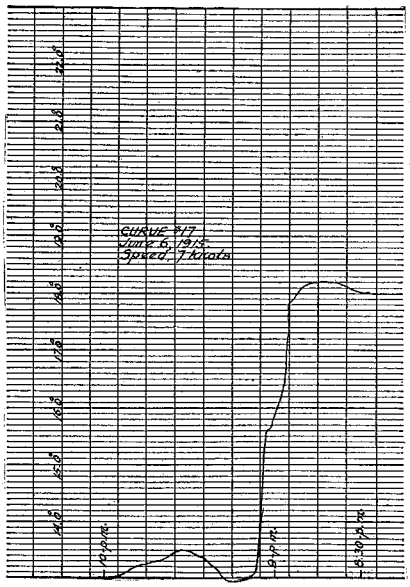

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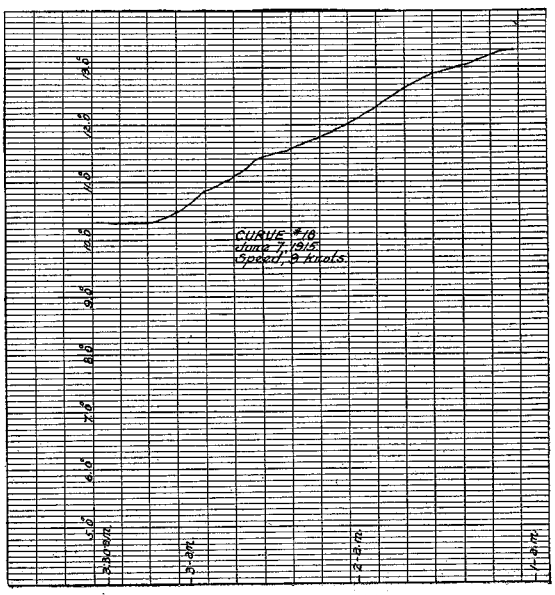

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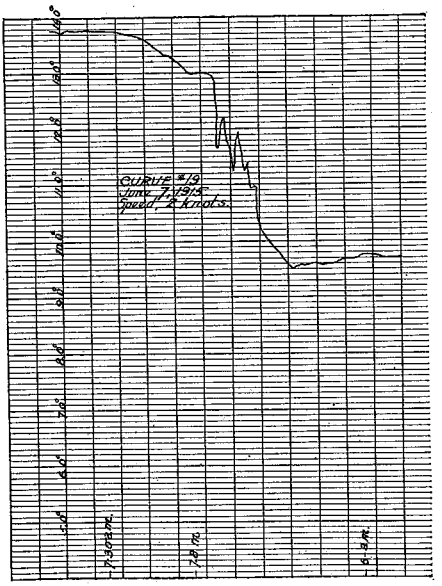

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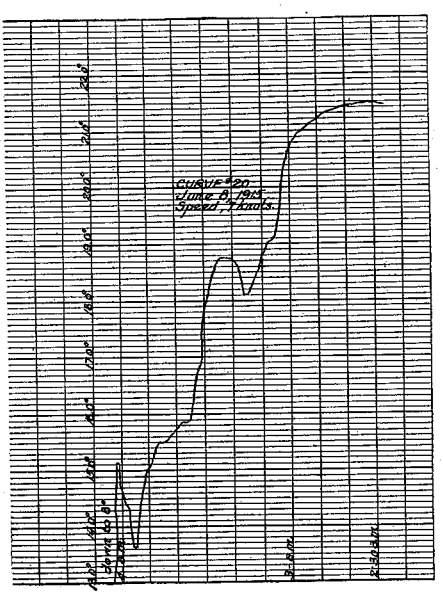

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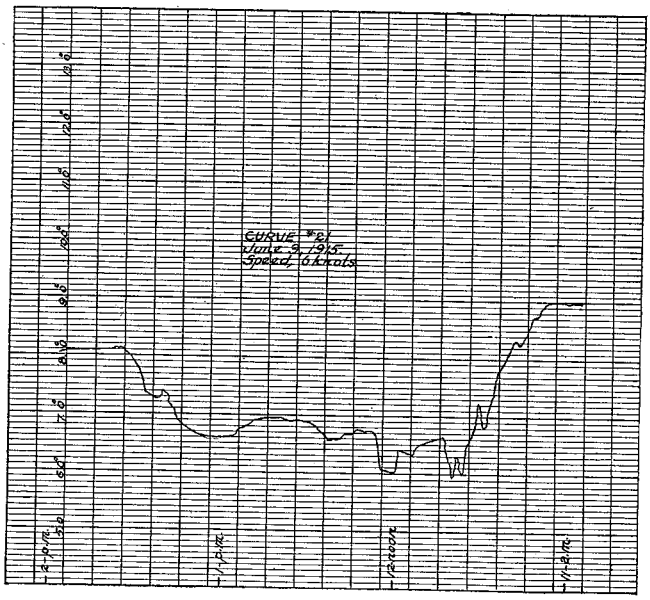

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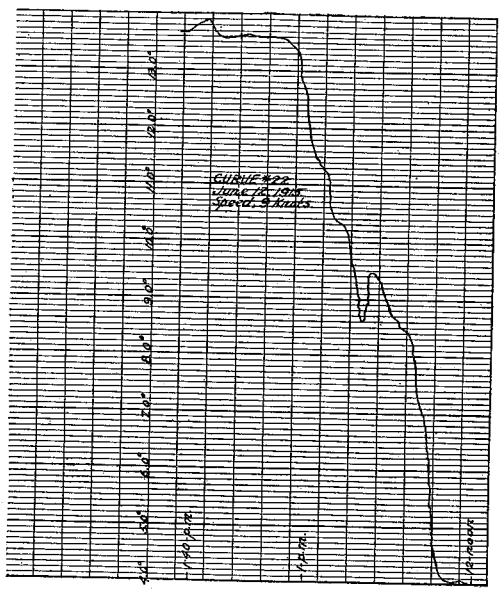

