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INSTRUCTIONS FOR USE

Change 1 to Pub. 607, Instruction Manual for Obtaining Oceanographic Data, 3d edition, 1968 consists of change pages and additional pages listed below:

Table of Contents	V—XIV
Chapter B	B–1, B–2
Chapter C	C–1—C–4
	C–9—C–13
Chapter I	I–15, I–16
Chapter L	L–21—L–27
Chapter M	M–1—M–24

Substitute change pages and insert new pages in basic manual, as indicated by chapter and page number.

Change 1 will be distributed automatically to the original distribution list only. Holders of all other copies of the basic manual will be required to request issue or to purchase the 1970 changes and additions.

TABLE OF CONTENTS

Chapter	Page

Chapter	Page

M. CURRENT MEASUREMENTS—Continued

LIST OF ILLUSTRATIONS

TABLES

CHAPTER B

METEOROLOGICAL, SEA AND SWELL, AND SPECIAL OBSERVATIONS

B–1 General.—The interaction of sea and air is extremely important in the studies of various oceanographic problems. Almost all oceanographic observations must be accompanied with simultaneous meteorological and sea surface observations. Spaces for such observations usually are provided on oceanographic log sheets, and codes and tables to assist in recording these observations are included in this chapter.

An oceanographic observer must be able to take and record marine meteorological observations that are called for by the various log sheets. The tables and methods used in this chapter are adapted from manuals used by the U.S. Weather Bureau for recording marine meteorological observations.

B–2 Types of Meteorological and Sea and Swell Observations.—The types of meteorological and sea and swell observations required with the oceanographic log sheets include: Weather, cloud type and amount, visibility, wind speed and direction, dry- and wet-bulb air temperatures, barometric pressure, and wind wave (sea) and swell. On certain surveys, other meteorological and/or sea surface measurements are required, and these are obtained with special instruments. For example, solar radiation studies are made with data recorded by the pyrheliometer. Also, precise temperature measurements taken and recorded simultaneously at different levels on the ship are made with a temperature-lapse-rate indicator. Such measurements are valuable in explaining varying conditions in the upper layers of the ocean. Much of the information that follows has been extracted from Weather Bureau manuals. For a more comprehensive discussion of instructions, reference should be made to Weather Bureau Observing Handbook No. 1, Marine Surface Observations, 1st Edition 1969 and the World Meteorological Organization Cloud Atlas.

B–3 Weather.—Table B–1 is used to indicate and record on the A-Sheet (see ch. E) the state of the weather at the time of observation. The 100 descriptive terms include most weather phenomena that will be encountered. *Code figures should not be used to record weather on the A-Sheet.* If a code figure is used to describe a weather condition in reporting or recording any observation, the code designation must be plainly indicated on all log sheets and rigorously adhered to; otherwise, the data are of no value. Terms selected should describe the weather at the time of observation or during the preceding hour. Neither when selecting the general description nor in determining the complete description of the weather must account be taken of weather phenomena which occurred more than 1 hour preceding the observation time.

B–4 Clouds.—The type of the significant cloud layer should be recorded on the A-Sheet using the descriptions given in table B–2 and figures B–1 through B–26. If fragments of a cloud layer (i.e., covering less than $1/10$ of the sky) are observed under a cloud layer covering $1/10$ or more of the sky with bases below 8000 feet, the fragments will be disregarded. The height of the cloud is the distance from sea level to the base of the cloud. The amount of total cloud cover should be recorded on the form in tenths of sky covered. In the thin types of mackerel sky there are almost always gaps or spaces through which clear sky can be seen. When these conditions prevail, the amount of cloud should never be recorded as greater than $9/10$ even though such clouds are spread over the entire sky.

B–5 Visibility.—Horizontal visibility often is very useful as an indicator of the condition of the lower atmosphere, which in turn has effects on the sea surface. As a general rule, the visibility is good when the air temperature is lower than the sea temperature and very poor when higher. The reason for this is that, in the former condition, the lowest layers of the atmosphere are being heated by the sea. This tends to make the atmosphere thermally unstable and favors

Table B–1. Descriptive terms for present weather (extracted from WMO Code 4677)

	Code figure		
No meteors except photometeors	00	Cloud development not observed or not observable	characteristic change of the state of sky during the past hour
	01	Clouds generally dissolving or becoming less developed	
	02	State of sky on the whole unchanged	
	03	Clouds generally forming or developing	
Haze, dust, sand or smoke	04	Visibility reduced by smoke, e.g. veldt or forest fires, industrial smoke or volcanic ashes	
	05	Haze	
	06	Widespread dust in suspension in the air, not raised by wind at or near the station at the time of observation	
	07	Dust or sand raised by wind at or near the station at the time of observation, but no well developed dust whirl(s) or sand whirl(s), and no duststorm or sandstorm seen	
	08	Well developed dust whirl(s) or sand whirl(s) seen at or near the station during preceding hour or at the time of observation, but no duststorm or sandstorm	
	09	Duststorm or sandstorm whithin sight at the time of observation or at the station during the preceding hour	
	10	Mist	
	11	Patches of	shallow or ice fog at the station, whether on land or sea, not deeper than about 2 metres on land or 10 metres at sea
	12	More or less continuous	
	13	Lightning visible, no thunder heard	
	14	Precipitation within sight, not reaching the ground or the surface of the sea	
	15	Precipitation within sight, reaching the ground or the surface of the sea, but distant (i.e. estimated to be more than 5 km) from the station	
	16	Precipitation within sight, reaching the ground or the surface of the sea, near to, but not at the station	
	17	Thunder storm, but no precipitation at the station	
	18	Squalls	at or within sight of the station during the preceding hour or at the time of observation
	19	Funnel cloud(s)*)	
	20	Drizzle (not freezing) or snow grains	not falling as shower(s)
	21	Rain (not freezing)	
	22	Snow	
	23	Rain and snow or ice pellets, type (a) (sleet)	
	24	Freezing drizzle or freezing rain	
	25	Shower(s) or rain	
	26	Shower(s) of snow, or of rain and snow	
	27	Shower(s) of hail,** or of rain and hail**	
	28	Fog or ice fog	
	29	Thunderstorm (with or without precipitation)	
	30	Slight or moderate duststorm or sandstorm	has decreased during the preceding hour
	31		no appreciable change during the preceding hour
	32		has begun or has increased during the preceding hour
	33	Severe duststorm or sandstorm	has decreased during the preceding hour
	34		no appreciable change during the preceding hour
	35		has begun or has increased during the preceding hour
	36	Slight or moderate drifting snow	generally low (below eye level)
	37	Heavy drifting snow	
	38	Slight or moderate drifting snow	generally high (above eye level)
	39	Heavy drifting snow	
	40	Fog or ice fog at a distance at the time of observation, but not at the station during the preceding hour, the fog or ice fog extending to a level above that of the observer	
	41	Fog or ice fog in patches	
	42	Fog or ice fog, sky visible	has become thinner during the preceding hour
	43	Fog or ice fog, sky invisible	
	44	Fog or ice fog, sky visible	no appreciable change during the preceding hour
	45	Fog or ice fog, sky invisible	
	46	Fog or ice fog, sky visible	has begun or has become thicker during the preceding hour
	47	Fog or ice fog, sky invisible	
	48	Fog, depositing rime, sky visible	
	49	Fog, depositing rime, sky invisible	

CHAPTER C

MEASURING WATER TEMPERATURE AND DEPTH WITH A BATHYTHERMOGRAPH

C–1 The Bathythermograph or BT.—The BT (fig. C–1) is an instrument for obtaining a record of the temperature of sea water at moderate depths. The BT is lowered into the sea and retrieved by means of a wire rope. It can be operated while the ship is underway at speeds up to 18 knots. It works mcre satisfactorily, however, at speeds of 12 knots or less.

C–2 How a BT Works.—The thermal element of the BT, corresponding to the mercury column in a glass thermometer, consists of about 45 to 50 feet of fine copper tubing filled with xylene (fig. C–2). As the xylene expands or contracts with the changing water temperature, the pressure inside the tubing increases and decreases. This pressure change is transmitted to a Bourdon tube, a hollow brass coil spring, which carries a stylus at its free end. The stylus records, on a coated glass slide, the movements of the Bourdon tube as it expands or contracts with changes of temperature. The slide is held rigidly by the depth element assembly which is on the end of a coil spring enclosed in a copper bellows or sylphon. The temperature range of the BT is 28° to 90° F.

Water pressure, which increases with depth, compresses the sylphon as the BT sinks. This pulls the slide toward the nose of the BT, at right angles to the direction in which the stylus moves; thus, the trace scratched on the coated surface of the glass slide is a combined record

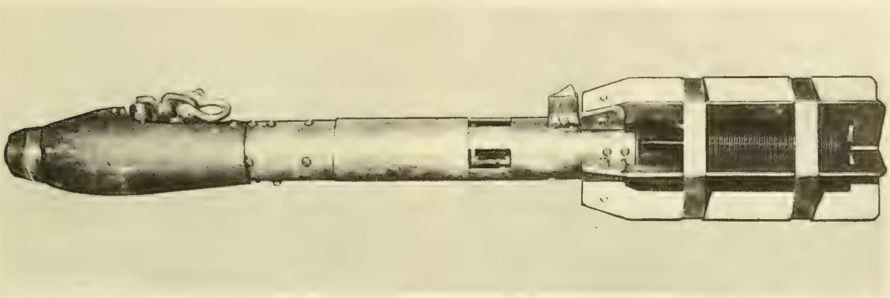

Figure C–1. The Bathythermograph (BT).

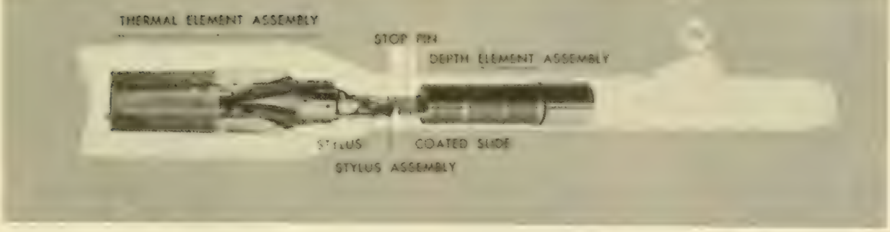

Figure C–2. BT thermal element, depth element, and styllus assemblies.

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of temperature and depth. The depth range is stamped on the nose of the BT. It is either 200, 450, or 900 feet.

C–3 Equipment Needed to Operate the BT.—In addition to the BT, the following list of equipment is required to operate the instrument:

1. A BT winch. Examples of winches include: The E6/S Winch (fig. C–3) and the ACCO Equipment Division Winch (fig. C–4).
2. A BT boom.
3. A BT towing block, counterbalanced.
4. Wire rope. $\frac{3}{32}$-inch diameter, 7 x 7 stainless steel, in 3,000-foot length per reel.
5. A grid mount assembly.
6. Metallic-coated glass slides.
7. A slide viewer.
8. A thermometer for measuring surface water temperature.
9. Tools (8-inch pliers, medium screwdriver, and a $\frac{3}{32}$-inch Nicopress).
10. Nicopress sleeves, thimbles, swivels, wire clips, and shackles.

One other tool, which is not essential but is always handy if the wire should jump the block sheave or backlash, is a cable-grip (come-along).

Shown in figure C–5 are the Nicopress tool and sleeves, wire rope, thimbles, swivels, wire clips, and shackles.

C–4 Recording BT Data.—BT data are recorded on the National Oceanographic Data Center *Bathythermograph Log*, NODC–EXP-3167/10 (Rev. 7–68) (fig. C–6). It is designed to provide NODC with information required for BT analog and digital processing and to provide a standard message format for radio transmission of synoptic BT data for automatic data processing. Instructions for completing the items on the Bathythermograph Log are printed inside the cover of each pad of log sheets.

C–5 Taking a BT.—Making a BT lowering is described by the term "Taking a BT." It is a relatively simple operation; nevertheless, a new operator should practice lowerings and recoveries with a dummy BT before undertaking the lowering with an actual instrument.

Certain operations are necessary to assure that good data are obtained. Taking a BT includes the following procedures:

Step 1. Check the operating instruction manual for the model winch to be used. The hand lever on the E6/S winch (fig. C–3) serves both as a brake and clutch. It has three positions: (1) When it is vertical, the winch is in neutral and the drum can be turned in either direction; (2) When it is pushed outboard to the engaged (hoist) position, the motor turns the drum and spools on the wire; (3) When the lever is pulled inboard toward the operator, to the brake position, the drum is locked and cannot be rotated. On other models the operation is different. The operating lever and the brake are separate.

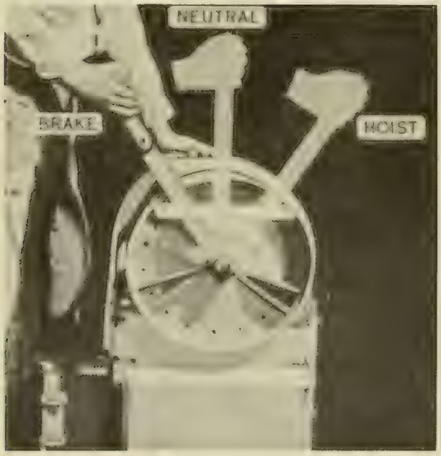

Figure C–3. E 6/S BT winch operating positions.

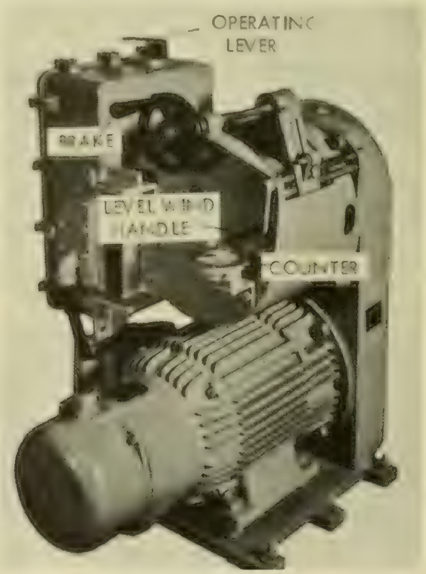

Figure C–4. ACCO Equipment Division BT winch.

Figure C–5. The Nicopress tool and sleeves, wire rope, thimbles, swivels, wire clips, and shackles.

Examine the winch installation to assure that the wire comes across the top of the drum. Run the free end of the wire through the towing block at the end of the boom. This block is of a special counterbalanced design for BT use. Make certain that the winch drum and block are properly lubricated.

Step 2. Connecting BT to Lowering Wire.—Cut off rusted, kinked, or frayed wire and make a new connection using a thimble with three Nicopress sleeves or wire clips. Check the swivel and if the BT does not have a built in swivel include one in the connection. Connect the lowering wire thimble to the BT swivel with a shackle. *NOTE:* More BT's are lost by poor connections than from any other cause. Another important precautionary measure is to paint the last 50 feet of the BT wire a bright color. This will signal the operator during retrieval to be on the immediate lookout for the BT, preventing accidental "two-blocking" and loss of the instrument. It is unwise to trust the counter dial on any BT winch.

Step 3. Inserting Slide in BT.—It is important that the slide is inserted in the BT properly.

Slide the BT sleeve forward toward BT nose (fig. C–7). This will uncover the stylus assembly and slide holder.

Hold slide between thumb and index finger with coated side up.

Insert the slide into the hole on the side of the BT, and push the slide into its bracket. The edge of the slide with the beveled corner goes in first, with bevel towards the nose of the BT.

Push the slide all the way in. Occasionally check the grooves of the slide holder to make sure they are clean and free of glass chips. Also, check the spring to assure that the slide is being held firmly in position.

Move the sleeve back to cover the opening prior to putting the BT over the side. This will bring the stylus assembly in contact with the glass slide.

Step 4. Putting the BT Over the Side.—When permission has been obtained from the bridge, the BT can be put over the side.

Hold the BT at the rail; take up the slack wire.

Lower the BT into the water to such a depth that it rides smoothly just below the surface (fig. C–8).

Put on the brake and hold the BT at this depth for at least 30 seconds to enable the thermal element to come to the temperature of the surface water.

Turn on the motor, so that power is available instantly for the rest of the operation.

Set the counter on the winch to zero.

Step 5. Taking the Sea Surface Reference Temperature.—While the BT is being towed at the surface, the sea surface reference temperature is taken. Any reliable thermometer can be used. The most common method of obtaining the temperature is to collect a bucket of surface water, immediately immerse the thermometer in the water, stir the thermometer with a circular motion, and read the thermometer with the stem still immersed in the water. Make several readings to assure a valid observation (fig. C–9).

Record the sea surface reference temperature on the Bathythermograph Log.

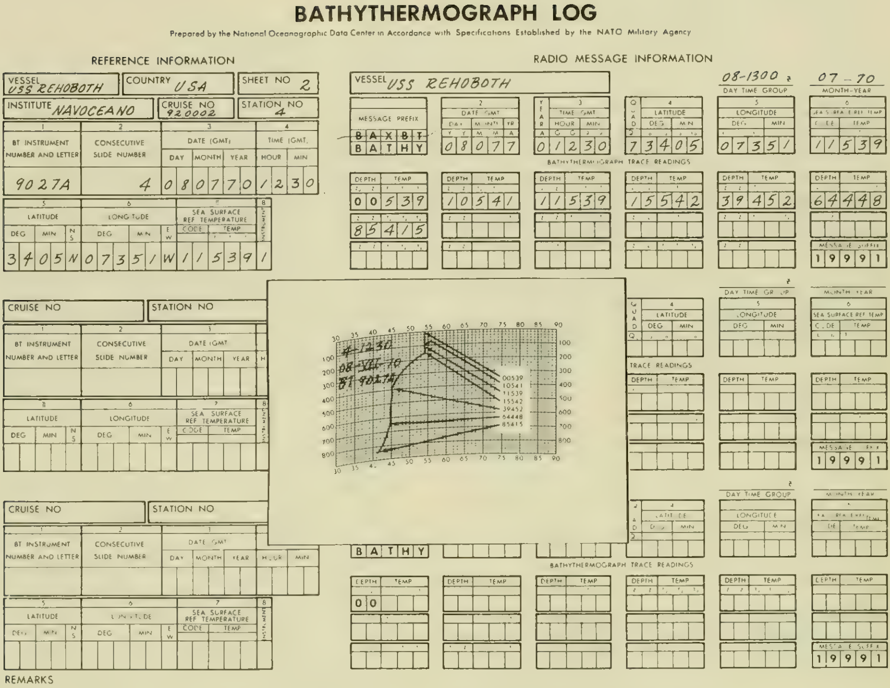

Figure C–6. Bathythermograph Log with slide and grid inset.

Step 6. Lowering the BT.—After the sea surface reference temperature has been taken the BT can be lowered. The operator should provide himself with a round stick about 15 inches long to be used to control the speed of the drum. The following instructions apply to underway lowering:

CHECK THE DEPTH OF WATER JUST BEFORE MAKING EACH LOWERING.

Release the brake, and allow the wire to pay out freely. Success in reaching the maximum desired depth depends on paying out the wire as quickly as possible.