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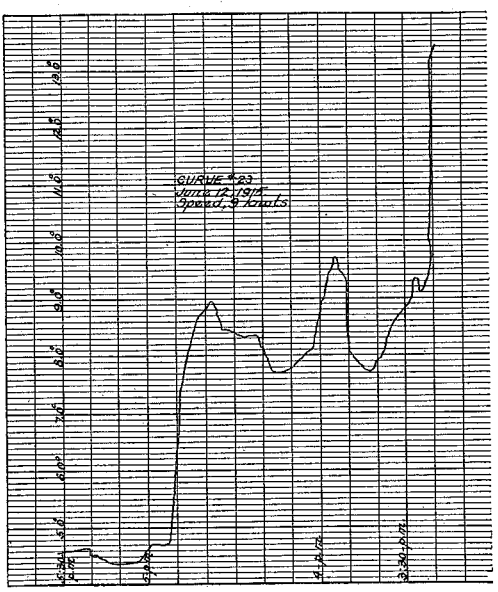

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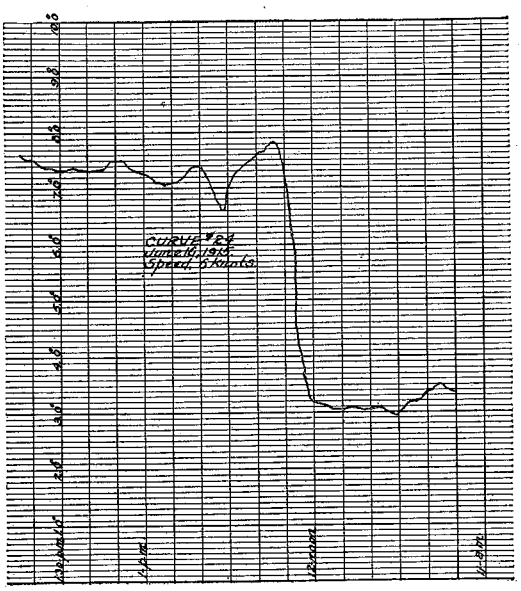

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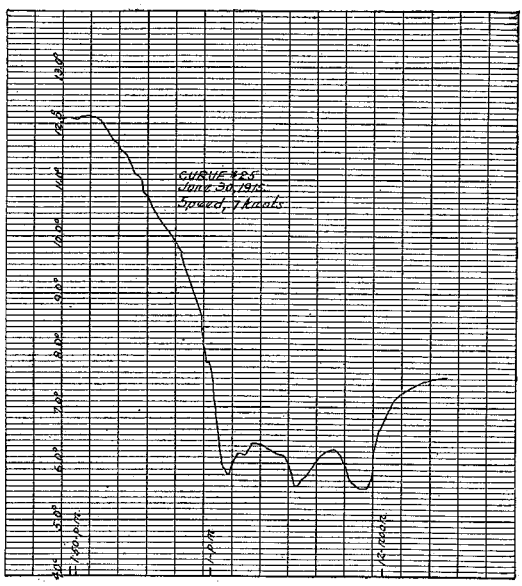

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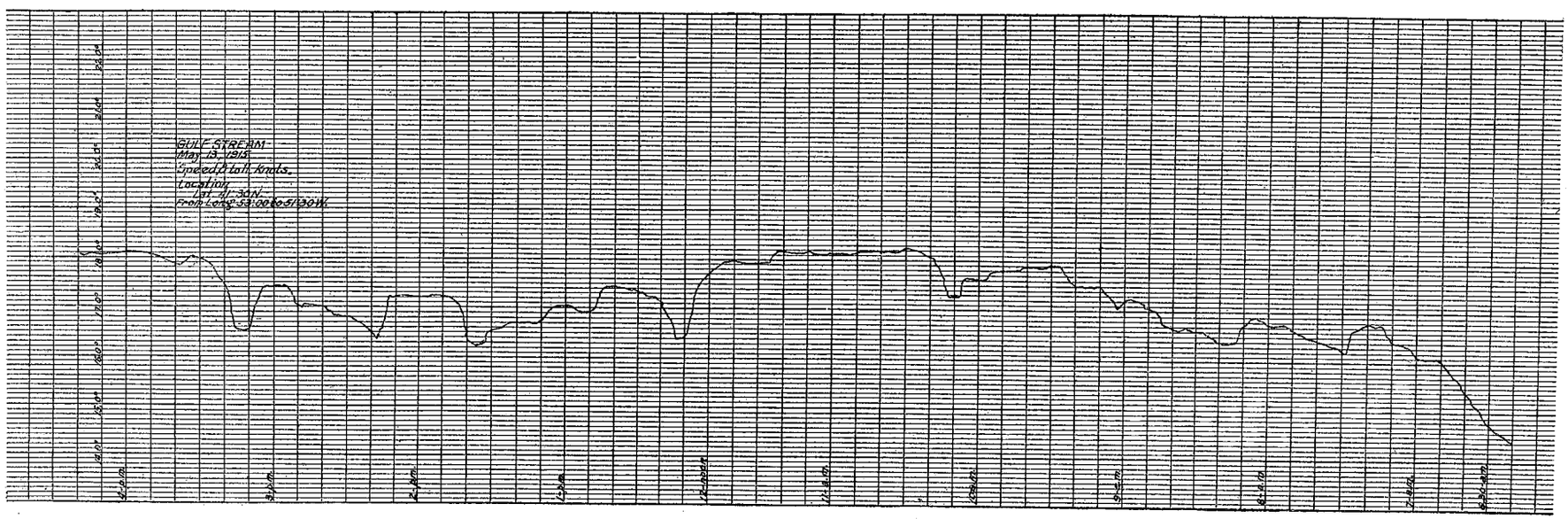
Curve 26.



Curve 27.

REPORT ON AN INVESTIGATION OF FOG IN THE VICINITY OF THE GRAND BANKS OF NEWFOUNDLAND, DONE ABOARD THE ICE PATROL CUTTER "SENECA" DURING THE MAY CRUISE OF 1915, BY THE BUREAU OF STANDARDS.

By P. V. WELLS and A. L. THURAS.[1]

INTRODUCTION.

Disaster has emphasized the importance of fog in relation to the safety of vessels at sea, and has justified including the study of fog in the scientific work of the ice patrol. In the performance of ice patrol duty, the *Seneca* sailed from Halifax, Nova Scotia, May 1, 1915, and for three weeks cruised about the southern end of the Grand Banks of Newfoundland and the near-by steamer lanes. This region of the North Atlantic is of great interest oceanographically and meteorologically, the meeting of the warm waters and winds over the Gulf Stream with the cold waters and winds over the Labrador current giving rise to a wide range of phenomena. Fogs are produced here in an abundance and variety which could hardly be duplicated elsewhere at sea.

The ice patrol, therefore, offers an exceptional opportunity not only for the study of fog at sea but for oceanographic research in general. Yet any scientific work attempted is subject to the limitations of practical sea conditions, and of the main purpose of the cruise, which is patrolling the ice fields.

The present report gives a brief description of a preliminary study of fog aboard the *Seneca* during the May cruise. A more complete treatment of the properties of fog, and a more detailed description of the methods of measurement employed and of the scientific results obtained, is reserved for a forthcoming scientific paper of the Bureau of Standards. Here the problem and the results are treated in a general way only.

THE GENERAL PROPERTIES OF FOG.

The word *fog* usually denotes a condition of the atmosphere such that vision is difficult at ordinary working distances. This condition is due to the scattering of light by suspended fog particles. At sea the particles are usually water drops, so small that they fall only very slowly. The air currents carry them about with much higher velocity so that they persist.

Nevertheless, the fog particles are essentially unstable. This is is of fundamental importance. They exist in a *critical region* of

[1] Delegated by Dr. S. W. Stratton, Director of the Bureau of Standards, to take scientific observations on the international ice patrol of the U. S. Coast Guard cutter *Seneca*.

atmospheric conditions, where *small* changes in one variable, such as temperature or pressure, are accompanied by *large* changes in the fog variables, such as size of particle, mass of liquid, and especially scattered light. Since the obstruction to vision depends upon the scattered light, small changes in the pressure or temperature may make enormous differences in our ability of seeing objects at a distance.

Because of the instability of fog, its study is attended with difficulty. Conditions producing the same phenomenon can only rarely be reproduced. Measurements must usually approach the instantaneous, as the quantities under observation are changing continuously. Moreover, the substance experimented with can not be brought back to its original state, so that the natural samples must be continually renewed. It is probably for this reason that the large body of scientific literature on fog which has already accumulated contains little quantitative information.

However perplexing and distressing to the mariner, fog is essentially a physical phenomenon, and all its various manifestations are but the result of changes in such properties as temperature and pressure, and can therefore be treated as a definite physical problem. It resolves itself to a consideration of a change of state occurring under special conditions.

The change of state is the condensation of water from a state of vapor to that of liquid. But it is different from ordinary condensation in that it takes place upon minute particles, sometimes called Aitken's "dust particles," or condensation nuclei. These nuclei are always present in the air in enormous numbers. Even pure air, removed from all pollution, has been found to contain more than 500 per cubic centimeter.

The "dust particles" of Aitken, or condensation nuclei, must not be confounded with the visible motes seen floating in the air whenever a sunbeam shines into a room. They are much too small to be visible even with the most powerful microscope. They form one class, the largest in size, of minute particles, the study of which has led to some of the most recent and profound advances of science. Sometimes some of them are charged, and are then called "large ions." They are formed in an infinite variety of ways, one of which is of great interest in connection with the source of nuclei over the ocean, namely, by the bursting of bubbles or by shattering jets of liquid. This immediately suggests the possibility of their formation from ocean spray. Barus has given this special type of nuclei the name "solutional nuclei." The impact of the wind on the waves blows off drops of spray into the air. If a drop evaporates before falling back into the water, a minute residue of salt remains suspended in the air as a solutional nucleus.

Whenever the air becomes sufficiently supersaturated with water vapor it condenses suddenly upon the nuclei in the form of fog or rain, if not too cold. The size of the drops formed depends upon the amount of water vapor which condenses and upon the number of nuclei among which this water is distributed. The number of nuclei per cubic centimeter is called the "nucleation." This number depends in no way upon the changes which cause the condensation, such as those of temperature and pressure.

The supersaturation, on the other hand, depends directly upon sudden expansion, or drop in pressure, and chilling, or drop in temperature. For instance, a moisture-laden warm wind from the Gulf Stream strikes the cold air over the Labrador current and is suddenly chilled, precipitating water upon the nuclei, forming fog. If the air had been chilled to a much lower temperature, much more water would have precipitated, and, as there would have been the same number of nuclei, larger drops, or rain, would have formed.

The mass of air is so large compared with the minute quantity of liquid water present in fog that a large proportion of this water can evaporate without causing much change in the temperature of the air. The fog is thus unstable.

WORK ATTEMPTED.

In a complete study of fog the physical, optical, electrical, and chemical properties should be included. For the practical purpose in view, that of increasing the safety of vessels at sea, the important properties are those which influence the optical effects of fog. The very fact, however, that the optical effects are most important is due to the great changes in these effects caused by very small changes in other properties. But this sensitiveness involves a study of the optical properties in difficulties.

The physical properties are evidently:

(1) The number of drops per unit volume.
(2) The size of the drops.
(3) The temperature.
(4) The pressure of the air around the drops.

These properties define its physical state.