Watch the wire and the drum carefully, and gently slow the drum with the stick if excessive slack appears. Do not apply too much pressure to the drum with the stick. Once the diving motion of the BT is arrested it will not dive deeper regardless of the amount of wire payed out.

The proper amount of wire to be payed out will depend upon the speed of the ship, the type of BT, whether or not the nose sleeve is attached, and operator experience. Several lowerings should be made to obtain ship-speed/wire-out ratio for BT used.

Stop the winch when the counter indicates the proper length of wire has been payed out. Apply the brake smoothly; avoid excessive jerk, it may part the wire. *NOTE:* Never pay out the last layer of wire on the drum.

Step 7. Retrieving BT.—As soon as the brake is applied, the BT will stop diving and return to the surface far astern.

Haul in the BT at full speed.

Guide the wire back and forth in even layers on the drum. If the winch does not have a level wind, use the wooden stick for proper spooling.

Decrease the winch speed when BT is close astern. Continue to haul in until BT begins to porpoise (breaking clear of the surface and swinging forward as the ship rolls or as wave crests pass). *NOTE:* This is the most critical the amount of this error for accurate results. In order to determine the amount of correction to apply to depth for accurate work, the following procedures can be used in an emergency:

> With the sleeve all the way back, immerse the thermal element in a cold and then in a warm (less than 105° F.) bucket of water. This will cause a long zero depth line to be drawn across the slide. The slide is then placed in the viewer and the difference, in feet, of the trace above or below the zero depth line on the grid is the error for which corrections must be made at all depth readings.

BT's that have a depth error of more than 10 feet for a 200-foot instrument, 20 feet for a 450-foot instrument, or 40 feet for a 900-foot instrument should be replaced.

C–10 The Expendable Bathythermograph or XBT.—An expendable bathythermograph system (XBT), built by the Sippican Corp., is used aboard ship for measuring the temperature of sea water in the water column from the surface down to a depth of 1,500 feet. (Measurements to depths of 2,500 or 5,000 feet can be obtained with special probes and recorder modifications.) The XBT can be used while the ship is hove to, but it is especially designed to be used while the ship is underway. The XBT includes three components: the launcher, the recorder, and the expendable probe (fig. C–15).

The launcher (fig. C–16) includes the discharge tube, the breech, the stanchion, and the launcher/recorder cable.

The recorder (fig. C–17) is a conventionl type, 120 VAC, 60HZ, analog recorder with a temperature scale from 28° to 96° F or −2° to 35° C. Special depth/temperature scaled chart paper is used in the recorder.

The expendable probe (fig. C–18) includes the canister, the probe with calibrated thermis-

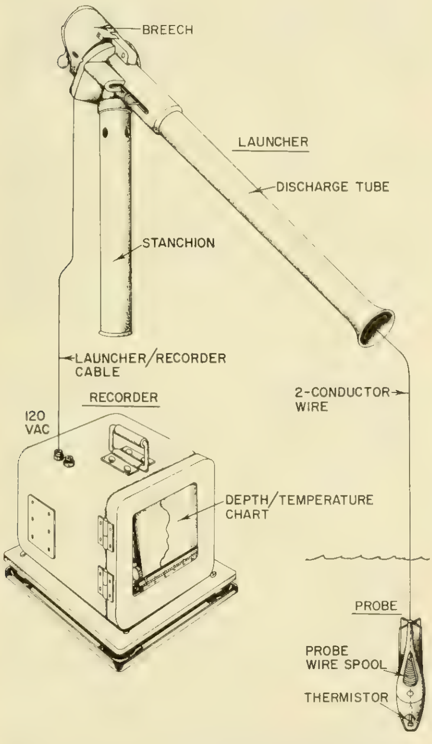

Figure C–15. Expendable bathythermograph (XBT) system.

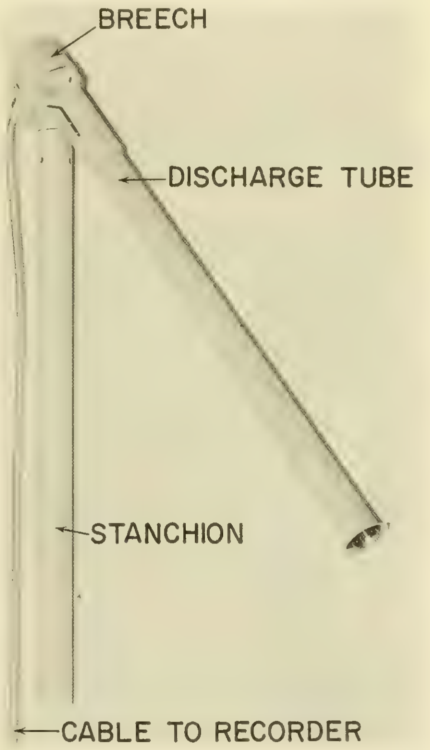

Figure C–16. XBT launcher, Sippican model LM–2A.

Figure C–17. Recorder, Sippican model MK–2A.

tor, two spools of wire, and the probe launch pin.

C–11 How the XBT Works.—The thermal element of the XBT is the probe. It is a ballistically shaped device containing a calibrated thermistor in its nose. The thermistor is con-

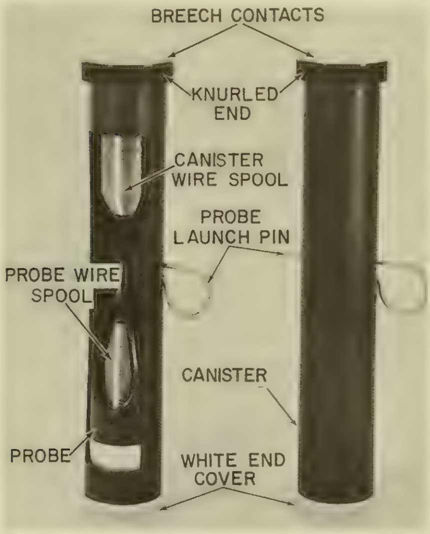

Figure C–18. Expendable probe and canister, Sippican model T–4 (cutaway view at left).

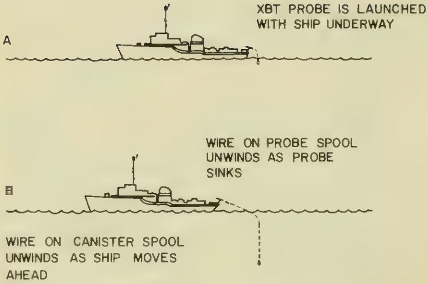

Figure C–19. Launching the XBT.

nected to a very fine two-conductor wire.[1] Approximately half of this wire is wound on a spool inside the probe, and the other half is wound on a spool inside the upper portion of the canister. The probe is held in place in the canister by the probe launch pin. To take an XBT, the canister case is placed in the breech of the launcher and the breech is locked, completing the electrical circuit from thermistor to recorder; then the probe launch pin is pulled, and the probe falls through the discharge tube and into the water (fig. C–19A). When the probe is launched, the fine wire from both spools is free to unwind, permitting the probe to free-fall through the water and the ship to move away from the station without breaking the wire (fig. C–19B). As the probe drops through the water, the resistance of the thermistor in the probe changes with the water temperature. This causes voltage changes at the recorder, and the temperature and depth[2] are recorded on an analog chart. When all the wire on the spools is payed out, the wire breaks, and the probe drops to the bottom of the sea.

C–12 Installation of XBT Launcher and Recorder.—The XBT launcher and recorder shown in figures C–16 and C–17 should be installed on the ship in accordance with manual R–667A "Instructions for Installation, Operation, and Maintenance of Sippican Expendable Bathythermograph System." In locating the components on the ship, consideration should be given to protection of the recorder from weather and spray, to line voltages, ambient temperatures, and electrical noise, to garbage chute and waste outlet locations, and to the location of any devices being towed by the ship. XBT probes should be stored in a cool place out of direct sunlight.

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[1] Various models of the XBT probe contain different lengths of wire depending on the depth to be observed and the speed of the launching ship.
[2] The chart paper drive speed is constant and is directly proportional to the probe's assumed rate of descent.

C–13 Checking Out the XBT System.—After the XBT launcher and recorder are installed and always before beginning an operation aboard ship, the recorder and the launcher to recorder circuit should be checked by performing the following steps:

Step 1. Plug in the recorder power cord to 120 VAC (the instrument does not have an On-Off switch). This will cause the red reload indicator signal (A) to light (fig. C–20).

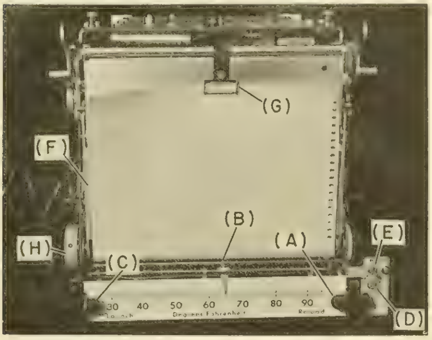


Figure C–20. XBT recorder panel.

Step 2. After a 15-minute warmup period, open the launcher breech and clean contacts, using a clean rag and alcohol. Check the launcher discharge tube for salt deposit, and clean as necessary, using fresh water and a cloth swab. Insert the test canister. *NOTE:* Included with each XBT system is a Model A2–A test canister. Its circuit is shown in figure C–21. The test canister should be calibrated every 6 months.

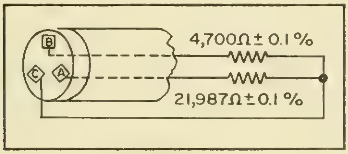


Figure C–21. Test canister circuit.

Step 3. Close the breech and lock securely. The reload light will go out, the chart drive will operate for 2 seconds, and the chart stylus (B) will plot 62° F ±0.2° F (1.67° C ±0.1° C) for that period (fig. C–20). The chart drive will then stop, and the green launch light (C) on the left of the temperature scale will go on. *NOTE:* Check for jitter on the plot and adjust the gain if necessary.

Step 4. Press and hold the 30°/94° test switch (D) in the 94° position (fig. C–20) for 30 or 40 seconds. The launch light will go out, the chart drive will start, and the chart stylus will plot 94° F ±0.2° F (34.4° C ±0.1° C).

Step 5. Release the 30°/94° test switch, and press and hold it in the 30° position. Now the stylus will plot 30° F ±0.2° F (−1.1° C ±0.1° C). The chart paper will advance for 88 seconds ±2 percent, then the chart paper drive will stop and the reload light will go on.

Step 6. Press and release the recycle switch (E) (fig. C–20). The reload light will go out. The chart drive will operate for 2 seconds with the chart stylus at 62° F ±0.2° F (16.7° C ±0.1° C). Then the chart drive will stop and the launch light will go on.

Step 7. Repeat steps 4 and 5 several times to make sure that the chart stylus is recording temperatures within tolerances, that the signal lights are operating properly, and that the chart paper drive advance time (step 5 above) is between 86.2 and 89.8 seconds. When the test switch is changed from the 94° to the 30° position, the stylus should require 1 second for a full scale excursion. Excessive overshoot or sluggishness of movement will require gain adjustment. If any tolerances are exceeded or any malfunctions are noted, the recorder should be calibrated as described in manual "Instructions for Installation, Operation and Maintenance of Sippican Expendable Bathythermograph System", and on the NAVOCEANO Planned Maintenance Card (NAVOCEANO 10510/14 (5–68)).

C–14 Recording XBT Data.—XBT data are recorded on the National Oceanographic Data Center *Bathythermograph Log* NODC–EXP–3167/10 (Rev. 7–68) (fig. C–6). Mechanical BT's and XBT's should be kept on separate BT logs. Instructions for completing the items of the Bathythermograph Log are printed inside the cover of each pad of log sheets. For item 2, consider the XBT chart as a BT slide and number it accordingly. Obtain the sea surface reference temperature in accordance with instructions in paragraph C–5, step 5 "Taking the sea surface reference temperature", or from the ship's injection temperature log. Enter any comments concerning the conditions at the time the XBT was taken in the remarks space of the log sheet. Such comments might include: high seas, changing course, wire unspooling improperly, wire fouled on the side of ship, premature parting of wire, etc.

C–15 Deployment of the XBT.—After the XBT system has been checked out and the ship is coming up on a station, take the XBT by performing the following steps. *NOTE:* One person can take the XBT, however, this requires several trips between recorder and launcher; therefore, if two persons are available one should be stationed at the recorder and the other should be at the launcher.

Step 1. Plug in the recorder power cord to 120 VAC. This will cause the red reload light indicator signal (A) to light (fig. C–20). Allow a 15-minute warmup period.

Step 2. Complete items one through three on the Bathythermograph log.

Step 3. Remove the canvas cover from the launcher, and open the launcher breech fully clockwise; remove the expended canister used when taking the previous XBT, making sure no scrap wire remains in or around the discharge tube or breech.

Step 4. Take a canister from the packing case, and remove the white end cover.

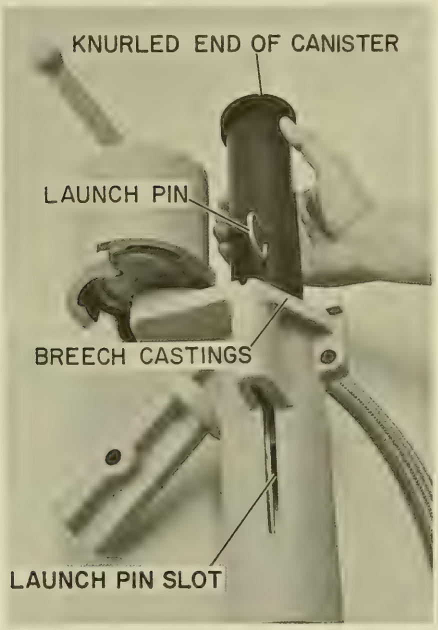


Figure C–22. Loading canister in breech.

Step 5. Insert canister in breech (fig. C–22) guiding the probe launch pin loop through the launch pin slot until the knurled end is on the breech castings.

Step 6. Close breech and lock handle fully counterclockwise. This will cause the red reload light to go out at the recorder, and the chart drive to run for approximately 2 seconds. Check the chart paper to make sure that the "surface" line appears directly under the stylus. To adjust paper, turn knob (H) (fig. C–20) at lower left of chart drive, ending with clockwise motion to eliminate any backlash error.

Step 7. When the green launch indicator signal (C) (fig. C–20) goes on, pull the probe launch pin by grasping the loop and removing the pin with a firm continuous motion. *NOTE:* If the sea is high, try to deploy the probe so it will hit the water between wave crests.

Step 8. When the chart drive stops and the red reload indicator signal goes on, annotate the chart with the following information: ship, cruise, latitude, longitude, time (GMT), day/month/year, e.g., 19/08/70, and consecutive chart number. In addition, bottom depth should be indicated beside the trace as shown in figure C–23.

Step 9. After the XBT observation is completed, charts may be left on the takeup spool in the recorder or removed individually. To remove XBT chart(s) from the recorder, cut the chart paper along the bottom of the chart paper locking plate (F) (fig. C–20) with a penknife. To reconnect the chart paper, attach the chart-saver clip (G) (fig. C–20) to the chart paper by stretching the clip elastic downward.

Step 10. Secure XBT system by replacing launcher canvas cover and disconnecting recorder power cord.

Step 11. Complete Bathythermograph Log in accordance with instructions printed inside the cover of the pad of log sheets.

Step 12. If the XBT system will not be used within the next 4 hours, unplug the recorder power cord.

C–16 Mailing XBT Charts and Logs.—At the completion of an operation, XBT charts and logs should be mailed to a Fleet Weather Facility. Instructions for mailing XBT charts and logs are printed inside the cover of each pad of log sheets.

Step 1. Cut charts (do not mail in a roll) so that each consecutive observation includes the baseline which was recorded above the surface line of the chart when a new probe was loaded in the launcher.

Step 2. Mail charts and logs together, but do not fold charts. Stack and mail flat. If pressure sensitive chart paper was used, protect the charts by folding each log sheet and inserting the charts in the fold.

Step 3. Include all checkout charts made at the beginning of or during the operation with the XBT charts and logs.

C–17 XBT Maintenance.—XBT routine and preventive maintenance and trouble shooting instructions are presented in manual R–467 A "Instructions for Installation, Operation and Maintenance of Sippican Expendable Bathy-

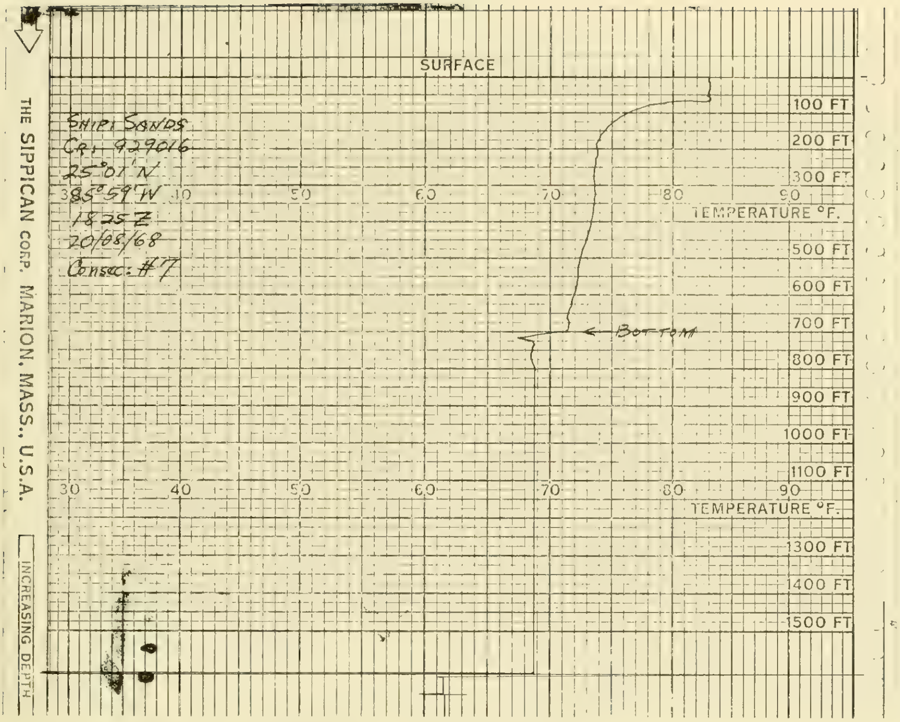


Figure C–23. **XBT chart annotated.**

thermograph System", and on the NAVOCEANO Planned Maintenance Card (NAVOCEANO 10510/14 (5–68)).

The launcher discharge tube should be checked periodically for salt buildup. Any salt should be removed with fresh water and a cloth swab.

The insulation around the canister contacts in the launcher breech should be inspected for contamination before inserting a canister. Any contamination should be removed with a cloth dipped in alcohol.

Installation of a new chart roll, chart alignment, and preventive maintenance only should be performed by the operator. Recorder trouble shooting maintenance should be performed only by an electronic technician. Recorder and test canister should be calibrated every 6 months, and this calibration should be performed only by a calibration electronic technician.

It is important that the A2–A test canister is kept with the XBT system at all times. It should be considered an integral component of the system.