It is evident that since fog at sea is nothing but the condensation of water vapor on nuclei, the nucleation—that is, the number of the nuclei per cubic centimeter—is also the number of fog particles per cubic centimeter. Moreover as the nuclei are present whether the fog exist or not, it is possible to obtain a continuous record of the nucleation, which gives the number of fog particles which would form if condensation occurred. The first physical property of the foggy atmosphere of which the measurement was attempted, was the nucleation.

The second physical property attacked was the size of the fog particle. If the amount of water present in a fog in the liquid state is known, since the number can be measured, the size of the fog particle can be calculated. The number of grams of liquid water per cubic meter, we have called the "liquid content" of the foggy atmosphere.

The remaining physical properties, the temperature and pressure, involved no difficulty and were needed in obtaining the first two. It was hoped to be able to measure an optical property of fog, the intensity of the scattered light, but the attempt was abandoned.

EXPERIMENTAL METHODS USED.

The "Corona" apparatus of Barus offered itself as the best method of measuring the nucleation. This method depends upon an optical principle. If a distant spot of light is viewed through a cloud of

particles of uniform size, around the source of light are seen brilliant colored rings or "coronas." Everyone has seen such rings around the moon or around street lamps at night. The angular diameter or aperture of these rings is determined by the size of the particles. The sample of air is admitted to the fog chamber; saturated with water vapor, suddenly expanded to precipitate water on the nuclei, forming an artificial fog. All the drops are of uniform size, and therefore give sharp coronas. The mass of water precipitated is computed from the amount of the expansion, and from this mass and the diameter of the drops the number of nuclei per cubic centimeter or the nucleation is calculated.

To measure the size of the fog particles, the first method that suggests itself is simply to get out a microscope and look at them. This, however, is involved in difficulties. Fog exists in a critical region. A slight change in the temperature changes the diameter of the drop by large amounts. A temperature rise of 2°, and the fog is gone. This is immediately evident at sea, where the ship is usually much warmer than the atmosphere, and over the deck the fog is thinner. One can not get close enough to the fog to use a microscope, and the size can not be measured directly.

The "liquid content" of the fog, that is the number of grams of liquid water per cubic meter of air, was measured by a humidity method. From the total amount of water present per cubic meter at one temperature, it is possible to calculate the state at another temperature. The fog is drawn into the apparatus through a wire grating which is electrically heated so that the drops evaporate. The humidity at this higher temperature is measured by a wet and dry bulb thermometer, from which the amount of liquid water at the original temperature of the fog is computed, assuming the water vapor to be saturated.

The pressure and temperature were obtained in several ways The temperature of the fog was carefully measured by holding a thermometer in various positions from the windward rail near the bow. The thermometer and barometer records of the ships' log and of the Weather Bureau's observer, Mr. C. W. Wood, were placed at our disposal, giving check readings for both temperature and pressure. Data from the ship's log for position, direction, and speed, wind direction and velocity, weather, and state of the sea, were also very useful in correlating nucleation with the climate. For the use of these records we wish to thank both the Weather Bureau and the Coast Guard.

RESULTS: NUCLEATION.

The corona apparatus designed and constructed at the bureau especially for this work was installed in the lower pilot house of the *Seneca*, with the pipe for admitting the atmosphere projecting about a meter from port hole toward the port bow. Thus when the ship was under way, and especially when the breeze was on the port side, an uncontaminated sample of the atmosphere was obtained. A northeast storm prevented working during the first five days of the cruise. The apparatus was then carefully tested and found to work satisfactorily at sea, and thereafter three determinations of the nucleation were made daily.

Each determination consisted of from ten to twenty successive corona observations, made after the air in the apparatus had been filtered until dust-free, and brought to equilibrium so that successive coronas checked. The values of the nucleation are plotted in figure 3. The precision is better than 15 per cent, except in two or three cases where it is better than 25 per cent.

The striking facts brought out by these results are (1) the remarkable uniformity of the nucleation; that is, number of nuclei per cubic centimeter, during most of the time, for the values remain between 500 and 3,000 for over 11 out of 15 days; (2) the nucleation three times rises rapidly to values about 50,000, and as suddenly falls again to its normal value, the whole excursion occupying about a day only; (3) the normal value is about 1,000 nuclei per c. c. and (4) the nucleation at sea is very small compared with the values in the harbor which were about 150,000. The peaks in this curve immediately suggest contamination, but on scrutinizing the direction of the wind and its velocity, in the first case, port beam, about 5, Beaufort scale,

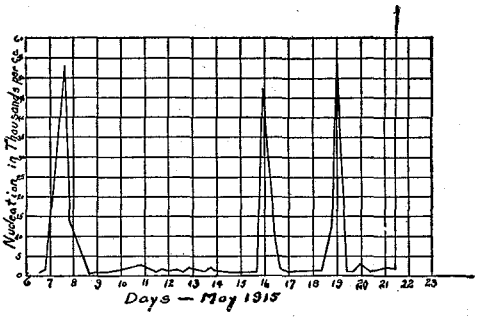


Figure 3 (fog).

in the second, slightly forward of port beam, 4 Beaufort scale, and in the third case, astern, 4 Beaufort scale, are found. Contamination seems impossible in the first two cases, but the third is doubtful. It is included, although no weight will be given to it.

In order to show the relation of the nucleation to the other atmospheric conditions, figure 4 is given. To bring the nucleation curve to the proper scale, its logarithm is plotted. Exact relations are, of course, not expected, but there is a fairly definite indication that each marked cyclonic period is accompanied by a peak in the nucleation curve. The inference is that the nucleation of the atmosphere removed from the effects of the sea is about 1,000, the nucleation near the surface of the sea nearer 50,000. The effect of storms seems to be to increase the nucleation. This would be the case if the nuclei were evaporated salt particles from ocean spray. The results are in agreement with the ideas and observations of Aitken and Barus.

RESULTS: LIQUID CONTENT.

The measurement of the liquid content of the foggy atmosphere; that is, the number of grams of liquid water per cubic meter, revealed the surprising fact that there are very few fogs which contain more than a very minute quantity of liquid at all. In the thickest fog

encountered, only 8 per cent of the water in the atmosphere was in the liquid form. This fact limits very seriously the measurement of the liquid content, for unless a method is used which measures the liquid content directly, and not the total water content, the error in the liquid content is at least ten times the error in the total content, and if the latter is measured to 1 per cent the liquid content is measured only to 10 per cent.

During the May cruise one determination was obtained. This was at about 9 p. m. on May 9, during an exceedingly thick fog. It seemed the thickest fog of the cruise. The ship's log states "dense fog; rain."

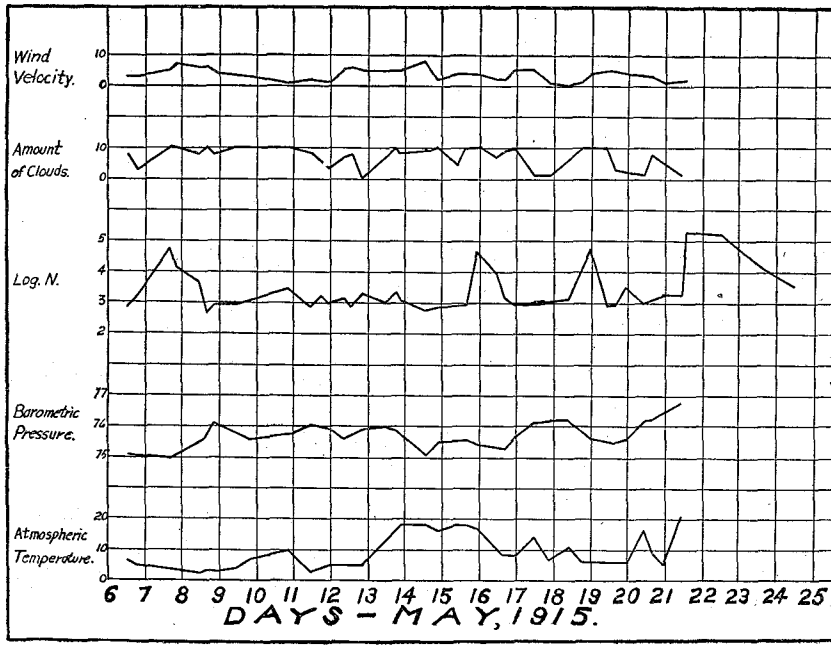


Figure 4 (fog).

Five runs were made, varying the speed of the air past the wet and dry bulb thermometers, and the current through the wires used to evaporate the fog. Each run consisted of a series of alternate readings of the wet and dry thermometers, eight on each. From the mean of these readings the values of the total water content given in column 2 of the table, were computed. In column 3 are given the deviations of each value from the mean. Assuming the water vapor to be saturated in the fog, the vapor content, at the temperature of the fog, 6.6° C. is 7.51 grams per cubic meter. Subtracting this from the values in column 2, the values of the liquid content in column 4 are obtained. The table shows that even with this very dense fog, and with humidity measurements as good as can be obtained (1.1 per cent), the liquid content can be determined to 15 per cent only. Two determinations were made on the June cruise, the mean values obtained being given in the table:

Date.	Total water content (grams per cubic meter).	Deviation.	Liquid content (grams per cubic meter).
1915.			
May 9, 9 p. m	8.21	0.08	0.70
	8.01	.12	.50
	8.10	.03	.59
	8.27	.14	.76
	8.05	.08	.54
Mean	8.13± 1.1%	.09	0.62±.09 15%
June 9:			
Mean	10.62± 1.8%	.19	.17±.19 110%
11 a. m			
June 24	10.14± 1.4%	.14	.39±.14 36%
A. m			

On June 9 the fog was recorded rather light; on June 24 a dense fog. The liquid content was less in each case than on May 9.

The nucleation on May 9 at 9 p. m. was 1,200 per c. c. Hence the diameter of the fog particles was 0.0010 c. m., or 10 microns. This value has a precision of better than 9 per cent.

To gain some idea of the order of magnitude of the quantities involved in this dense fog, assume that one can not see beyond 100 feet. A block of fog 3 feet wide, 6 feet high, and 100 feet long contains less than one-seventh of a glass of liquid water. This water is distributed among 60 billion drops.

The temperature at the top of the mast was measured simultaneously with the liquid content on May 9. The temperature was 9.1° C., or 2.5° above that on deck. Now, a rise of 1.2° C. would have entirely dispelled this fog. Hence it is hard to imagine how fog could possibly exist at the top of the mast if the air there contained the same total water content as that on deck. Nor is this phenomenon uncommon. The observations of the Weather Bureau consistently showed strong temperature inversion above the Labrador current, and the observations of the past year's cruise have usually shown (during fog) a temperature from 1° to 5° C. higher at the top of the mast than on deck. It is therefore reasonable to suppose that fogs over the Labrador current are low lying and rarely extend far above the surface of the sea.

The existence of low-lying fog is in agreement with the accepted theory of fog formation over the sea, namely, the slow mixing of masses of air at different temperatures. The existence of masses of air of different temperatures is considered to be due chiefly to the differing temperatures of the bodies of water over which they pass.

If fog over cold water does not usually extend as high as the mast of most vessels, a method is immediately suggested which should be of consequence in navigation, for it should be possible for an observer on the masthead of one ship to see a flag or a powerful light on the masthead of a near-by ship.

It is interesting to calculate roughly the energy or heat necessary to dissipate fog. The result shows immediately that no earthly radiator, such as a combination of arc lamps, could radiate enough energy to dissipate the fog in front of a ship sufficiently to be of practical use in navigation.