OCEANOGRAPHIC LOG SHEET – DDD
FRM-NAVOCEANO-3167/4 B (10-64)

U.S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D.C. 20390

SALINITY DETERMINATION BY INDUCTIVELY COUPLED SALINOMETER

From table I-3

	CRUISE NUMBER	STATION NUMBER	BRIDGE NUMBER	CHEMIST	SAMPLE TEMP.	TEMP. COMP. DIAL SETTING	STD. DIAL SETTING	DATE ANALYZED	CHECKED BY
EDISTO	E. ARCTIC-65	31	90421	J. J. C	23.80	79	4715	10/7/65	KAC

SERIAL NUMBER	BOTTLE NUMBER	CONDUCTIVITY RATIO			NOMINAL SALINITY ‰	CORRECTIONS ‰				CORRECTED SALINITY ‰	REMARKS
		1ST DETERM.	2ND DETERM.	AVERAGE		DRIFT	TEMP	[illegible]	TOTAL		
	Std 1			.99995	34.998	0				34.998	
568	568	.99770	.99766	.99768	34.909	.001	0		0	34.909	
569	569	.99796	.99794	.99795	34.920	.001	0		+.001	34.921	
570	570	.99800	.99800	.99800	34.922	.001	0		+.001	34.923	
571	571	.99780	.99780	.99780	34.914	.001	0		+.001	34.915	
572	572	.99789	.99789	.99789	34.918	.002	0		+.001	34.919	
573	573	.99824	.99824	.99824	34.931	+.002			+.002	34.933	
	Std 2	.99990	.99990	.99990	34.996				+.002	34.998	
		Drift.			From Table		From Table				
	Std1	34.998			I-2		I-4				
	Std2	34.996									
		-.002									
		Std.1 → Std2									

If Conversion of Conductivity Ratio to Salinity Table is not available, Nominal Salinity (S) can be computed from Average Conductivity Ratio (R) by using the following formula from Roland Cox et al:

$$S = -0.08996 + 28.2972R + 12.80832R^2 - 10.67869R^3 + 5.98624R^4 - 1.32311R^5$$

Figure I–14. Oceanographic Log Sheet DDD with formula inset.

Table I–3. Abstract of Temperature Compensation Dial Settings table

For temperature °C. reading	Set temperature compensation: Left dial	Right dial
16.00	4	6
18.00	5	4
20.00	6	3
22.00	7	2
24.00	8	0
26.00	8	7

Table with Temperature Compensation Dial Settings for temperatures from 6° to 40° C. is furnished with each salinometer

Step 9. Set the Function Selector knob to Salinity, refill the sample cell, set the Stir Fill switch to Stir, and adjust the Standardization dials until the null indicator needle is on scale. Then turn the Stir Fill switch to Off, drain the cell, refill again, stir the sample, and finally zero the null indicator needle with the Standardization dials. Turn the Stir Fill switch to Off, the three-way valve to Fill, and let the sample drain back into the bottle of standard sea water. Refill the sample cell once again and make sure the Standardization dial settings zero the null indicator meter.

Step 10. Record the Standardization dial settings in the *Std. Dial Setting* block.

2. Salinity Sample Runs.—Salinity samples should be within one or two degrees centigrade of the sample temperature obtained during standardization (Step 7 above) when they are analyzed, and the steps listed below should be followed carefully as the salinity samples are run:

Step 1. Open the first sample bottle, turn all Conductivity Ratio dials to zero, fill the sample cell full, and set the Stir Fill switch to Stir to rinse the cell with the sample. While rinsing, adjust the Conductivity Ratio dials to obtain an on scale reading on the null indicator meter. *DO NOT CHANGE THE STANDARDIZATION DIALS.*

Step 2. Drain the cell into the waste bottle, refill the cell, set the Stir Fill switch to Stir, and adjust the Conductivity Ratio dials to obtain a zero reading on the null indicator meter; then, stop the stirrer and record the Conductivity Ratio dial settings in the *Conductivity Ratio 1st Determ.* column.

Step. 3. Immediately drain the cell either into the waste bottle or back into the sample bottle, depending on the amount of sample available. Refill the cell, stir, and adjust the Conductivity Ratio dials to obtain a zero reading on the null indicator meter. Stop the stirrer, record the dial settings in the *Conductivity Ratio 2nd Determ.* column.

Step 4. If the 1st and 2nd Determ. conductivity ratios are within ±.00010, go on to step 5. If they do not agree within the above limits, rerun a third or fourth sample until acceptable values are obtained.

Step 5. Recap the sample bottle, and return it to the salinity sample case. Samples are not discarded until salinity analysis data are computed and verified.

Step 6. Repeat steps 2 through 7 for other salinity samples (the maximum number of samples run at one time usually is 24).

Step 7. After the salinity samples have been run, analyze a sample from the standard sea water used for the standardization; this time, however, adjust the Conductivity Ratio dials to obtain a zero reading on the null indicator. Enter the dial settings in *Conductivity Ratio* column(s), and write Std and the number 2 in *Bottle Number* column. The second standardization run is most important because the salinometer usually has a tendency to drift.

3. Conversion of Conductivity Ratio to Salinity.—Average conductivity ratios are computed and entered in the *Conductivity Ratio Average* column, and then converted to nominal salinity ‰ by means of the Conversion of Conductivity Ratio to Salinity table (see table I–2). Determine salinity ‰ to the nearest thousandth by interpolation, and enter in the *Nominal Salinity ‰* column.

4. Computation of Drift Corrections.—After the conductivity ratio is obtained by rerunning the standard (Std2), the drift that occurred in the salinometer can be determined.

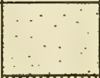
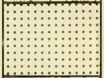
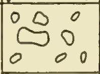
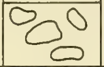
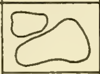
Step 1. Determine the difference between the nominal salinity ‰ of Std1 and Std2 and enter this value in the *Drift* column of Std2 line. If Std1 > Std2 the drift correction is plus; if Std1 < Std2 the drift correction is minus.

Step 2. Distribute the drift corrections proportionally between the salinity samples run, beginning with zero (or minimum) drift correction for the first sample run after standardization (Std1) and increasing to maximum drift correction at the last sample run before rerunning the standard Std2. Enter in *Drift* column.

An excessive drift may require a standardization following the running of 12 salinity samples. Drift can be reduced by maintaining a constant temperature in the laboratory and by analyzing the series of salinity samples in the minimum time consistent with good techniques.

5. Computation of Temperature Corrections.—Sample temperatures have an effect on salinity values. This temperature correction is determined by using the Temperature Corrections to Salinity table (see table I–4). Using sample temperature (*Sample Temp.* block) and the nominal salinity ‰ for each sample, determine the temperature correction and enter the value in the *Temp.* column. It is most important that temperatures of the samples vary no more than one or two degrees celsius.

Table L-1. Classification table for bottom samples to be symbolized on nautical charts

FIELD CLASS	TYPE	SIZE in (mm)	VISUAL GUIDE	APPROX. SIZE (inches)	FIELD CRITERIA
Mud (M)	Clay (Cl)	less than 0.005			Smooth, plastic, and sticky
	Silt (Slt)	0.005-0.1			Somewhat gritty
Sand (S)	Fine (f)	0.1-0.3			Individual particles can be distinguished easily by eye
	Medium (med)	0.3-0.5			
	Coarse (crs)	0.5-2.0			Roundness or angularity of particles can be determined easily by eye
Gravel (G)	Fine (f)	2.0-4.0			
	Coarse (crs)	4.0-6.0			
Pebbles (P)	Fine (f)	6.0-10.0		¼-½	
	Medium (med)	10.0-20.0		½-3/4	
	Coarse (crs)	20.0-64.0		3/4-½	
Stones (St)		64.0-256.0		2½-10	
Boulders (Blds)		greater than 256.0		10	
	Shell (Sh)	Calcium carbonate fragments which may be any size are visually identifiable when gravel-sized or larger. Indicate size as well as composition; e.g., gravel-sized Shell, or pebble-sized Coral.			
	Coral (Co)				
	Rock (Rk)	Visible reefs or rock outcrops			

agree with those entered on the M-Sheet, as this is the only means of identifying the samples when they arrive at the laboratory. A feature of the label is that when it is properly attached the top of the core liner is indicated by the word "top" and two flanking arrows. Labels should be taped to sample containers, and in those cases where the core liner is waxed, the coat of wax should be applied over the label. Because the waxing process often obscures the writing on the label, it is good practice to duplicate the label before waxing and to tape the duplicate label over the waxed surface.

L–41 Packing, Storing, and Shipping Bottom Sediment Samples.—All cores should be stored aboard ship in an upright position to prevent disturbance to the structure of the sediment. Cores to be analyzed for engineering properties, however, should be handled with extra care, and the engineering properties analysis should be performed at the first available shore facility. When sediment samples are taken off the ship and will require packing for shipment to a laboratory, special shipping cases should be used for the cores, and the sample jars should be packed carefully to reduce the possibility of breakage during shipment. The cases for the cores should be provided with a screw-fastened top and should be plainly marked *HANDLE WITH CARE* and *THIS SIDE UP.*

Cases of cores and bottom samples to be shipped to the Oceanographic Office for analysis should be addressed to the Pacific Support Group if collected west of the 100°/70° line as shown in figure L–25 or to the Commander U.S. Naval Oceanographic Office if collected east of the line.

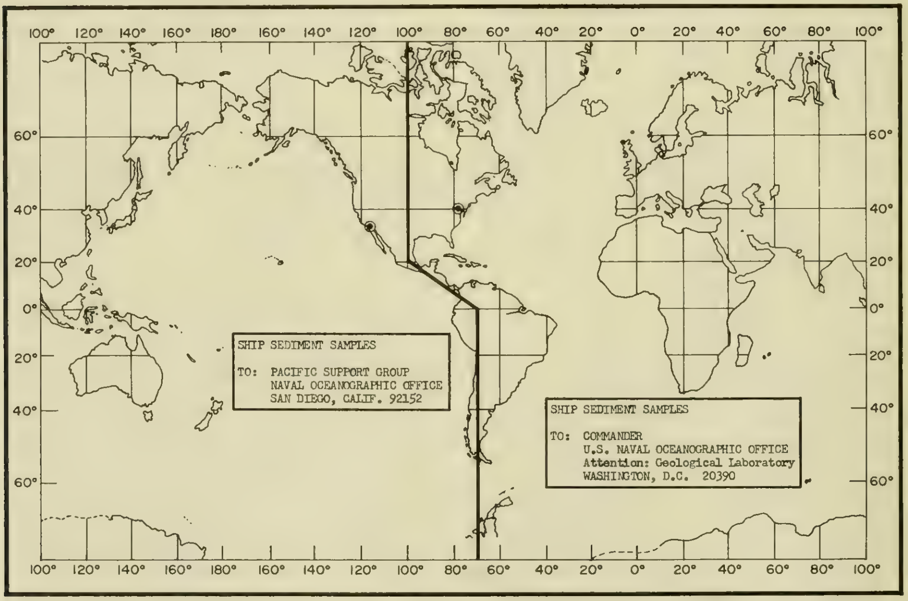


Figure L–25. World chart showing where to ship sediment samples.

L–42 Boomerang Sediment Corer.—The Boomerang sediment corer (by Benthos) is a gravity corer that requires no wire or winch for launching and retrieving. It is designed to obtain cores up to 4 feet in length from water depths as great as 6,700 meters. This corer is especially adaptable to those situations where the wire on the ship's winches will not reach the ocean floor because of excessive depths.

The Boomerang corer assembly consists basically of two components: (1) The ballast component; consisting of the float retaining shell, ballast weight, steel core barrel with nose piece, and pilot weight (fig. L–26), and (2) the float

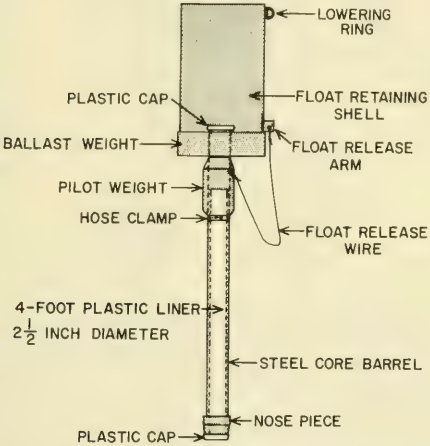


Figure L–26. Boomerang corer ballast component.

component; consisting of a 10-inch diameter fused glass sphere, a PVC spacer, a 9-inch diameter sphere containing the flashing assembly, a nylon net bag (rigged with purse string, rubber band, nylon line for stretching net bag, and a float-release-arm ring), a core liner valve/release mechanism tube with 6-foot nylon tether line, a core catcher, and a hollow rubber ball (fig. L–27). The items of the float component, which are recoverable, are installed in the ballast component, which is expendable.

The complete assembly is shipped with a 48-inch CAB (Cellulose Acetate Butyrate) plastic liner in the core barrel and with plastic caps taped over the ends of the core barrel. The float-release arm and the pilot weight are connected by a wire, and the pilot weight is held snugly against the ballast weight with a hose clamp.

After being rigged to take a core, the complete assembly is dropped overboard into the ocean; it free falls and its core barrel is driven into the ocean floor by gravity (fig. L–28). As the Boomerang core barrel penetrates the ocean floor, the float component with the sediment core liner is released from the ballast component. The float component then rises to the surface with the core. The ballast component remains on the ocean floor.

L–43 Instructions for Assembling the Boomerang Corer.—The Boomerang corer is not difficult to assemble. First, the float component is checked out, and it is then connected up with the ballast component. The following tools, equipment, and materials are required or will facilitate the assembly process:

A sphere stand (see fig. L–29).
A ballast component cradle (see fig. L–33).
Screwdriver.
A solvent (such as trichloroethylene).
Electrical vinyl tape.
Fiber vinyl tape.
Tubular tool.
Silicone gasket grease.
Float recovery hook.
Net, long handle.

Step 1. Check the battery and the electronic circuit of the flashing component by removing the magnetic switch from the side of the 9-inch

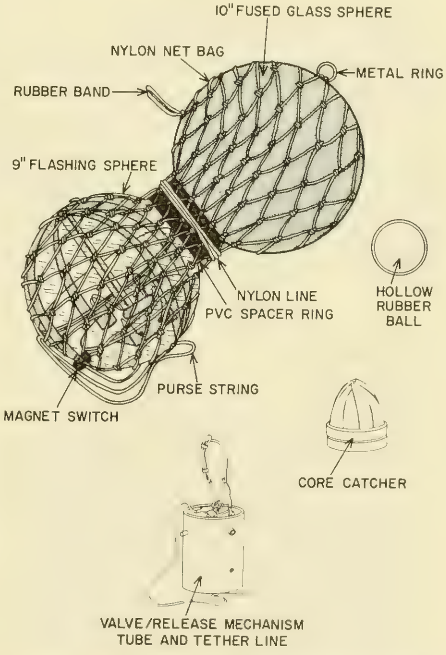


Figure L–27. Boomerang corer float component.

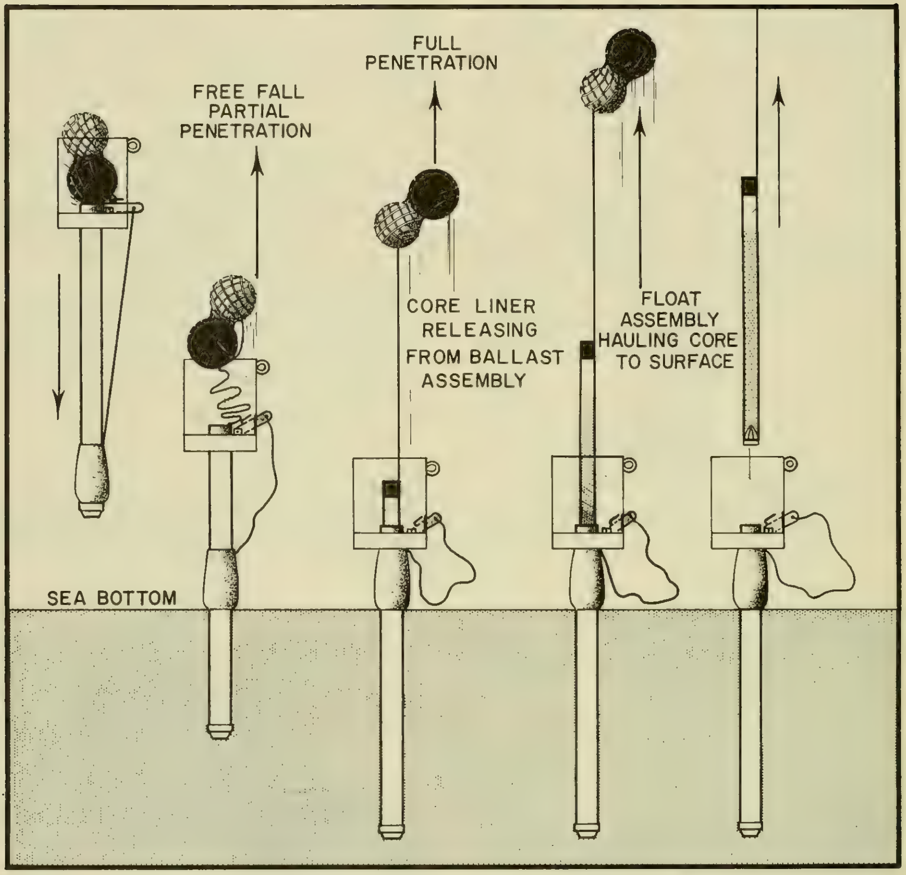


Figure L–28. **Principle of operation of Boomerang gravity-type corer.**

sphere. If the flash rate is below the 2- to 3-second nominal rate or if the flash assembly has been in operation for 16 hours, replace the battery. If the battery is to be replaced, proceed to steps 2, 3, and 4; otherwise go to step 5.

Step 2. Remove the glass spheres from the nylon net bag and place the flashing sphere in the sphere stand. With a screwdriver, remove the two hose clamps from the flashing sphere and disassemble. Tape magnetic switch in place when hose clamps are removed.

NOTE: A lower air pressure inside the sphere may make it necessary to slide the hemispheres apart by tightening one of the clamps as shown in figure L–29a. Care should be taken to avoid scratching or chipping the sealing surfaces of the two halves of the sphere (fig. L–29b). Replace battery with a 240V Burgess U–160 or Eveready 491, and check flashing circuit by removing magnetic switch. Mark "OLD" in several places on the used battery.

Step 3. Reassemble the flashing sphere, taking extreme care to clean the sealing surfaces, to coat them with a thin layer of silicone gasket grease, and to line up the match marks of the two halves as they are assembled. Any air in the joint will appear as a white area and should be eliminated by rotating or sliding the hemispheres. Replace clamps and tighten them down firmly as shown in figure L–29 (c).

Step 4. To reassemble the glass spheres in the nylon net bag as shown in figure L–27, first place the 10-inch fused-glass sphere in the bag. Next place the PVC spacer ring on the sphere.

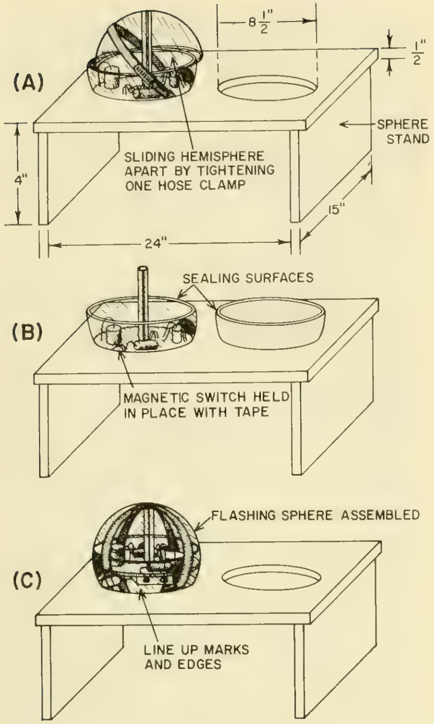


Figure L–29. Flashing sphere in sphere stand.

Then place the flashing sphere on the spacer, and draw the purse string of the net bag tight and tie with several knots. Finally, stretch the net as tight as possible by wrapping and tying the piece of ⅛-inch diameter nylon line around the net between the spheres. Care should be taken to avoid contact between the spacer and a hose clamp. Mouse all knots with tape or thread.

Step 5. Remove the plastic caps from the steel core barrel of the ballast component (see fig. L–26) and slide the plastic liner out of the core barrel. Save the plastic caps.

Step 6. With a solvent (trichloroethylene), clean the outside of both ends of the liner and also the lip of the core catcher.

Step 7. Install the core catcher in one end of the plastic liner and tape the liner and core catcher together. Use no more than five turns of ¾-inch black vinyl tape (equal to Scotch No. 88) and keep the tape above the groove on catcher lip (fig. L–30) so that the liner will slide freely inside the steel core barrel.

Step 8. Set the valve in the valve/release mechanism tube as shown in figure L–31 by

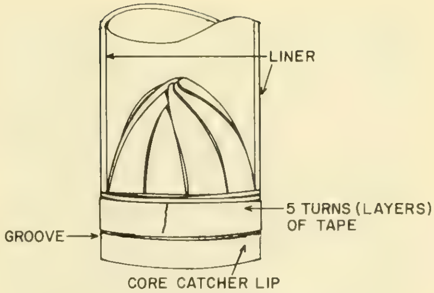


Figure L–30. Core catcher installed in liner.

turning the valve to vertical and pushing the valve/release pin through the pin tube on the liner release lever rod and into the pin hole in the valve. Do not push the pin all the way down as this might cause the valve/release mechanism to malfunction. Test the setting several times by pulling the tether line as shown in figure L–31 and tripping the mechanism. Then set the pin so that a very light pull on the tether line will pull the pin and let the valve close and free the liner release lever rod.

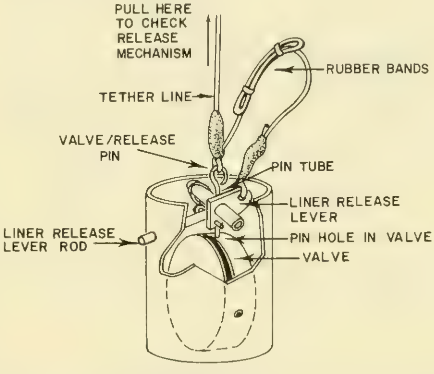


Figure L–31. Boomerang corer valve/release mechanism tube (cutaway view).

Step 9. Tape the valve/release mechanism tube to the other end of the core liner. Use five strips of vinyl fiber tape and not more than four layers of ¾-inch black vinyl tape as shown in figure L–32 so that taped liner will slide freely inside core barrel.

Step 10. With the ballast component in its cradle (fig. L–33), remove the hose clamp that holds the pilot weight against the ballast weight and slide the pilot weight down below the spiral row of holes in the core barrel.

Step 11. Slide the core catcher end of the liner down through the float retaining shell and

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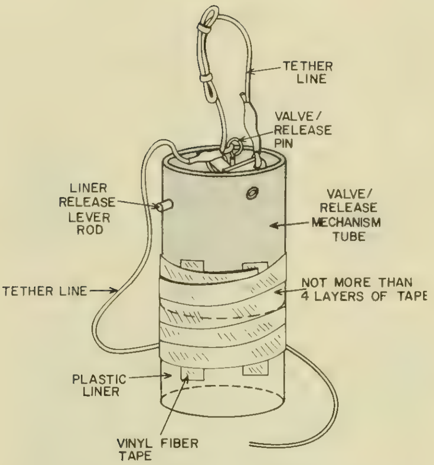


Figure L–32. Valve/release mechanism tube installed on liner.

into the core barrel until the liner release rod on the valve/release mechanism tube reaches the top of the barrel (fig. L–31). Then, push the rod inward against its spring, and slide the liner into the barrel until the catcher lip rests on the flange inside the nose piece.

Step 12. As the valve/release mechanism tube enters the core barrel, orient the liner release rod so that it is in line with the spiral row of holes in the barrel (fig. L–33).

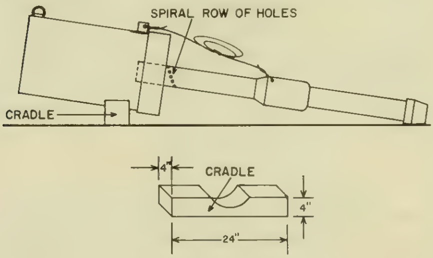


Figure L–33. Ballast component in cradle.

Step 13. Check that the catcher lip is seated against the flange inside the nose piece, and then with the tubular tool twist the liner and valve/release mechanism until the release lever rod seats itself in one of the holes in the spiral row of holes in the barrel.

NOTE: Since the length of the core liner increases about .008 inch for every degree centigrade increase in temperature and since each hole in the spiral is .062 inch higher or lower than the previous hole, it is better to wait until just before launching the corer to seat the liner release rod. In addition, when seating the liner release rod, consideration should be given to the differences between air and bottom water temperatures.

L–44 Obtaining the Boomerang Core.—After the float component has been checked and the liner has been inserted in the ballast component, the corer is ready for final preparation prior to launching.

Step 1. Fasten the free end of the 6-foot tether line from the valve/release mechanism of the liner to the nylon net bag of the float. Make the tie on the bottom side of the flashing sphere so that the flashing component will float in an upright position. Mouse the knot to guard against untying. *NOTE:* Wet nylon is very slippery.

Step 2. Seat the liner release lever rod, place the net bag containing the spheres in the float retaining shell, fused sphere first, and hook the metal ring over the hook on the float release arm.

Step 3. Slide the pilot weight down to the nose piece of the core barrel. This should draw the float release wire tight, and the float release arm should be held down against the ballast weight.

Step 4. Press the hollow rubber ball into the hole in the float retaining shell to hold the float release arm in place during launching.

Step 5. Remove the magnetic switch, note the time, and then with a line through the lowering ring hoist the Boomerang corer over the side.

Step 6. When on station, drop the corer, and again note the time. At a depth of about 10 meters, the air in the hollow rubber ball will become compressed, and the ball will float free and return to the surface. Retrieve it with a net.

L–45 Retrieving the Boomerang Corer.—Since retrieving the Boomerang corer is very difficult even under ideal conditions, the following precautions should be taken to avoid losing or damaging the float component and/or the core during retrieval:

Step 1. Obtain a depth measurement for the station, determine the approximate time the float component should surface, and standby to watch for the float. *NOTE:* The corer will descend at approximately 450 meters per minute, and the float component will rise at approximately 75 meters per minute. The float component is difficult to sight during daylight hours; therefore, if possible, schedule Boomerang corer operations during hours of darkness. If the ocean bottom is too hard and the corer fails to penetrate enough to release the float component or if the ballast component falls over on its side, the float component and core liner will be lost.

Step 2. When the float component is sighted, pull alongside with the spheres on the leeward side so that the ship drifts down on the component. Hook the nylon net bag with a boathook, a gaff, or an improvised recovery tool, and hold the float component away from the side of the ship until it can be hoisted aboard. Avoid, if possible, having the glass spheres crash against the ship as they may break, in which case the core will sink. In addition, if the float component receives too much rough handling or if the core liner strikes the side of the ship, the taped joints between the valve/release mechanism tube and/or the core cutter and the liner may give away, which would cause the core to be lost. *NOTE:* In some instances, it may be necessary to put a diver in the water or a manned small boat over the side to retrieve the float component. Also, several additional loops of tether line connected to the net may facilitate retrieval. In addition a rope netting over the side at the point where the float will be hoisted aboard may eliminate damage to the float component.

Step 3. When the float component and liner are aboard, keep the liner in a near upright position, place the float spheres in the sphere rack, replace the magnet switch on the flashing sphere, and note the time.

L–46 Removing, Logging, and Labeling the Boomerang Core.—To remove, log, and label the Boomerang core proceed as follows:

Step 1. Keeping the core liner in a near upright position, peel the tape from the bottom of the liner and the core catcher. Then remove the core catcher and cover the end of liner with a plastic cap and tape it in place.

Step 2. Put any sediment retained by the core catcher in a sample jar.

Step 3. Peel the tape off the joint between the liner and the valve/release mechanism tube and remove it from the liner. Then, with a saw, make a cut through the plastic liner just above the top of the core sample. Let the water drain off slowly, then finish cutting off the liner. Finally, cap the top of the liner with a plastic cap, and tape it in place.

Step 4. Log the samples (core as one, jar as one) on the Oceanographic Log Sheet-M according to instructions given in paragraph L–39, Oceanographic Log Sheet-M Bottom Sediment Data. In addition under remarks, record the total number of minutes the flashing unit was in operation.

Step 5. Label samples according to instructions given in paragraph L–40, Labeling the Bottom Sediment Sample(s).

Step 6. If the liner used was CAB plastic, coat it with wax according to instructions given in paragraph L–30, Applying Wax to Core Sample Liners.

L–47 Maintenance of the Boomerang Corer.—In general the Boomerang corer requires very little maintenance since the ballast component is never recovered. The float component, however, usually is recovered and should be kept and matched with another ballast component. The following maintenance should be performed on the items in the float component:

Nylon lines and net bag—Rinse with fresh water and dry before storing.

Spheres and spacer—Rinse with fresh water.

Core Catcher—Rinse with fresh water, dry, and oil lightly.

Valve/release mechanism tube—Rinse with fresh water, dry, and oil lightly.

CHAPTER M

CURRENT MEASUREMENTS

M–1 General.—Probably more types of instruments are used for measuring currents than for any other single oceanographic measurement. Devices range from the simple drift bottle to sophisticated electronic instruments.

Types of current-measuring instruments may be divided into four broad and general categories: Free-floating, fixed, tethered, and shipboard. Those in the first category include dye marks and floats or drogues that can be observed from ship, shore, or aircraft. Those in the second category include instruments that are attached to piers, towers, or beacons, or placed on the bottom of rivers, bays, estuaries, and other nearshore areas. Those of the third category include buoys in either deep or shallow water, and those of the fourth category include instruments that can be operated when the ship is underway and/or anchored. Dye marks, drogues; Ekman, Roberts, and Woods Hole (Richardson) current meters; and the Geomagnetic Electrokinetograph (GEK) method of measuring currents will be discussed in this chapter.

M–2 Dye Marks.—Rhodamine-B dye is used to determine current patterns in coastal waters. This technique involves releasing quantities of the dye at a given point and checking the dispersion of the dye by means of visual observation, color photography, or fluorometric measurement. In some applications, divers carry the containers of dye to a predetermined depth and release it, and in other projects, the dye may be dumped over the side of a vessel.

M–3 Parachute Drogues.—The parachute-drogue method of measuring current speed and direction has become increasingly important at the Naval Oceanographic Office during recent years.

In making these observations, an improvised array consisting of a parachute, a length of wire rope, and a lighted, radar reflector equipped buoy is launched from a ship and tracked. Since the parachute sinks to a predetermined depth, opens, and moves with the prevailing currents, tracking the surface buoy and recording time and position results in a record of current speed and direction. This method is very satisfactory for measuring surface and shallow water current velocity, but because of drag force and depth uncertainty, drogues are less accurate for deeper observations. The technique of launching a series of drogues with parachutes at various depths is especially effective where counter currents exist, or where topography may have an influence on currents. The path followed by the drogue will be that of the general water mass, and internal waves or minor current fluctuations generally will not be reflected; however, by recording positions at more frequent intervals rotary tidal currents and changing current patterns can be detected. The

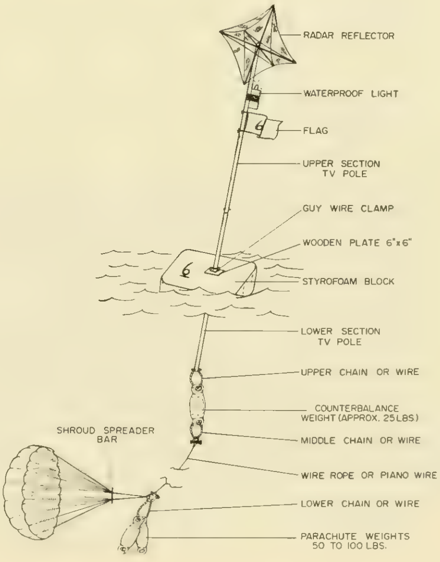


Figure M–1. Parachute drogue array.

parachute drogue array used by Naval Oceanographic Office personnel is shown in figure M–1. The parachutes usually are surplus material; and the aluminum TV antenna poles, styrofoam block, radar reflector and light, chains, connectors, cables, and weights all are relatively inexpensive so that the entire array can be considered expendable if it does eventually sink or become lost. Concrete blocks often are used for weights.

M–4 Assembling the Parachute Drogue.—The components of the drogue should be assembled on deck near the point where the drogue will be put over the side.

Step 1. Assemble drogue according to diagram (fig. M–1).

Step 2. Examine the parachute for tears and rips; fold the chute into the launching carton (a corrugated cardboard carton approximately 12 x 16 x 12 inches) ; separate the chute shrouds and attach the spreader bar.

Step 3. Allow approximately 5 meters of wire rope between the counterbalance weight and the parachute weight when launching a surface drogue. Lower buoy and counterbalance weight into water first; then, lower boxed parachute and weight into water. When launching drogues for greater depth, launch buoy and weight; pay out enough wire rope to obtain desired depth, permitting buoy to drift away from ship; cut wire; attach it to the parachute and weight, and put them over the side.

M–5 Tracking the Drogue.—The most important phase of drogue current measurement operations is tracking the drogue. A position should be taken at the time of launching, and at approximately each hour as long as the drogue is afloat. The best positioning technique is to have the ship come alongside each buoy and take a position; however, an alternative technique is to position the ship and take ranges and bearings to the buoys. Accurate records of time and position are extremely important. A suggested format for logging parachute drogue data is given in figure M–2, and drogue plots are shown in figure M–3.

Often, a marked change in drift or a different attitude of the float indicates that a parachute has been lost or has either opened or closed. Enter unusual changes in drift or attitude of the drogue buoy on the reverse side of the log sheet.

M–6 Retrieving the Drogue.—Generally no effort is made to retrieve the entire array. It is usually the practice to come alongside the buoy, to lift it aboard, and to disconnect the shackle connecting the wire rope. This permits wire, chute, and weights to sink. The buoys may break

PARACHUTE DROGUE LOG

DATE 15 July 1966

LAUNCH SITE NO. 5

DROGUE NO.	14	15	16
LIGHT (COLOR)	White	Red	Green
FLAG COLOR	White	Red	Yellow
FLAG DESIGN	▲ Red	□ White	● Green
DEPTH (METERS)	100	500	1000

TIME (GMT)	POSITION LAT. N	POSITION LONG. W	TIME (GMT)	POSITION LAT. N	POSITION LONG. W	TIME (GMT)	POSITION LAT. N	POSITION LONG. W
1000	34°00′	59°41′	1020	34°00′	59°40.5′	1040	34°00′	59°40′
1130	34°03′	59°42′	1140	34°01′	59°43′	1200	34°02′	59°39′
1230	34°08′	59°42′	1230	34°05′	59°45′	1330	34°02′	59°35′
1410	34°07′	59°40′	1430	34°09′	59°45′	1500	34°05′	59°39′
1600	34°12′	59°40′	1640	34°10′	59°42′	1800	34°05′	59°35′
1850	34°15′	59°45′	1940	34°10′	59°37′	2030	34°05′	59°29′

Figure M–2. Suggested format for parachute drogue log.

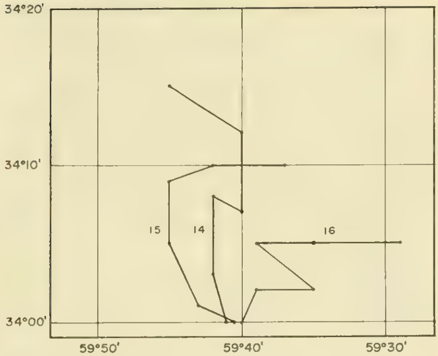


Figure M–3. Drogue plots.

up or sink within a period of several days, and in some cases, the drogues have been lost because they could not be located. Since the above operations are improvised, it is expected that parachute drogue techniques will be improved; nevertheless, the directions given, if followed, will enable inexperienced personnel to obtain excellent results.

M–7 Ekman Current Meter.—The Ekman current meter was developed by Dr. V. Walfred Ekman, a Swedish scientist, whose original design, although modified, remains basically unchanged. The meter, shown in figure M–4, is designed to give current speed and direction at any depth. The speed-measuring mechanism consists of an impeller, or screw, and a shaft connected to a set of dials which indicate impeller revolutions. The direction device consists of a magnetic compass and a compass-ball receptacle. The receptacle is divided into 36 chambers, each representing 10° of azimuth. As the impeller rotates, bronze balls fall, one at a time, from their reservoir onto the top of the compass needle and, depending on the heading of the meter, are guided to one of the 10° direction chambers. This gives the direction *toward* which the current is flowing.

The current meter is lowered by either the oceanographic or bathythermograph winch, using $\frac{3}{32}$-, $\frac{5}{32}$-, or $\frac{3}{16}$-inch wire. The impeller is locked while lowering and hoisting. One messenger is sent down the wire to unlock the impeller and set the meter in operation. A second messenger is sent down to lock the impeller before hoisting. The platform from which the Ekman current meter is suspended should be anchored to obtain valid measurements.

M–8 Assembling the Ekman Current Meter.—The following components, spare parts, and accessories for the Ekman current meter are contained in a carrying case:

Main body of the meter.
One tail section (vane and two brass tubes).
Two impellers and shafts.
Compass box and compass needle.
Two compass-ball receptacles.
Two messengers.
One metal container of bronze balls.
Miscellaneous items including a graduated reading frame, a special wrench, tweezers, bronze-ball loading tube, and small weight.

The meter is assembled for operation as follows:

Step 1. Attach the vane to the two brass tubes (left-hand threads), and attach the tubes to the main body of the meter by right-hand unions. A special wrench is provided for tightening the unions.