The sun, however, is a much more powerful radiator. Assuming, from Abbot's results on solar radiation, that 1.4 calories strike each square cm. per minute, and that 65 per cent is reflected back again, 0.49 calories are absorbed. This quantity of heat is sufficient to dissipate the fog throughout a depth of 7 meters, if the fog particles in this depth could absorb all the radiation. Even if this radiation were not all absorbed in the first 7 meters, but were nevertheless all absorbed in a thickness of 50 meters, the fog in this thickness would evaporate in 7 minutes in overhead sunshine. The general conclusion from this estimation is that the upper surface of a fog bank is continuously evaporating in the sunshine at a rapid rate and that the fog bank would probably disappear entirely were it not forming as fast as it disappeared. This point is of great interest, explaining many of the curious transient phenomena observed in fog.

The authors desire to express their indebtedness to the commanding officer, Capt. F. A. Levis, and to the officers of the *Seneca* for their assistance and interest in the work and to Prof. C. Barus for his kind advice, criticism, and encouragement.

SUMMARY.

The results of this preliminary attempt to study fog at sea are these:

1. Only small energy changes cause fog and are sufficient to dispel them.
2. The mass of liquid water present in the densest fogs is very minute, less than a gram per cubic meter.
3. The size of the fog particles is just about the limit of visibility with the naked eye.
4. As the nucleations are the smallest that have been obtained, the air measured was probably the natural atmosphere in its purest state. This atmosphere never contained less than 400 and averaged 1,000 per cubic centimeter.
5. The nucleation at the surface of the sea in cyclonic areas, probably due to the nuclei produced from the action of the wind on the waves, sometime rises as high as 50,000, but is usually nearer 1,000.

PRELIMINARY REPORT ON OCEANOGRAPHIC OBSERVATIONS CONDUCTED ON THE UNITED STATES COAST GUARD CUTTER "SENECA" IN 1915.

During the spring of 1915, as during the cruises of the preceding year, oceanographic observations were conducted with the cooperation of the United States Bureau of Fisheries. This phase of investigation embraced the determination of the temperature, salinity and density of the water at various depths, and the collection of plankton by means of townets. A small beam trawl was also used for the collection of bottom forms.

Observations at 27 stations were conducted by Mr. Harold W. Nightingale, of the Bureau of Fisheries. The positions of these stations are shown on the ice and current chart of the *Seneca* report.

The results of the studies of the plankton and bottom collections are expected to be embodied in special reports. The hydrographic data will also be analyzed and discussed at a later time in connection with the results of subsequent investigations. Meantime the hydrographic records are presented in the following table. In one or two instances the records appear abnormal. With the limited data available, it is impossible to determine if the aberrancy is attributable to an overlapping of conflicting currents or to defective operation of an instrument.

The instruments and methods were identical with those used during the past season and described in the report for 1914. For convenience of reference, the description is here repeated.

INSTRUMENTS AND METHODS.

Serial temperatures and water samples were taken at each station by the use of Eckman reversing water bottles with reversing thermometers attached. These were secured at intervals to a wire cable and tripped by messengers.

As a rule the results were satisfactory, but at times the Eckman bottles failed to operate when used in a high sea. The water samples obtained were preserved in citrate of magnesia bottles and determinations of salinity were subsequently made by titration at the Bureau of Fisheries. The titration of the samples and determinations of salinity and density were made by Mr. Harold W. Nightingale.

Collections of plankton were made at each station by the use of townets of various types, sizes, and mesh. Small nets of No. 20 bolting silk were employed to take the microplanktonic forms, and larger nets 1 meter in diameter and of coarser mesh were used for macroplankton. A sheerboard or Helgoland net was used for deeper towing. A small beam trawl, 3-foot beam, was used for the collection of bottom fauna.

The densities given in the following table are expressed in an abbreviated form. The actual densities are 1.02601, 1.02695, 1.02735, etc.