Step 2. Open shutter by pressing tripping mechanism arm (A) (fig. M–5). Depress catch (B) and release the impeller forward bearing

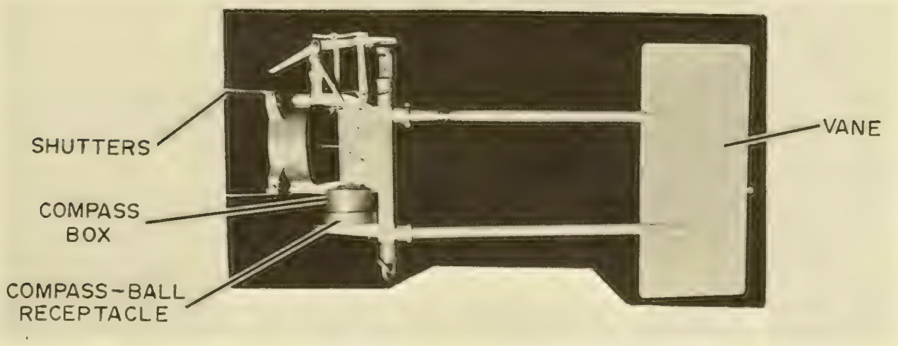


Figure M–4. Ekman current meter.

bar at the front of the meter, and insert the worm gear end of the impeller shaft through the hole in the gear box. Then, engage the impeller shaft in the forward bearing bar and lock the bar in place. The impeller is very delicate; therefore, it must be handled with care.

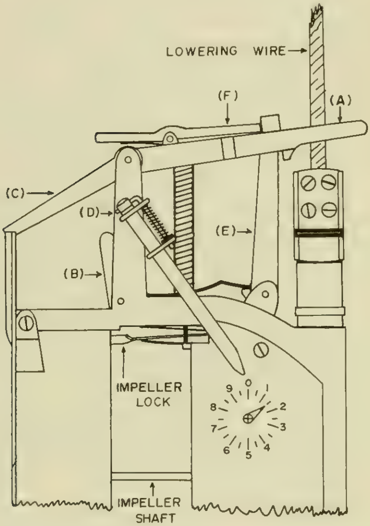


Figure M–5. Trigger mechanism Ekman current meter.

Step 3. Depress the catch located in front of the compass box, and remove the compass box and compass-ball receptacle.

Step 4. Pry off the compass-box cover with small screwdriver, and set the compass needle on the *pivot point* in the compass box. Care should be exercised in handling the meter after this step since the compass needle again could be jarred off of the *pivot point* by an extremely sharp blow or jolt.

Step 5. Replace the compass-box cover with the countersunk center hole up and the small lug on the box in the small notch on cover.

Step 6. Replace compass-box and compass-ball receptacle; close the shutters and lock by engaging arm (C); then, fill the reservoir (D) with bronze balls, using the filling tube.

Step 7. Secure the meter to the lowering wire by tightening the four-screw wire clamp with a screwdriver.

M–9 Operating the Ekman Current Meter.—Ekman current meter operations are recorded in record of current observations for Ekman current meter (fig. M–6).

Step 1. Record: *Current station No.*, *Date*, *General locality*, *Location of station*, *Latitude*, *Longitude*, and other items in the heading of the data record.

Step 2. Set the meter trigger mechanism by compressing the two parts of arm (E), drawing the arm toward the vane, and depressing the long end of arm (F) until it rests against the trigger mechanism arm (A).

Step 3. Make sure that impeller is locked in place, record initial meter reading (upper dial 0 to 100; lower dial 0 to 4000), then lower the meter.

Step 4. When meter is lowered to the desired depth, record depth of observation from meter-wheel reading, taking into consideration any wire angle greater than 5°.

Step 5. Attach a messenger to the wire; release it; and record local time. This messenger open the shutters and unlocks the impeller.

Step 6. After a definite interval of time (usually 10 minutes), attach a second messenger to the wire and release it. Record this interval of time in *Length of Observation* column. This messenger stops the impeller.

Step 7. After permitting sufficient time for the second messenger to reach the meter, allowing 200 meters per minute, hoist the meter to the surface, bring it aboard, and record the final meter reading. Note that dials rotate in counterclockwise direction. The upper pointer makes one revolution for each hundred revolutions of the impeller; the lower pointer makes one revolution for each 4,000 revolutions of the impeller. Care must be taken to keep the meter in a vertical position until the compass-ball receptacle is removed.

Because some Ekman current meters in use may have reverse-pitch impellers, the direction mechanism of each meter should be checked out before the meter is placed in operation. To do this, revolve the impeller by hand until several pellets have dropped into the compass-ball receptacle. Then establish the direction toward which a current would be flowing to turn the impeller, using the impeller pitch, the heading of the meter, and the pellets in the compass-ball receptacle.

M–10 Computing the Current Direction and Velocity.—Current direction and velocity computations are made on the record of current observations (fig. M–6).

Step 1. Remove the compass-ball receptacle, and place it in the graduated-reading frame with the red compartment aligned with zero; then, count the number of bronze balls in each compartment, and record the number and direction in the *Distribution of Pellets* column. Three pellets for each 100 revolutions of the impeller will be dropped in the compass-ball receptacle.

Current station No.: 5
General locality: PANAMA CANAL (PAC)
Location of station:
Latitude: 08°50.75′ Longitude: 79°31.65′

Date: 11 July 1965
Water Depth: 20 meters
Mag. Variation: 4° E

Position angles at station occupied: (Radar)
True bearings of reference objects:
Time meridian:
Tide gage at

SERIAL NO.	TIME LOCAL h. m.	DEPTH of OBS (m) (ft)	LENGTH OF OBS.	INITIAL METER READING	FINAL METER READING	DIFF.	NO. of Pellets	DISTRIBUTION of Pellets NO.	DISTRIBUTION of Pellets DIR.	MAG. DIR.	TRUE DIR.	VELOCITY Knots	VELOCITY Tenths	WIND Dir °True	WIND Vel Knots	TIDE	REMARKS	OBSERVER
1	1730	13	10min	3015	2410	605	19	3	310°	328°	324°		7	090°	5			TMcK
								5	320°									
								4	330°									
								7	340°									
2	1800	13	10	2410	1885	525	15											

NOTE: THESE SHEETS ARE BOUND IN BOOKLET FORM.

Figure M–6. Record of current observations for Ekman current meter. (PRNC NHO 3167/46)

Step 2. Determine the current direction by a system of weighted averages. For example:

	Number of pellets	*Compartment*	*Direction*	
	3	31	310°	930
	5	32	320°	1600
	4	33	330°	1320
	7	34	340°	2380
Total	19			6230

$\frac{6230}{19}$ = 328° Current direction (magnetic)

Step 3. Obtain true direction by correcting magnetic direction by magnetic variation. Compasses with bronze-ball trough on the (BLACK) south-seeking end of the compass produce direction toward which the current is flowing. The ships hull may cause compass deviation.

Step 4. Subtract the final meter reading from the initial meter reading, and enter the difference in *Diff.* column.

Step 5. Compute current velocity by the following equation:

$$\text{Current velocity in knots} = 0.010 + 0.012 \frac{\text{Diff.}}{\text{Length of observation in minutes}}$$

e.g. $0.736 = 0.010 + 0.012 \frac{605}{10}$

Step 6. Round current velocity to 10ths and enter in *Velocity* column.

M–11 Maintenance of Ekman Current Meter.—The Ekman current meter is a delicate instrument, and it requires careful handling. After each current-measurement operation, rinse the meter with fresh water and lightly oil all moving parts.

M–12 The Roberts Radio Current Meter.—The Roberts radio current meter is an instrument designed to measure current speed and direction. As the word "radio" in its name description implies, this meter was designed to be used as a part of a current-measuring system that transmits current data to the observer by radio. When the meter and the system of radio transmission and remote monitoring of the current data were developed by Captain Elliot B. Roberts of the Coast and Geodetic Survey, they were a marked improvement over the other methods of current measurements in use at that time, and the Roberts radio current meter has been used successfully by the Naval Oceanographic Office on numerous surveys for over 10 years. Recently, however, more sophisticated current meters have replaced the Roberts radio current meter in most applications, but because the Roberts meter has been used so extensively in the past and is still being used in some operations, a brief discussion of the meter is presented.

M–13 Principles of Operation.—Three models of the Roberts radio current meter along with the internal mechanism of a meter are shown in figure M–7. The gear mechanism (cut

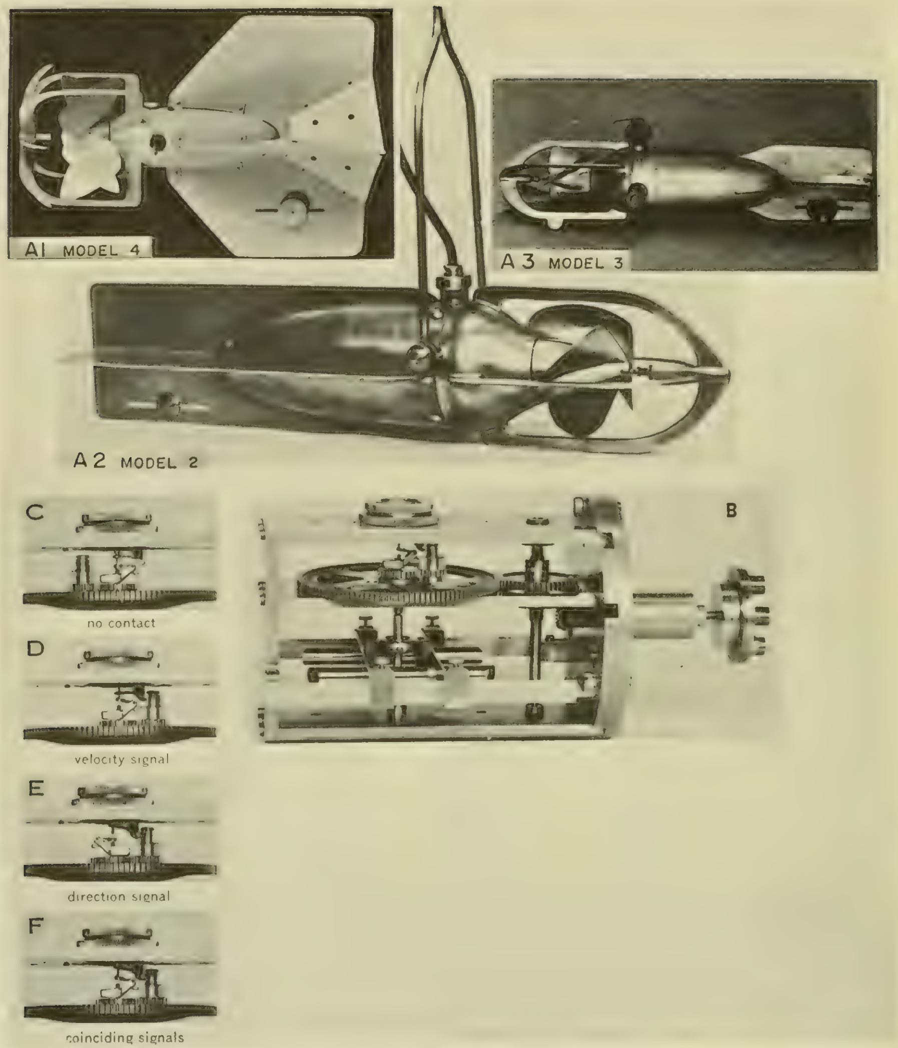


Figure M–7. Roberts radio current meters.

B) is enclosed in a watertight main body of the meter, and the rotation of the impeller is transferred to the gears through the bulkhead by magnetic drive. As the impeller turns, two devices in the mechanism make and break (cut C) an electrical circuit to produce the speed and direction signals (cuts D and E). One device is fixed relative to the meter; the other is connected with a built-in magnetic compass. The fixed device makes contact at each fifth turn of the impeller, the other at every 10th turn. The frequency of the contacts serves as a measure of current speed, and the time relationship of the contacts serves as a measure of current direction.

Speed and direction signals are relayed via watertight cable either to a buoy or to a ship. If the current meters are suspended from an anchored ship, the cable can be brought aboard and meters can be monitored directly. If the current meters are suspended from a buoy, the signals are transmitted by radio and received at a remote-monitoring base station.

M–14 Operating the Roberts Radio Current Meter.—The Roberts radio current meter can be suspended from a buoy and monitored from a remote base station, or it can be suspended from the side of an anchored survey ship. Figure M–8 shows a buoy-operated system with a diagrammatic sketch of the remote base station. Figure M–9 shows a shipboard-operated system with a diagrammatic sketch of the ship recording station. When operating and maintaining the Roberts radio current meter, refer to "Roberts Radio Current Meter Manual," first (1964) edition, publication 30–2, Department of Commerce, Washington, D.C.

M–15 Recording Roberts Radio Current Meter Data.—Roberts radio current meter data can be recorded on any analog recording instrument that will record the make and break electrical contact signals relative to time. Ordinarily, these current data are recorded for a period of approximately 1 minute each 15 or 30 minutes during the time the current station is being monitored. Station number, date, time (local or G.M.T. can be used but should be specified), and meter depth are annotated on the analog record at the beginning of the observation. During the observation, the monitor adjusts the tape speed to ensure that the make and break signals on the tape can be distinguished clearly when the tape is analyzed. After the meters at a station are monitored, the analog tape is analyzed for current speed and direction, and this information is then entered in the record of current meter observations for Roberts radio current meter (fig. M–10).

M–16 Determination of Current Speed and Direction.—To determine current speed and direction, analyze the analog tape as follows (fig. M–11):

Step 1. Enter current station number, general locality, location of station, latitude and

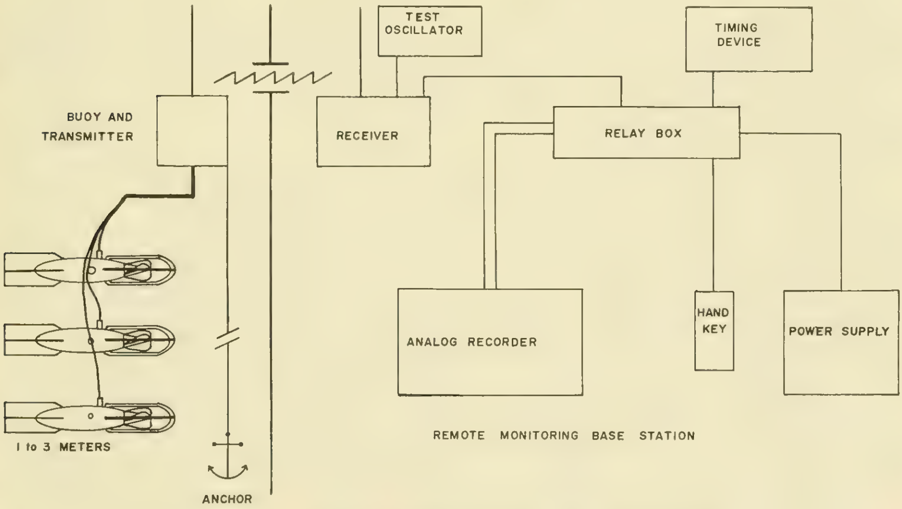


Figure M–8. Telemetering system for Roberts radio current meters.

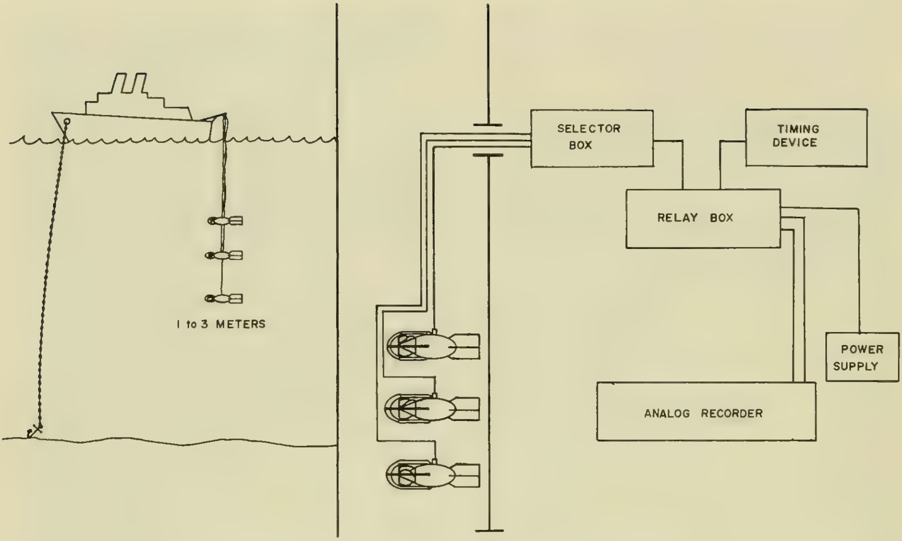


Figure M–9. Roberts current meters suspended from ship.

Current station No.: 62-55

Date: 17 Nov. 1967

Position angles at station occupied:

General locality: PUERTO RICO

True bearings of reference objects:

Location of station: Roos. Rds.

Depth:

Time meridian:

Tide gage at

Latitude: 18°11′39″ N

Longitude: 65°36′42″ W

TIME Z h. m.	Depth of Meter ft.	Number of Revs.	Time in Seconds	Time Interval	DIR. by Meter	Number of Dir. Signals	COMPASS VAR.	DIR OF CURRENT True	VELOCITY by Meter Knots	VELOCITY by Meter Tenths	WIND Dir. True	WIND Vel. Knots	Tide	REMARKS	OBSERVERS
1030	6	2	28	14	40°	1	8°	48°		4	100°	3		meter A	TMcK
	25	3	34	11.3	50°	1	8°	58°		4				B	
	45	3	32	10.6	90°	1	8°	98°		5				C	
1100	6	5	42	8.4	65°	2	8°	73°		5	110°	4		A	
	25	5	39	7.8	45°	2	8°	53°		6				B	
	45	3	35	11.2	90°	1	8°	98°		4				C	
1130	6	7	42	6	55°	3	8°	63°		7	095°	5		A	
	25	8	43	5.3	60°	3	8°	68°		9				B	
	45	6	39	6.5	75°	3	8°	83°		7				C	
1200	6	9	43	4.8	65°	5	8°	73°	1	0					
	25	8	42	5.3	50°	4	8°	58°		9					
	45	2	13	6.5	60°	1	8°	68°		7					
1230	6	8	40	5.0	90°	4	8°	98°		9	100°	4		A	
	25	8	41	5.1	55°	4	8°	63°		9				B	
	45	5	38	7.6	65°	3	8°	73°		6				C	
1300	6	7	39	5.5	75°	4	8°	83°		8	105°	5		A	
	25	7	40	5.7	50°	4	8°	58°		8				B	
	45	5	37	7.4	50°	2	8°	58°		6				C	

NOTE: THESE SHEETS ARE BOUND IN BOOKLET FORM.

Figure M–10. Record of current meter observations for Roberts radio current meter (PRNC–NHO–3167/36).

longitude, date, water depth, etc. on the heading of the log sheet. Enter observation time in *Time* column. Enter depth below the surface of the water that each meter is suspended in *Depth of Meter* column.

Step 2. Label the speed marks (S) and the direction marks (D). At each fifth revolution of the impeller, a speed signal is produced by the meter, and at each tenth revolution, a direction signal is produced.

Step 3. Select a section of the tape where the speed and direction signals consistently follow the above pattern. Number the speed signals in the section and enter the number minus one in the *Number of Revs.* column. Enter the number of seconds in the section in the *Time in Seconds* column.

Step 4. Divide the "Time in Seconds" by the "Number of Revs." to obtain the entry for the *Time Interval* column.

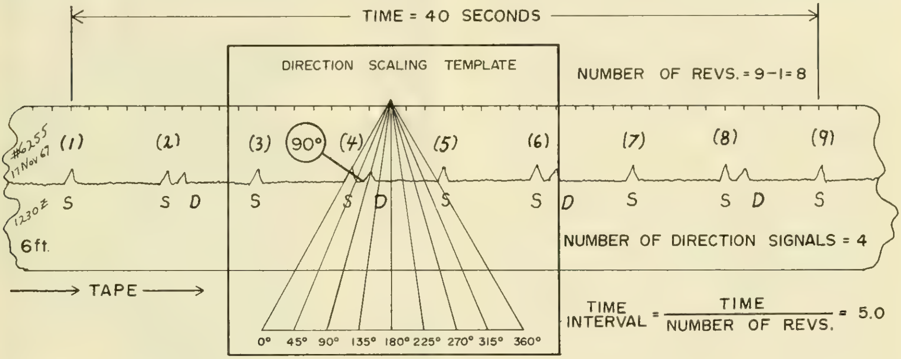
Step 5. Speed in knots is determined from the "Calibration Data for Meters" tables using the time interval. Enter in *Velocity by Meter* column.

Step 6. Count the number of direction signals in the section of tape selected and enter this number in *Number of Dir. Signals* column.

Step 7. Place the direction scaling template 0° and 360° lines at the base of the leading edge of two speed signals on the tape that have a direction signal between them. Read off the direction and enter it in the *Dir. by Meter* column. *NOTE:* A special case sometimes occurs when the direction signals and the speed signals overlap at 0° (North) (Fig. M-7F).

Step 8. Correct the *Dir. by Meter* column entry by using the local compass variation to obtain the entry for the *Dir. of Current True* column. Deviation caused by the ship's hull should be considered if the meter is in the magnetic field of the ship.

M-17 Maintenance of Roberts Radio Current Meter.—During current measurement operations, the meter should be inspected peri-



(abstract of)

CALIBRATION DATA FOR METERS

A: SPEED IN KNOTS	A: TIME INTERVAL	B: SPEED IN KNOTS	B: TIME INTERVAL	C: SPEED IN KNOTS	C: TIME INTERVAL
.9	5.0	.9	5.0	.7	6.5
.8	5.5	.9	5.3	.6	7.0
.7	6.0	.8	5.7	.6	7.4
.6	7.2	.6	7.8	.5	10.6
.5	8.4	.6	11.3	.4	11.2
.4	14.0	.4			

Figure M-11. Computing current speed and direction Roberts radio current meter.

odically. Any rope fibers, grass, or biological growth should be removed from the impeller and impeller bearing, and swivels, electrical and suspension cables, and ground tackle should be checked. When the operation is completed, meters should be rinsed with fresh water. Extensive repairs in the field to the interior mechanism and impeller mount of the meter must be undertaken with caution because calibration data for meters are determined by preset impeller response and magnetic linkage.

M–18 The Woods Hole Oceanographic Institute (WHOI) (Richardson) Current Meter.—The operation of the Geodyne Woods Hole Oceanographic Institute (WHOI) (Richardson) current meter is described in this section of the current meter chapter. Model A–101 of the current meter is used by the Naval Oceanographic Office at the present time (fig. M–12).

This self-contained digital-film-recording current meter measures current speed from 0.05 to 5 knots and current direction within ±10°. The data are recorded photographically at sampling intervals controlled by an internal mechanism, and as many as 4,500 sets of observations can be recorded on a 100-foot roll of film. The current meter may be programmed to operate for a period of several days or several months, depending on the frequency of the observations. The recording mechanism is battery powered, and the meter is constructed to withstand pressures encountered at water depths of 5,000 meters. Figure M–13 shows the location of the main components of the current meter. The intelligence from the sensing devices (rotor, vane, inclinometer, compass, and timing devices) is transmitted as light through optical fibers to the field of view of the camera. These light pipes are referred to as channels. A timing device activates the light circuits, causing the various channels in the field of view to flash and be photographed as a row of dots. The meter can be programmed to operate continuously or at predetermined intervals. When operating on *Interval*, the meter is activated one to 12 times per hour for a 50-second recording period, depending on the cam installed on the time mechanism. The following instructions are presented for guidance in operating the meter.

M–19 Operating the Current Meter.—Before operating the current meter, the battery should be checked, fresh film should be loaded, and the instrument should be inspected carefully. A suggested format for a Geodyne current meter checkout record is presented as figure M–14. Check each item on the sheet as the inspection or installation is completed. In addition, the manufacturer's instruction manual "TM 66–61 (Rev. 9–1–66), Instruction and Maintenance Manual Model A–101 Film Re-

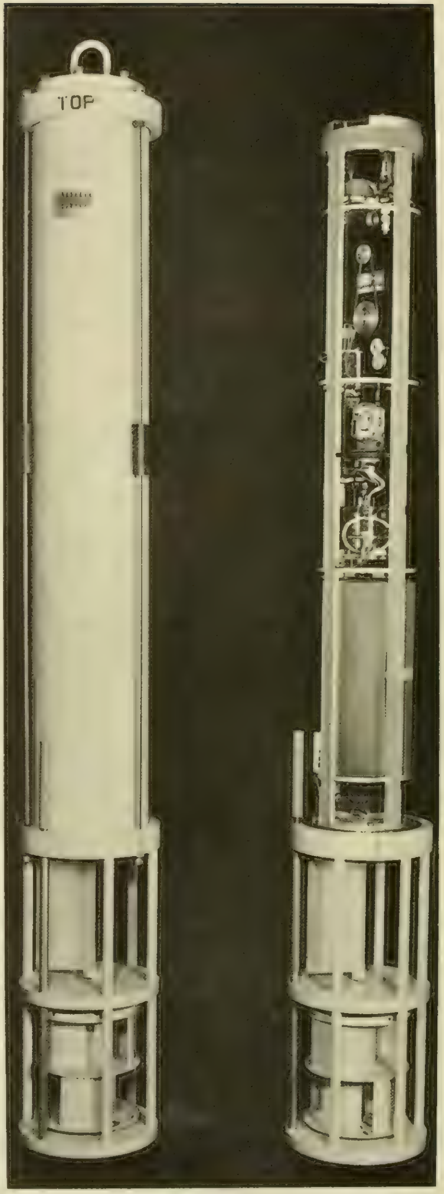


Figure M–12. Geodyne model A–101 current meter.

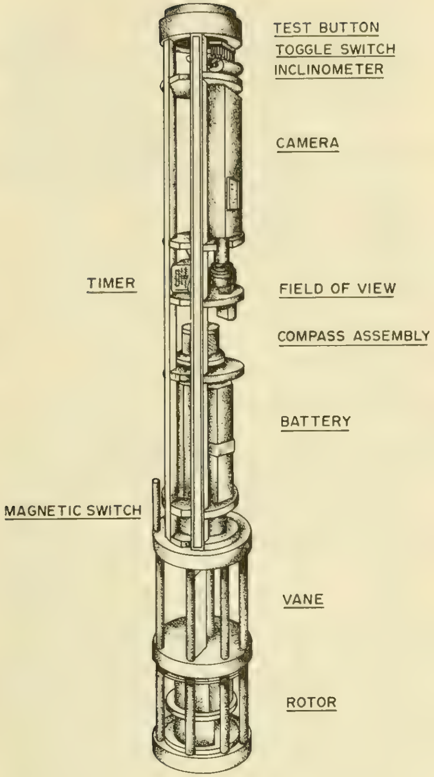


Figure M–13. Main components of the Geodyne current meter.

cording Current Meter" should be used as a reference to supplement these instructions. The following special tools are required:

Vise-grip pliers.
Open-end box wrench.
10-foot-pound torque wrench.
Screwdriver.

1. Checking the exterior of the current meter—

Step 1. Remove the meter from its shipping case, and stand it rotor end down on wooden platform provided in the case. As a safety precaution, always lash the meter to the bulkhead, stanchion, or the overhead. Secure line around pressure case, not to the tie rods.

Step 2. Visually check the exterior of the instrument for rotor or vane damage or bent tie rods. If instrument appears to be damaged, it should not be used.

Step 3. Remove the tape from the rotor and the vane, and inspect rotor and vane for proper bearing play.

The 5-inch red tube positioned on the lower end cap is the On-Off magnetic switch. When the On-Off switch magnet is in place, it causes the internal switch to open and stops the recording mechanism in the current meter.

2. Opening the current meter.—To install the battery, load film, and check out the instrument, the pressure case cylinder must be removed from the meter.

Step 1. With vise-grip pliers, hold the tie rod, and with open-end box wrench, loosen nut on lower end of rod.

Step 2. Remove nuts, lock-washers, flat washers, and fiber washers from the three tie rods, and lift off the upper cap assembly with tie rods. Put the assembly in a place where the tie rods will not get bent accidentally.

Step 3. Remove the on-off switch magnet, then lift the pressure-case cylinder straight up and off the lower end cap and the internal mechanism. Place the pressure case where it will not roll and accidentally injure personnel or be damaged.

Step 4. Place the on-off switch magnet in its holder to keep the instrument from operating, and lash the meter to the bulkhead, a stanchion, or the overhead to prevent damage or personnel injury.

3. Checking the battery.—Power for the current meter is supplied by a 12-volt, dry-cell battery. These batteries are designed specifically for the current meter. At NAVOCEANO, meters usually are shipped with battery installed, but the battery always should be checked each time the current meter is operated.

Step 1. Unsnap the battery-holding strap, slide the battery out of its compartment, and unplug the nine-pin battery connector.

Step 2. Check battery with voltmeter. If battery voltage is not at least 11.5 volts under a 100-ohm load at ambient room conditions (70° F.), the battery should be replaced. A replaced battery should be plainly marked by writing "old" in several places on the case.

Step 3. Check the new battery, as in step 2 above, before installing. Make sure that battery connector is completely seated and that lead wires are placed in clearance space above battery.

Step 4. Check to ensure that battery is connected properly by pressing red test button on top of meter. Secure battery-holding strap fastener.

4. Setting the sequence timer.—The sequence timer is located on the field of view platform. The timer operates on a 1-hour cycle, and a lobed cam which is installed on the 1-hour shaft determines the number of 50-second data records

GEODYNE CURRENT METER CHECKOUT RECORD

METER SERIAL NO.________MODEL NO.________OPERATOR_____________

1. Checking Exterior

   Shipping Case______Tie Rods______Rotor and Vane End Play_______

2. Battery

   Tested__________New Battery Installed____________

3. Sequence Timer__________Number of Lobes on Cam__________________

4. Checking Data Light Row Platen

   #1 Continuous_____________ #2 Inclinometer_____________

   #3-10 Rotor_______________ #11-17 Vane________________

   #18-24 Compass_____________ #25 Reference_______________

5. Loading Film________Pulley (B) rotated 10 to 20 Rev______________

   Drive Gears Checked______________Film Pulley Checked___________

6. Closing Meter

   Lens Cap Removed and Taped in Place______________

   Clean Dust from Lens and Platen_________________

   Dessicant___________Set Toggle Switch____________

   Inspect End Caps and Pressure Case Surfaces_______

   Clean and Lubricate O-Rings_____________________

   Torque and Tie Rods_______Tape Rotor & Vane______

7. Launching Date________Plant No.______Depth of Water______________

   Meter Depth______________Remove Tape____________

   Time On-Off Switch Removed______________(GMT)

   Time Meter in Place_____________(GMT)

   Time Meter was Brought Back on Deck__________________(GMT)

   Time On-Off Switch Attached___________________(GMT)

8. Retrieving

Figure M-14. Suggested format for Geodyne current meter checkout record.

that will be photographed each hour (table M–1).

The A–101 meter is shipped with six interchangeable cams with 1, 2, 3, 4, 6, or 12 lobes. The extra cams and a cam puller are kept with the meter. They are located on the lower side of the inclinometer platform.

Table M–1. Recording time versus recording interval for 100 feet of film (from table 3.2 TM 66–61)

Number of lobes on cam	*Minutes between data cycles*	*Recording time (days)*
1	60	207. 5
2	30	103. 7
3	20	69. 2
4	15	51. 9
6	10	34. 5
12	5	17. 3
At continuous operation		83 hrs.

To install the cam for the desired data cycle proceed as follows:

Step 1. Remove the two screws on the face of the timer, then remove the cam screw from the 1-hour shaft.

Step 2. Place the jaws of the cam puller behind the cam and slowly turn the thumbscrew in a clockwise direction until the cam is removed.

Step 3. Seat the desired cam on the shaft and replace the cam screw and the timer cover.

5. Checking data light row platen display.—Current data are recorded on film by photographing the data light row platen in the field of view beneath the camera lens. Each time the meter pulses, lights flash at the various meter components (rotor, vane, compass, inclinometer, clock, and chronometer), the light is transmitted to the field of view by optical fibers, and the field of view is photographed. The resulting film record (fig. M–15) is a series of spots that can be decoded and processed into current speed and direction. The optical fibers in the field of view should be checked before each operation to determine that all components are functioning properly and that the light is being transmitted to the field of view.

Step 1. Press test button to check light bulbs at compass, vane, and timer. Lights should remain on while the test button is depressed.

Step. 2. Set toggle switch to Continuous. Remove On-Off switch magnet.

Step. 3. Check to see that each optical fiber lights in the data light row platen. Using the following procedures and checking from right to left, with instrument serial number on left, indicate on the check out record that the data light row platen was inspected.

Current meter model A–101 has 25 data lights in the data light row platen.

No. 1 is a continuous channel; it should light during each 5-second pulse for approximately 2 to 3 seconds.

No. 2 is the inclinometer channel. Tilt the meter to check the channel. During one complete film-advance cycle (1 minute), the channel should pulse once for each 5° inclination of the meter, e.g., if the meter is upright, the channel will not light. If meter is tilted 10°, two pulses will light in channel 2. Zero to 35° meter inclination can be recorded.

Nos. 3 through 10 are the speed channels. Spin the rotor by hand altering the speed, and check to see that each of the eight channels light as the number of revolutions of the rotor is totaled each 5 seconds. It is not necessary to check rotor revolution versus lighted channels.

Nos. 11 through 17 are the vane-direction channels. Move the vane through 360° and observe whether each of the vane channels transmits light. These light spots and blanks are coded in gray binary.

Nos. 18 through 24 are the compass channels. Swing the compass 360° using the on-off switch magnet. Observe whether each of the channels transmit light spots and blanks. These are coded in gray binary.

No. 25 is the reference channel. It should light once every 5 seconds for 10 pulses and then not light for two pulses.

Instrument serial number. This number should light on the second pulse of a data cycle.

At each pulse, the sound of the camera drive motor should be audible. For 10 pulses, all channels could light up, but for the last two pulses, of a data cycle only channel 1 should light.

Step 4. If any of the optical fibers fail to transmit light, check the light-pipe connection at the source and at the data light row platen; next replace the complete instrument module involved, i.e., printed circuit, clock, compass, vane follower, or inclinometer.

Step 5. If any of the channels light improperly, replace the malfunctioning module involved.

6. Loading film.—Current data are recorded photographically on 16-mm. Kodak, Double-X Panchromatic, negative, movie film. A 100-foot roll of film will record 4,500 sets of data. A new roll of film should be loaded in the camera of the meter for each current meter plant.

Step 1. Remove camera from the instrument assembly (fig. M–13) by loosening two thumbscrews on the upper side of the inclinometer platform and two thumbscrews on the under side of the camera platform.

Step 2. Remove camera case cover, 2 screws hold cover in place, then remove the O-ring drive belt. See figure M–16.

Step 3. Place film supply reel on shaft (A), pull out about 1 foot of film, and thread it

355-756 O - 70 - 4

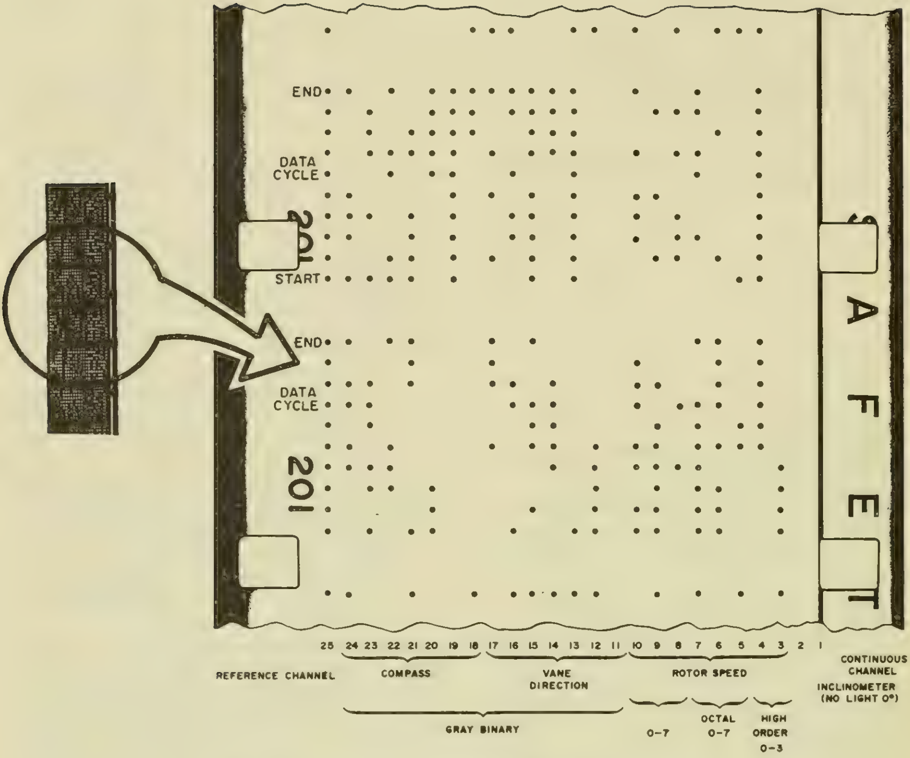


Figure M–15. Geodyne current meter model A–101 film record.

around sprocket(s) and guide rollers with emulsion side (light colored) facing lens.

Step 4. Insert end of film, emulsion side in, into hub slot of takeup reel. Take up a few turns on the reel and snap it onto shaft (B).

Step 5. Check to see that holes in film are engaged with teeth of sprocket(s), and that there is no slack between sprocket(s) and takeup reel. Replace O-ring drive belt, making certain that film is not slack, and that there is no play in the drive belt. Then replace camera case cover and place lens cap on the camera lens.

Step 6. Rotate pulley on shaft (B) 10 to 20 revolutions in counterclockwise direction to place unexposed film behind camera lens.

Step 7. Replace camera case on instrument assembly, making sure that drive gear properly engages worm gear on motor with no chance of slipping or binding. Secure with thumbscrews. *NOTE:* To be sure camera will remain secure during operation, tighten lower screws first. Colder temperatures require that screws be very tight.

Step 8. Check that drive gear is properly aligned and that film is threaded properly. With a pencil, mark the position of pulley (A) on the camera; set toggle switch on Continuous, remove on-off switch magnet, and operate meter for approximately 3 minutes. The pulley should advance in a counterclockwise direction, O-ring belt should have good tension, and pulleys should not have play.