Stations taken by U. S. Coast Guard cut

Station No.	Date.	Time of day.	Position. Lat. N.	Position. Long. W.	Depth in fathoms.	Bottom. Character.	Bottom. Sample.	Water, physical data. Depth.	Temperature.	Salinity.	Density.
			° ′ ″	° ′ ″				*Fathoms.*	° C.		
1	Apr. 2	7–8 a. m.	43 29 30	59 58 30	219	.....	.....	0	0.6	32.41	26.01
								50	6.9	34.36	26.95
								100	6.9	34.87	27.35
								150	5.1	34.33	27.15
								175	.....	.....	.....
2	do	4–5 p. m.	43 35	58 27 30	1,680	.....	.....	0	5.0	33.24	26.31
								50	4.4	33.98	26.96
								150	4.4	34.69	27.51
								250	4.1	34.90	27.72
								300	1.1	.....	.....
3	Apr. 3	10–11 a. m.	43 42	54 58	2,000	.....	.....	0	6.1	33.58	26.45
								50	7.4	34.51	27.00
								150	4.55	34.51	27.36
								250	4.6	34.16	27.08
								350	10.05	34.87	26.85
4	Apr. 7	8.30–9.30 a. m.	43 47	49 13	130	.....	.....	0	0.0	33.24	26.71
								25	− .55	33.24	26.73
								50	− .65	33.26	26.74
								75	−1.05	33.51	26.97
								125	0.45	33.89	27.21
5	Apr. 8	9–11 a. m.	44 47	49 13	38	Hard	Shells.	0	0.0	33.08	26.58
								10	0.0	33.08	26.58
								20	−0.4	33.24	26.72
								30	0.0	33.10	26.59
								35	0.05	33.10	26.59
6	Apr. 10	7–8 p. m.	43 49	49 41	27	do	.....	0	0.8	32.99	26.47
								5	0.8	33.19	26.63
								15	0.6	33.19	26.64
								25	0.65	32.97	26.46
7	Apr. 11	1–2 p. m.	43 46 30	47 55	2,000	.....	.....	0	5.5	33.22	26.24
								50	5.4	34.47	27.23
								100	3.8	34.33	27.29
								200	4.4	34.16	27.10
								400	3.7	35.07	27.89
8	Apr. 12	1–2 p. m.	43 25	49 39	30	do	Shells.	0	1.7	33.28	26.64
								10	0.2	33.19	26.66
								20	0.15	33.21	26.68
								30	0.05	33.21	26.68
9	Apr. 13	10–11 a. m.	43 25	49 39	30	do	do	0	0.85	33.12	26.57
								2	0.3	.....	.....
								10	0.0	33.19	26.67
								20	−0.1	33.28	26.74
								30	−0.2	33.28	26.75
								0	0.85	.....	.....
								2	0.3	.....	.....
								10	−.05	.....	.....
								20	−.15	.....	.....
								30	−0.2	.....	.....
10	Apr. 14	1–2 p. m.	43 27	49 41	32	do	do	0	0.8	33.19	26.63
								10	0.45	33.28	26.72
								20	0.15	33.30	26.74
								30	0.1	33.30	26.75
11	Apr. 16	2–3 p. m.	44	51	36	do	do	0	2.7	33.01	26.35
								10	2.7	33.01	26.35
								15	1.35	.....	.....
								20	0.8	33.01	26.48
								30	0.7	.....	.....
								35	1.0	.....	.....
12	Apr. 17	9–10 a. m.	44 35	57	216	.....	.....	0	1.0	.....	.....
								25	1.2	.....	.....
								50	1.0	32.65	26.18
								100	4.3	32.83	26.06
								150	4.0	32.72	26.01
13	May 4	10–11 a. m.	43 41	51 24	30	Hard S	Shells.	0	2.5	33.10	26.43
								10	3.0	33.08	26.38
								20	3.1	33.08	26.37
								30	2.6	33.10	26.42
14	do	6.45–8 p. m.	43 19	50 10	30	.....	.....	0	3.0	33.12	26.41
								10	2.7	33.19	26.49
								30	2.5	33.98	27.14
15	May 6	1.30 – 2.30 p. m.	41 54	49 25	1,800 to 1,900	.....	.....	0	5.4	33.80	26.70
								25	4.85	34.87	27.61
								100	4.05	.....	.....
								200	6.1	33.98	26.76
								400	4.5	34.78	27.58

ter "Seneca" during April and May, 1915.

Nets.				Currents.			Remarks.
Description.	Fathoms.	Time.	Speed.	Fathoms.	Flow.	Knots.	
		Minutes.				*Hour.*	
No. 20	0	30					Station No. 1 taken near SE edge of Sable Island bank, on run to tail of Great Bank.
No. 3	10	430					
Stramin	40	30					
No. 20	0	30					Plankton scanty.
No. 3	20	30					
Stramin	50	30					
Helgoland	50	30					
No. 3	20	30					
Stramin	70	30					
No. 20	0	30					Plankton abundant.
No. 3	20	30					
No. 20	10	30					
Stramin	50	30					
Helgoland	100	30					
Beam Trawl	35	30					Bottom fauna abundant.
No. 3	20	30					S=sand.
No. 20	0	30					
No. 20	10	30					
No. 3	20	30					
Beam Trawl	27	30					
No. 20	0	30					
No. 20	10	30					
No. 3	20	30					
Stramin	175	30					
No. 20	0	30					Plankton abundant.
No. 20	10	30					
No. 3	20	30					
Stramin	20	30					
							Trial No. 1.
							Trial No. 2, 15 minutes later.
No. 20	0	30					Tidal current.
No. 20	10	30		0	NE.-SE.		
No. 20	0	30					Haddock caught at this station.
No. 20	10	30					
No. 3	20	30					
B. trawl	20	30					
No. 3	20	30					
Stramin	70	30					
							Diatoms abundant.
No. 20	0	30					
No. 20	0	30					
							Plankton very abundant, diatoms, copepods, chætognaths.
No. 20	0	30					
No. 3	10	30					
No. 20	20	30					

Stations taken by U. S. Coast Guard cutter

Station No.	Date.	Time of day.	Position.		Depth in fathoms.	Bottom.		Water, physical data.			
			Lat. N.	Long. W.		Character.	Sample.	Depth.	Temperature.	Salinity.	Density.
			° ′	° ′				*Fathoms.*	° C.		
16	May 9	10.25–11.20 a. m.	42 31	52 30	1,800	.....	.....	0	1.4	33.19	26.59
								25	3.1	.....	.....
								50	4.2	33.96	26.96
								100	6.15	34.47	27.14
								200	6.95	33.13	25.98
17	...do....	3–4 p. m...	42 31	52 31	1,800	.....	.....	0	10.0	35.03	27.00
								100	5.2	35.05	27.71
								300	3.2	34.42	27.42
18	May 10	1.30 – 2.30 p. m.	42 34	51 36	1,420	.....	.....	0	10.0	34.42	26.51
								50	11.8	35.48	27.01
								100	10.3	34.45	26.49
								200	6.8	34.33	26.93
								400	3.55	34.87	27.75
19	May 11	2.30 – 3.30 p. m.	42 31	49 01	1,000	.....	.....	0	3.9	33.46	26.62
								50	3.05	34.29	27.33
								100	3.15	34.31	27.34
								200	4.5	34.92	27.69
								400	3.9	34.96	27.78
20	May 12	8–8.35 p. m.	42 17	48 48	2,000	.....	.....	0	5.0	.....	.....

Stations taken by U. S. Coast Guard

			° ′	° ′				*Fathoms.*	°*C.*		
21	May 17	8–8.15 a. m.	42 25	54 1	2,680	.....	.....	0	12.7	35.82	27.11
								25	13.0	35.73	26.98
								50	13.9	35.75	26.81
22	...do.....	6–6.15 p. m.	42 42	54 51	2,000	.....	.....	0	10.0	33.22	25.60
								50	7.15	34.42	26.95
								100	6.2	34.65	27.27
23	May 18	7–7.30 a. m.	43 1	56 4	1,800	.....	.....	0	7.2	33.71	26.40
								50	4.25	34.51	27.39
								100	4.05	34.33	27.27
								200	4.95	33.62	26.62
								400	5.8	33.66	26.54
24	May 19	8–8.13 a. m.	43 24	59 17	1,000	.....	.....	0	2.8	32.03	25.56
								50	4.6	33.66	26.67
								100	6.8	34.54	27.09
25	...do.....	6–6.15 p. m.	43 38	60 21	35	.....	.....	0	3.3	32.25	25.69
								10	3.5	32.39	25.79
								20	3.95	32.56	25.88
								30	2.4	32.57	26.02
26	May 20	8–8.15 a. m.	44 6	61 43	88	.....	.....	0	4.45	32.05	25.42
								15	4.2	32.12	25.51
								45	3.15	33.96	27.07
								85	2.0	32.92	26.33
27	...do.....	6–6.20 p. m.	44 21	62 49	80	.....	.....	0	4.45	.....	.....
								25	2.0	31.76	25.41
								50	1.3	31.24	25.03
								85	0.3	.....	.....

"Seneca" during April and May, 1915—Continued.

Nets.				Currents.			Remarks.
Description.	Fathoms.	Time.	Speed.	Fathoms.	Flow.	Knots.	
		Minutes.				*Hour.*	
No. 20	0	30					Plankton abundant.
No. 20	20	30					
No. 3	10	30					
Stramin	50	30					
No. 20	0	30					Copepods abundant in plankton.
No. 3	10	30					
No. 20	20	30					
No. 20	0	30					Plankton abundant.
No. 3	10	30					
No. 20	20	30					
Stramin	200	30					
No. 3	0	30					Rough weather.

cutter "Seneca" during May, 1915.

		Minutes.				*Hour.*	
No. 20	0	15					Stations 21–27 taken on run to Halifax with derelict in tow.
No. 3	10	15					
No. 3	0						
No. 20	0	30					
							No hauls at Stations 24–27.
							Diatoms abundant in filtered surface water.
							Plankton scarce.

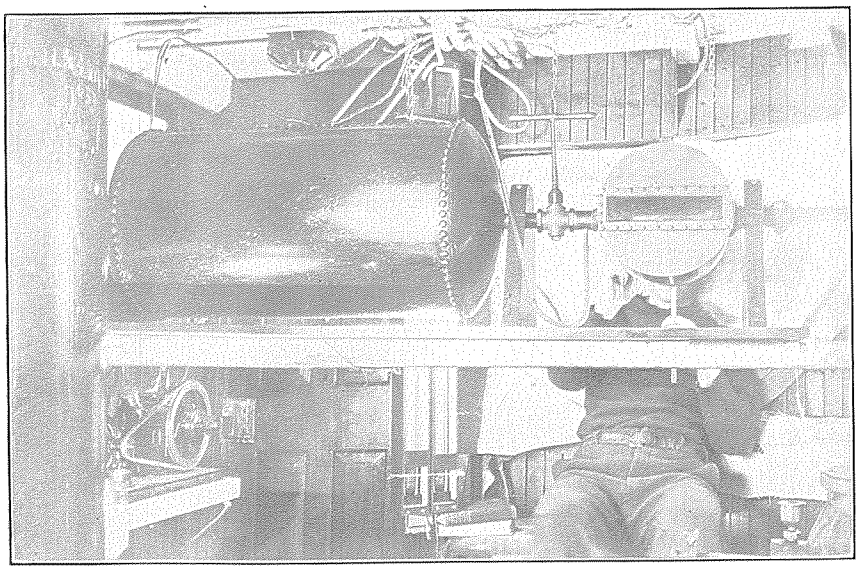


FIG. 1 (FOG).—THE "CORONA" APPARATUS FOR MEASURING NUCLEATION.

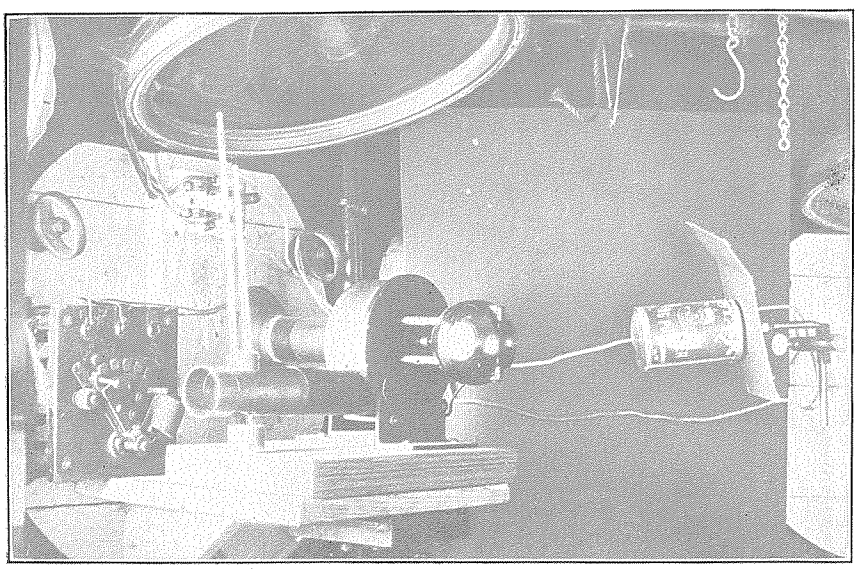


FIG. 2 (FOG).—METER FOR MEASURING THE LIQUID CONTENT OF FOG.