Step 9. The A–101 camera lens is preset. DO NOT ATTEMPT FIELD ADJUSTMENT.

7. Closing the current meter.—When battery is tested and installed, fresh film is loaded, and inspection is completed, the meter should be closed.

Step 1. Remove the lens cap from the camera and tape it to the platform under the timer.

Step 2. Set toggle switch to Interval. The meter will now record for a data block each time a lobe on the timer activates the system.

Step 3. Clean dust from camera lens and data light row platen (use lens-cleaning tissue),

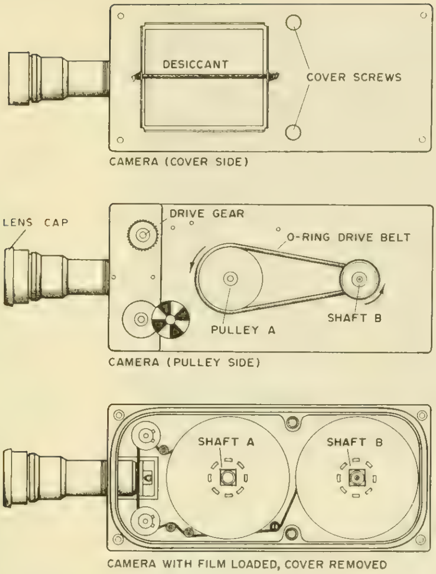


Figure M–16. Geodyne current meter camera model A–101.

and remove plastic bag from desiccant on camera cover.

Step 4. Remove O-rings from grooves in upper and lower end caps. Wipe rings clean of old silicone grease and inspect for scratches, cuts, or breaks. Replace if at all questionable.

Step 5. Clean O-ring grooves of end caps and lubricate and then replace O-rings.

Step 6. Inspect and clean ends of pressure-case cylinder; then, lower it down over the instrument. Check for proper seating of the cylinder on the lower end cap.

Step 7. Next, line up tie rods with holes in lower end cap, and lower the upper-cap assembly onto the pressure-case cylinder. Seat the end cap carefully and replace fiber washers, flat washers, lock washers, and nuts to the tie rods.

Step 8. With vise-grip pliers and open-end box or torque wrench, tighten the rod nuts to 10 to 15 foot-pounds, making sure that the rods are straight with meter axis.

Step 9. Tape vane and rotor to prevent their turning. Replace the On-Off switch magnet to inactivate the current meter.

8. Launching or planting current meter.—The (WHOI) (Richardson) current meters have been used successfully by Naval Oceanographic Office oceanographers in both deep water and shallow water. Figure M–17 shows the technique used to measure currents in areas where water depths permit divers to plant the meters on bottom-mounted tripods. This method has been extremely satisfactory because divers are able to inspect the meters from time to time to insure that the rotor and vane are functioning, to remove any organisms that may be fouling the meter, and to listen with a stethoscope to insure that the internal mechanism is operating. In deeper waters, the most satisfactory method of measuring currents at multiple depths with the meters is the mooring array shown in figure M–18.

Nylon lines ($^9/_{16}$-inch) are shackled to the meters, and anchor-first and free-fall techniques both have been used successfully in planting current meter arrays.

The most frequent causes of instrument operational failure are:

Improperly loaded film.
Failure to remove lens cap.
Improperly seated pressure case on O-rings.
Failure to remove the tape from vane and rotor.
Failure to remove the On-Off switch magnet.
Binding of gear drive or movement of camera.

NOTE: Always use the check-out sheet and avoid failures of careless oversight or neglect.

9. Opening the meter to obtain current data record.—

Step 1. As soon as the meter has been brought aboard the survey vessel, tape the vane and rotor, and open the meter following procedures outlined in steps 1, 2, 3, and 4 of paragraph 2. *NOTE:* Permit meter to come to ambient temperature before opening, or rinse with warm water; otherwise, condensation may damage the film.

Step 2. Remove the lens cover from the place where it was taped beneath the compass and cover the camera lens.

Step 3. Remove the camera case from the assembly by removing the four thumbscrews that hold camera in place.

Step 4. Rotate pulley B counterclockwise until there is no drag. The film is then all on the takeup spool.

Step 5. Open the camera case, grasp the outer edges of the takeup reel, apply thumb pressure to the center of shaft (A), and snap out the reel.

NOTE: It is not necessary to annotate the instrument serial number on the film since the number is photographed following each data block.

Step 6. Put exposed film in film can. Seal can with tape and place in film box. Label film can and box clearly with instrument serial number, recording location, launching and retrieval dates and time, and project or operation identifying numbers. Developed films are processed

Figure M–17. Divers planting Geodyne current meter on tripod.

with special equipment and data are decoded by computer.

To facilitate computer processing and analysis of the data, various data-identifier information should be logged when making current meter observations. A suggested format for a Geodyne current meter log sheet is presented in figure M–19.

M–20 Maintenance of Current Meter.—The current meter requires relatively little maintenance. After the meter is retrieved and the data-record film is removed, close the meter, wash the exterior with fresh water and dry, tape the rotor and vane to prevent turning, and replace the meter in the shipping case.

If flooding has occurred while the meter was submerged, the data record will usually be ruined, depending on the extent of the flooding. Nevertheless, to salvage the current meter components, remove components (camera, clock, etc.) from the instrument assembly, rinse with

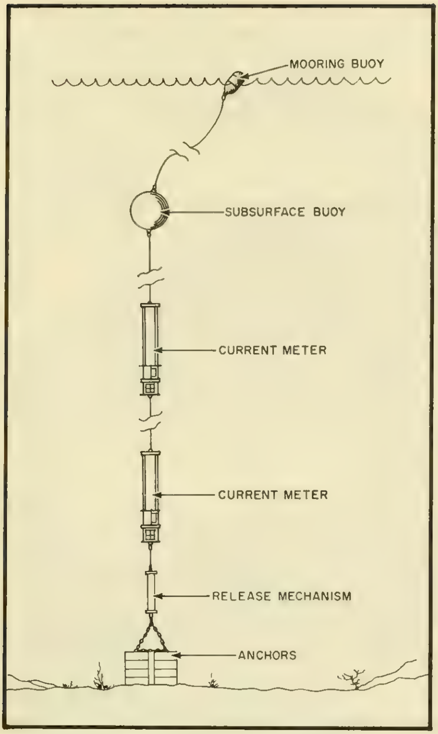


Figure M–18. Geodyne current meter array.

alcohol and dry; then rinse the instrument frame with fresh water and dry and reassemble the components, close the meter and place the meter in the shipping case for return to the Naval Oceanographic Office.

M–21 Geodyne Current Data Record Analysis.—Geodyne current data record films are returned to the Naval Oceanographic Office for developing and analysis. Automatic data-processing equipment is used to decode the binary record, and the computer analysis yields data printout sheets, strip charts, histograms, and direction and speed versus time plots. In addition, spectrum analysis, harmonic analysis, and frequency-distribution analysis are performed by computer.

M–22 The Geomagnetic Electrokinetograph (GEK).—The GEK is a shipboard current measuring device designed to record the electrical potential developed by the movement of an electrical cable and an electrolyte (sea water) through the earth's magnetic field (fig. M–20). The GEK measures the net current (i.e., the surface current minus the average currents to the bottom).

The essential physical equipment constituting the instrument is:

1. A matched pair of electrodes mounted 100 meters apart on a two-conductor cable long enough (ordinarily two or three times the length of the ship) to stream them astern, away from the magnetic and electrochemical influences of the ship.
2. A recording potentiometer assembly to which the cable is connected.
3. A gyrocompass repeater, mounted above or close to the recorder assembly.

With the above equipment, observations of the potential difference developed in the cable are made when the ship is underway. These potential differences result from the athwartship motion both of the cable and of the water through the earth's magnetic field. They are rigidly related to the set and drift of the ship and thus of the trailing cable. The potential difference changes sign when currents set the ship to port or starboard. The magnitude of the potential difference depends on the rate of drift normal to the course, on the length of cable between electrodes, on the local strength of the vertical component of the earth's magnetic field, and on the vertical distribution of water velocities at the location. Through measurements of the potential differences on two courses nearly at right angles, the drift or component velocities in these two directions are determined. The vector sum or resultant of these velocities is the net current vector for that locality.

NOTE: Near the magnetic equator where the vertical component of the earth's magnetic field is very small, small vertical water motions may interact with the horizontal component of the earth's magnetic field to produce large fictitious GEK signals. If measurement errors from this source are to be kept below 10 percent, it is advisable not to rely on GEK measurements made within approximately 200 miles of the magnetic equator.

M–23 GEK Models.—Navy survey ships have two models of the GEK in use. The earlier type was developed and constructed at the Woods Hole Oceanographic Institution (WHOI) and is referred to as the WHOI model. The later type is called GEK Model V. Although the two models operate in almost the same manner, there are minor differences in locations and arrangements of operating switches and dials. The GEK model V (fig. M–21) is more compact than the earlier WHOI model. Both use Speedomax type-G recorders. Operation and maintenance manuals for this type recorder are supplied by the manufacturer.

GEODYNE CURRENT METER LOG SHEET

CRUISE ________ PROJECT ________ AREA ________

POSITION: LATITUDE ____ ____ ____ ____ NAVIGATIONAL NOTES:

LONGITUDE ____ ____ ____ ____

STATION NO. or ID

CONSEC. STATION NUMBER ________

DEPTH TO BOTTOM ________ ◯ meters ◯ feet ◯ fathoms

DEPTH TO ROTOR ________ ◯ meters ◯ feet ◯ fathoms

TYPE OF MOORING ________

RECORDING MODE ________

METER NUMBER ________

AXIS ROTATION ________

DATE OF PLANT DAY ____ MO ____ YR ____

START PLANT ________ ◯ ZULU ◯ local

END PLANT ________ ◯ ZULU ◯ local

MAGNETIC VARIATION ________

NOTES:

DATE OF RECOVERY DAY ____ MO ____ YR ____

START RECOVERY ________ ◯ ZULU ◯ local

END RECOVERY ________ ◯ ZULU ◯ local

NOTES:

TOTAL HOURS OF OPERATION: ________

Figure M–19. Suggested format for a Geodyne current meter log sheet.

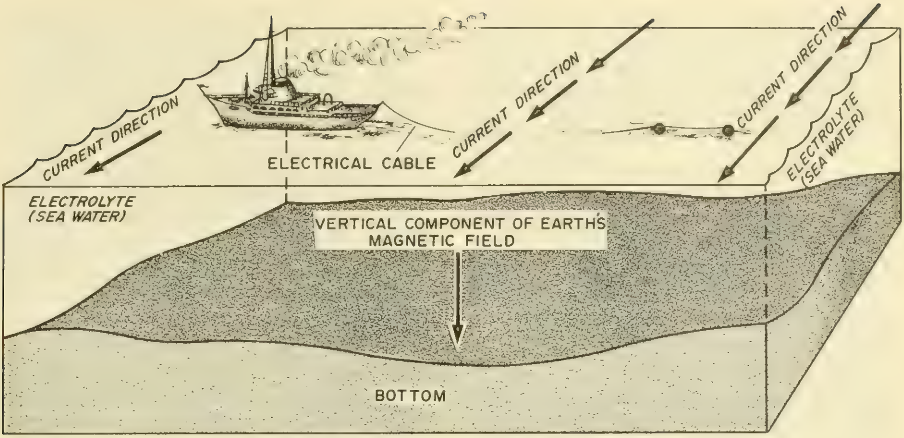


Figure M–20. Measuring currents with the GEK.

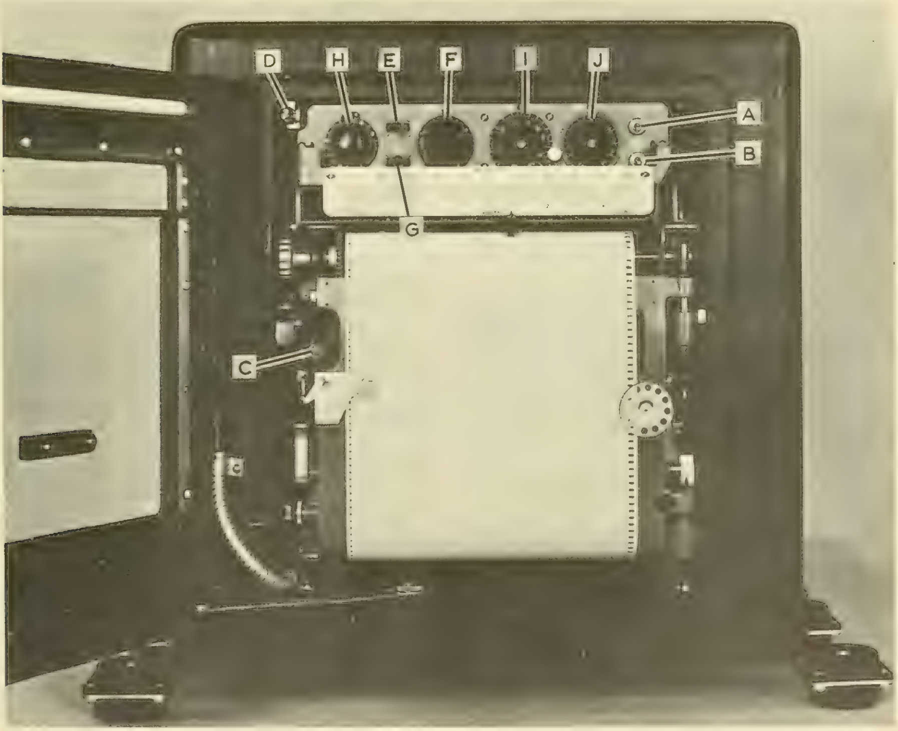


Figure M–21. GEK model V showing location of operating switches and dials.

The following spare parts are needed to operate and maintain the GEK:

- Spare cable with electrodes.
- Electronic service kit with a spare set of electron tubes for servicing the amplifier.
- Spare 1.5-volt dry cells.
- Spare glass pen with stopper and cleaning wire.
- Bottle of red recorder ink.
- Spare strip-chart rolls.
- Instruction manual, "Directions for Speedomax Type-G Recorders."

For normal operations, a medium-size screwdriver and a pen cleaner are all that ordinarily are needed.

The power required to operate the GEK usually is 110 volts, 60 cycles, AC, with a power consumption under 100 watts.

M–24 Isolation Transformer.—It is necessary to isolate the power with an isolation transformer to block any possible DC leakage that may be present on the lines. The voltage and frequency of the input power should be monitored to minimize any variation of timekeeping on the synchronously driven strip chart. Moreover, monitoring assures maintenance of optimum sensitivity of the recorder amplifier, which is slightly sensitive to supply voltage. All components of the power supply and the instrument side of the isolation transformer should be insulated from the ship.

M–25 Signal Input Leads.—The signal input leads connect the overside cable and electrodes to the recording potentiometer. They must be shielded and insulated from the ship.

M–26 Recording Potentiometer.—The potentiometer component is a recorder having a 2-second pen movement and 1/5-inch-per-minute basic strip-chart speed. The upper part of the instrument scale and the strip chart is calibrated in centimeters per second and the lower part in knots. A set of the ship to port is indicated to the left and starboard set to the right of the instrument zero at the center of the scale.

M–27 The Cable.—The primary function of the cable is to bring aboard a signal from far enough astern to be unaffected by the ship's magnetic field. The clearance between the ship and towpoint should be sufficient to allow the cable to pass clear of the stern even during rapid turns. An outhaul to the end of the boom permits convenient handling in streaming and retrieving the cable when underway. In streaming the cable, it is necessary to avoid kinks and to keep the cable clear of the screw. The cable may be towed in the ship's wake without adverse effect on the data because the turbulence in the wake usually is too small and too rapid to be resolved. Nevertheless, towing from a port or starboard boom is the preferred practice since it causes less damage to the cable.

M–28 Cable Connections.—Cable connections to the recorder should be made according to the following convention for the northern magnetic hemisphere: the conductor leading to the more distant electrode is connected to the input terminal which is made positive and gives a right-hand deflection of the pen. This convention allows the observer facing the recorder to see the pen on the same side of zero as the direction toward which the ship is being set. The connections must be reversed in the southern magnetic hemisphere to have the same convention apply.

M–29 Electrodes.—The electrodes have been specially lagged in order to withstand repeated changes of salinity and temperature. Allow at least 30 minutes wetting time on deck before the first towing of the electrodes. The electrodes then will require only about 5 to 10 minutes towing before they respond. It is not necessary to rewet the electrodes before additional towing even though they may have been on deck several hours.

NOTE: Care must be exercised not to inadvertently apply an electric potential to the GEK-towed electrodes, either from an external source such as an ohmmeter or from galvanic effects, since the electrodes may become polarized and exhibit a permanent bias potential beyond the range which the equipment can accommodate. For this reason, the following precautions must be observed: Do not ground the electrodes or the towing cables at any point; do not allow wet electrodes to come into contact with a metal surface, such as the ship's deck, because of galvanic potentials that may be developed; when electrodes are being soaked in salt water on deck prior to or between launchings, be sure that the container holding the salt water is of nonmetallic material (e.g. a plastic or wooden bucket).

M–30 Operating the GEK Model V.—Operation of the GEK Model V is carried out in the following manner.

Step 1. Rig out the boom and stream the electrodes. Connect a 10-foot piece of 3/8-inch manila line to the outboard electrode to dampen its oscillation.

Step 2. Turn the POWER switch (A) and the PAPER MOTOR switch (B) on the panel of the GEK recorder (fig. M–21) to OFF (DOWN) position.

Step. 3. Plug in the electrodes at the input terminals, turn on the 110-volt AC power supply, and turn POWER switch (A) to ON position.

Step 4. Move PAPER MOTOR switch (B) to ON position.

Step 5. After 1 minute of power-on, turn the SEMIAUTOMATIC CURRENT ADJUSTOR (C) clockwise for an instant and repeat until the recorder pen does not respond. The pen should now rest at zero in the center of the chart paper.

Step 6. Turn the SENSITIVITY CONTROL knob (D) clockwise all the way, and then return it to the point where the pen ceases to quiver.

Step 7. Set the FILTER TIME CONSTANT switch (E) to the center position RC = RC.

Step 8. Set the VERTICAL INTENSITY knob (F) to the value of the nearest standard isodynamic line shown on H.O. Chart No. 1702 for the position of the ship at the time of the observation.

Step 9. Set the FILTER SHORTING switch (G) to the center position SUPPRESS WAVE.

Step 10. Set the FILTER RESISTANCE dial (H) on zero; then, increase the setting until the wave signals are sufficiently suppressed to give a readable trace. Do not suppress the wave signal excessively as this will make the pen response too sluggish. An oscillation with a range of about 15 cm./sec. is best. In rough weather when heavy wave signal suppression is needed and after the ship has completed a turn, it is well to examine the wave signal without suppression from time to time. To do this, move switch E momentarily to the RC=0 position. In case a capacitor is faulty or the sea is on the beam, the suppressed signal will not coincide with the densest part of the unsuppressed signal. If a change of FILTER RESISTANCE dial (H) has no affect, the asymmetry is the result of the wave direction.

Step 11. Adjust the SIGNAL MULTIPLIER (K factor) dial (I) to increase the amplitude of the input signal to correct for effects of subsurface currents. The correct setting of the dial is determined as a function of the vertical-water-velocity profile. For water deeper than 75 fathoms and where tidal motions are weak, the SIGNAL MULTIPLIER dial should be set at 1.10. At depths of less than 35 fathoms and where tidal currents predominate, the dial should be set at 2.0. Between 75 and 35 fathoms adjust the dial between 1.10 and 2.0.

Step 12. Before the initial base-course run is begun, set switch (G) to ELEC. SHORT position, and adjust the recorder pen to the instrument zero point by use of the ELEC. ZERO dial (J). Return switch G to SUPPRESS WAVE position. Once the setting is made on dial J, it should not be changed during the period of the current observation.

NOTE: In the vicinity of such features as the westerly boundary of the Gulf Stream, the changing temperature and salinity may shift the zero point at each crossing. Study the zero-point trends, and if necessary adjust the zero point before the GEK run so that it will shift symmetrically about the instrument zero with each crossing.

M–31 Maneuvering the Ship for the GEK Observation.—The course the ship is required to steer for a GEK observation is determined by the requisites: (a) That potentials must be measured on at least two headings at right angles if possible and (b) that because of electrode polarization, the electrodes must be reversed end for end for each current fix to determine the zero point. This zero point is the average of the two voltages obtained by making a 180° course change. A current fix is accomplished by executing a steaming pattern as follows (fig. M–22):

Step 1. After the electrodes have become thoroughly soaked and the pen motion has steadied, remain on base course for 4 minutes.

Step 2. Change course 90° and run for 4 minutes after the electrodes steady-on the new course. This is the first fix-course.

Step 3. Change course 180°, turning in the direction of the base course, and run for 4 minutes after the electrodes steady-on the new course. This is the second fix-course.

Step 4. Change course 90° and resume the base course. Run for 4 minutes after the electrodes steady-on the base course to obtain the resumed base-course data.

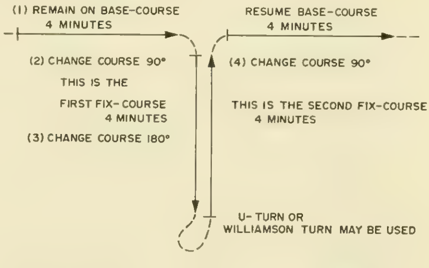


Figure M–22. Directions for executing a GEK current fix.

M–32 Recording the GEK Data.—GEK data obtained by executing the current fix are recorded on oceanographic log sheet—GEK (fig M–23), and certain items of the data are annotated on the recorder strip chart (fig. M–24). Print all entries accurately and neatly.

Instructions for filling in the log sheet and annotating the recorder chart follow:

Step 1. On the log sheet and the recorder strip chart, enter the ship's name and number,

OCEANOGRAPHIC LOG SHEET - GEK
PRNC-NHO 3167/7 (Rev. 5-55)

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

ELECTROMAGNETIC CURRENT OBSERVATIONS
For use with H.O. Pub. No. 607

VESSEL	CRUISE	YEAR	SURFACE GEOMAGNETIC ELECTRO-KINETOGRAPH NO.	COMPUTED BY	CHECKED BY	
USS SAN PABLO (AGS-30)	Project 290	1965	GEK mod V	J Beller	S Oliver	29 August 1965

Specify algebraic signs and units of all measurements. In northern magnetic hemisphere The current velocity vector lies 90° to the RIGHT of the resultant electric signal vector, and the more distant electrode should be connected to the POSITIVE input terminal. Consult H.O. Chart No. 1702 for local value of H_z and set recorder scale to value of nearest standard isodynamic line.

GEK SERIAL NO.	DATE (Day, Month)	HOUR (GMT)	POSITION OF CURRENT FIX: LATITUDE (N or S)	POSITION OF CURRENT FIX: LONGITUDE (E or W)	SHIP'S AVERAGE SPEED (Knots)	DEPTH OF WATER	VERTICAL MAGNETIC INTENSITY (Millioersteds): STAND I	VERTICAL MAGNETIC INTENSITY: LOCAL II	INITIAL BASE-COURSE: DIR. (°T) III	INITIAL BASE-COURSE: SIG. (cm/sec) IV	FIRST FIX-COURSE: DIR (°T) V	FIRST FIX-COURSE: SIG (cm/sec) VI	SECOND FIX-COURSE: DIR (°T) VII	SECOND FIX-COURSE: SIG (cm/sec) VIII	RESUMED BASE-COURSE: DIR. (°T) IX	RESUMED BASE-COURSE: SIG (cm/sec) X	ZERO POINT (cm/sec) XI	AVERAGE BASE-COURSE SIGNAL: MAG (cm/sec) XII	AVERAGE BASE-COURSE SIGNAL: DIR. (°T) XIII	AVERAGE FIX-COURSE SIGNAL: MAG (cm/sec) XIV	AVERAGE FIX-COURSE SIGNAL: DIR. (°T) XV	RESULTANT SIGNAL VECTOR: MAG. (cm/sec) XVI	RESULTANT SIGNAL VECTOR: DIR. (°T) XVII	CORRECTION TO STANDARD ISODYNAMIC LINE (Multiplier) XVIII	CURRENT VELOCITY: SPEED (cm/sec) XIX	CURRENT VELOCITY: SPEED (Knots) XX	CURRENT VELOCITY: DIR (°T) XXI
1	13 Aug 65	0354	39°06'N	71°15'W	13 5	1480	0 5	0 520	138	-5	228	-75	048	-50	138	-1	-62 5	+59.5	138	12	048	60	126	1 00	60	1.17	216
2	13 Aug.65	1647	37°22'N	70°27'W	13 5	2550	0 5	0.510	030	30	120	-122	300	60	030	32	-31 0	62 0	030	91	300	111	334	1 02	113	2 20	064
3	14 Aug.65	0245	36°59'N	70°15'W	13 5	2590	0 5	0 510	050	-15	140	-153	320	145	050	-15	-4.0	11 0	230	149	320	149	316	1 02	152	2.95	046
4	14 Aug 65	1246	35°33'N	70°11'W	13.5	2500	0 5	0 510	180	45	270	53	090	41	180	51	47 0	01.0	000	4	270	4	282	1.02	4	0.08	012
5	15 Aug 65	0046	36°11'N	70°06'W	13 5	2550	0 5	0 510	015	75	105	-65	285	85	015	40	10 0	47 0	015	75	285	90	318	1.02	92	1.79	048
6	26 Aug.65	1044	44°27'N	30°16'W	13 5	2450	0 5	0 510	090	-20	180	-85	000	122	090	-25	18 5	41 0	270	104	000	112	339	1.02	114	2.21	069
7	26 Aug.65	1345	44°27'N	30°25'W	13 5	2550	0 5	0.490	010	25	100	38	280	-70	010	17	14.0	07 0	010	24	100	25	081	1.06	26	0.51	171
8	27 Aug.65	1420	43°58'N	29°42'W	12 0	1350	0 5	0.480	034	-147	124	-157	304	-749	034	-149	-153 0	05 0	034	4	304	6	355	1.08	6	0.12	085

GEK MEASURES SURFACE CURRENT MINUS AVERAGE CURRENT TO BOTTOM

EQUATIONS

$XI = \frac{1}{2}(VI + VIII)$

$Y = \frac{1}{2}(IV + X) - XI$
$XII = |Y|$

$XIII = III$ if $Y \geq 0$
or $= III \pm 180°$ if $Y \leq 0$

$XIV = |VI - XI|$

$XV = V$ if $VI \geq VIII$
or $= VII$ if $VI \leq VIII$

*$XVI = \sqrt{XII^2 + XIV^2}$

*$\tan A = XIV/XII$

*$XVII = XIII + A$
If $XIII + 90° = XV$
or
*$XVII = XIII - A$
If $XIII - 90° = XV$

*May be computed on Mark 3a Plotting Board

$XVIII = 1.04 \times I/II$

$XIX = XVIII \times XVI$

$XX = .0194 \times XIX$

$XXI = XVII + 90°$
if $II > 0$
or
$XXI = XVII - 90°$
if $II < 0$

REMARKS

Figure M–23. Oceanographic log sheet—GEK.

Figure M-24. Annotating the GEK record.

cruise name and number, the GEK instrument number, the GEK serial number or consecutive number for each fix, commencing with the numeral 1 for the first fix of each cruise, the day, month, year, and the hour and minute (G.M.T.) for the beginning of the current fix; i.e., the start of the 4-minute run on the initial base course.

Step 2. Record, in the *Vertical Magnetic Intensity* column the F dial setting (Stand I) of the GEK at the time of the current fix and the standard isodynamic value (Local II) for the position of the current fix taken from H.O. Chart 1702, the vertical intensity of the Earth's Magnetic Force. Record to the nearest 0.005 oersted. On the strip chart, enter the wave-signal suppression, the FILTER RESISTANCE dial (H) setting, e.g. C=0.

Step 3. Record the Initial Base-Course Direction III in degrees true and Signal IV in centimeters per second. The signal is obtained from the chart during the 4 minutes prior to the first course change. The instrument zero is the centerline of the strip chart and the range is plus and minus 250 cm./sec. to the right and left respectively of this line.

Step 4. Record the First Fix-Course Direction V in degrees true and the Signal VI as in step 2 above, and annotate the recorder chart with the course change as follows:

$$\frac{138^\circ \text{ T}}{228^\circ \text{ T}} 0358\text{Z}$$ (GEK serial No. 1 fig. M-23).

If the wave signal suppression is changed during a run, annotate the strip chart as follows:

$$\frac{\text{C } 0}{\text{C } 2}(\text{G.M.T.}).$$

Step 5. Record the Second Fix-Course Direction VII and Signal VIII as above.

Step 6. Record the Resumed Base-Course Direction XI and Signal X as above.

Step 7. Record depth of water in meters or fathoms using Sonic depth at the time of the beginning of fix, the ship's position at the time of the beginning of the fix, and the ship's average speed in knots during the fix.

During a GEK run, the operator should be alert for spurious records caused by cable failures.

NOTE: Use one line for each GEK serial No., and use remarks section to enter significant information concerning depth, wind direction, and sea state.

M-33 Reading the GEK Strip Chart.—In reading the voltage signals on the strip chart, some variability of results will be inevitable from person to person. The principal sources of this variability arise in making estimates of the average voltage due to the mean water current through the confusion of turbulence and wave signals and in making estimates of each turn signal. Better results are obtained in determining the average voltage if done entirely by eye without the use of pencil marks or a ruler. Estimation of the beginning and end of a turn signal can be aided by measuring the interval of time during execution of a turn. Inasmuch as the electrodes are towed at a considerable distance behind the ship, there is a lag in the electrode's turn signal. Thus the electrodes do not steady on the new course for a minute or so after the ship has steadied and similarly do not commence their turn when the ship commences turning. The turn signal lasts as long as the ship's turning time and is received approximately L/C_3 minutes after the ship has commenced turning. L is the length in meters of the cable towed astern, and C_3 is the ship's speed in meters per second. Anticipating and marking the beginning and ending of the turn signals as they occur will improve the consistency of interpretation of the data, both at sea and in later study of the records. It is well to be extravagant in delineating the turn signals, for if the voltage shift on the two courses is large, both the electrodes and the capacitors in the wave-signal suppressor (filter resistance) must have time to come to equilibrium.

Best results are obtained if the first half of a fix signal is viewed with suspicion and greatest weight is given the latter portion of the trace when the ship's heading, the electrochemical system of the electrodes, and the capacitors in the wave-signal suppressor system have all had time to come to equilibrium. Although instrument zero lies in the center of the chart paper, the electrode zero point does not necessarily coincide with the instrument zero point, unless adjusted by the electric zero control.

M–34 Computing the Current Fix.—To compute the current fix, complete oceanographic log sheet—GEK, using the values obtained during the run and the equations given on the log sheet.

M–35 Securing the GEK.—After a current fix, secure the instrument by turning the PAPER MOTOR switch (B) and the POWER switch (A) to OFF (DOWN) position. In addition move FILTER SHORTING switch (G) to the CAP. SHORT position. This short circuits the capacitors and releases any accumulated dielectric strain. If the ship is to be stopped before taking the next current fix, the cable also must be retrieved. In the case of a long cessation of operations, the AC power supply should be unplugged from the recorder, and the automatic current adjuster should be taken out of the operating (standard cell) position, by unlatching the chart-drive-reroll and releasing the standard cell connection.

M–36 Maintenance of the GEK.—Both routine and special maintenance for the recording unit are described in detail in the direction manual supplied with the instrument.

1. The parts of the recorder are easily accessible. The door opens wide to the left. The chart-drive-reroll unlatches to swing out to the right, bringing the chart to a handy position for replacement and exposing the main slidewire. With or without the chart-drive-reroll latched in place, the entire assembly swings out around the same hinge making the balancing motor, paper-drive motor, standardizer, and dry cell completely accessible. Amplifier, fuses, and terminal boards are then exposed on the back of the recorder case. To inspect the amplifier, remove the entire unit from the case.

2. A roll of strip-chart paper is 120 feet long. It is driven at a speed of ⅕ inch per minute; consequently, it should last for about 5 days of continuous operation. Note how the roll in the instrument is threaded through the guides so that the fresh roll can be threaded properly when it is necessary to change rolls. Sometimes the paper on the takeup roll tends to bunch or bind at one end. This can be straightened by adjusting the thumbscrew at the left end of the feed roll until both edges of the paper line up in the slot cut in the platen above the telltale wheel at the right. Badly bunched paper should be rerolled before adjusting the thumbscrew.

3. If the pen stops inking while it still contains ink, moisten a finger and draw it across the penpoint. If this fails to start the flow of ink, remove the pen from the carriage, and push a fine wire through the point to clean out any particle clogging it. If the ink still does not flow, install a new pen. Place the clogged pen in alcohol or hot water for an hour or so. Remove the pen from the solution, and insert a cleaning wire as previously directed. Then fill the pen with alcohol or warm water, and blow the liquid out through the penpoint. Allow the pen to dry thoroughly before using.

4. In case of cable and/or electrode failure the entire unit of cable with electrodes must be replaced. Since the electrodes are matched and balanced very carefully, any damage to one electrode requires replacement of both. However, fish bites or cable insulation leaks can be repaired with rubber tape and covered with electronic tape.

To check the cable while underway, first, place a voltmeter between one of the cable leads and ground. The meter should read between 0.5 to 0.7 volts. No voltage indicates a break in the cable or an electrode failure. *NOTE:* Never place an ohmmeter across the cable leads.

5. The junction box, where the cable plugs into the recorder line, usually is located in a relatively exposed position. It must be kept dry and clean as it is likely to be the principal source of instrument failure.

6. To insure proper operation of the GEK, always be certain that:

a. The conductor leading from the more distant electrode (black lead wire in the electrode string) is connected to the positive input terminal when operating in the northern hemisphere (see paragraph M–28).

b. The dry cell in the recorder is in good condition. A small indicator at the left edge of the strip chart shows a red signal when a new dry cell is needed; however, if any difficulty is experienced in zeroing the pen, install a new dry cell even though the red signal is not showing.

c. The junction box is dry and its contact bright.

d. The cable is plugged in properly at the junction box when the instrument is in operation.

e. The recorder is not stopped for an extended period with the automatic current adjuster in the operating (standard cell) position.

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INSTRUCTION MANUAL

FOR

OBTAINING OCEANOGRAPHIC DATA

Third Edition

1968

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FOREWORD

The continuing necessity for naval and maritime operations throughout the world has made it increasingly important to obtain accurate oceanographic data of the various ocean areas. As our Nation's interest in the exploration of the oceans has increased, there have been more and more demands for an up-to-date instruction manual for obtaining oceanographic data.

This edition, a revision of the old H.O. Pub. No. 607, "Instruction Manual for Oceanographic Observations" (1955), has been prepared to meet this need. It describes the methods, techniques, instruments, and log sheets used at sea by Naval Oceanographic Office oceanographers. No claim is made for originality, nor is it proposed that these methods become universal.

This new publication, Pub. No. 607, "Instruction Manual for Obtaining Oceanographic Data," has been designed to facilitate updating of the contents by presenting a unique page-numbering system. It is intended that methods and techniques will be added to or deleted from this manual as the state of the art improves or as techniques become obsolete. Several additional chapters are in preparation at this time and will be published in the near future.

Your comments and suggestions concerning this instruction manual are invited.

L. E. DeCamp.

L. E. DeCamp,
Captain, U.S. Navy,
Commander.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLES

CHAPTER A

INTRODUCTION

A–1 Oceanography, a Definition.—Oceanography is the study of the sea, embracing and integrating all knowledge pertaining to the sea's physical boundaries, the chemistry and physics of sea water, and marine biology.

A–2 The Types of Information Sought.—In the sense that oceanography encompasses portions of all the physical sciences, types of information sought on oceanographic surveys and expeditions include data from these fields.

Because of the high costs of maintaining a laboratory, such as a ship needed to obtain oceanographic information, the most profitable use must be made of its time at sea. Although a particular project may concern itself primarily with a certain oceanographic feature, other supporting data from any other variables usually are required. For example, investigations of the growth of plankton become immediately involved with water temperatures and salinities, nutrient concentrations, transparencies, and mass transport of water. Information pertaining to these variables requires, in turn, related observations of air temperatures and other meteorological data.

Inasmuch as characteristics of the sea may change with respect to both space and time, the periodicity and extent of these changes must be investigated. Conditions that vary with time may need to be observed during repeated surveys of the same area, whereas conditions that change from place to place should be measured by simultaneous observations taken throughout an area from two or more ships or recording units.

Oceanography may be divided into five basic sciences: Physics, chemistry, meteorology, biology, and geology. A few comments concerning the general types of information sought in each of the fields are given below.

A–3 Physical Oceanography.—Physical oceanography is probably the largest and most diversified of the five basic divisions. Its study involves all the other fields, especially chemical oceanography. It includes tides, currents, sea and swell, temperatures, densities, origin and circulation of water masses, sound propagation, transparency, sea ice, and other physical properties of sea water.

Of major importance is knowledge concerning surface and subsurface currents—whence they originate, their speed and direction, and their influence on other oceanic factors. Determinations of subsurface currents may be made by direct measurements with current meters, or by mathematical computations utilizing the densities of the masses in question.

Density is a function of the temperature and salinity of the water under a given pressure. It is desirable, therefore, to gain knowledge of the vertical distribution of temperatures and salinities at accurately determined depths. These variables also provide basic information required to determine sound propagation patterns, both vertically and horizontally, in sea water.

Internal waves have concerned investigators in the field of underwater sound transmission. These waves are similar to the commonly observed surface waves but occur at the interface of layers of water of different densities rather than at the sea-air boundary. The study of wind waves (sea) and swells, until a few years ago, has been limited mainly to observations of deep-water waves by visual means. Recent developments of pressure-operated wave indicators, however, provide new types of recorded data for analyses. The success of research into long- and short-range wave forecasting from meteorological data is dependent upon the number of observers reporting and the accuracy of the observations. Such forecasts are of utmost value for many marine operations, including military, commercial, and scientific.

Observations of water transparency, light penetration, light scattering, and water color are aided by the use of photoelectric cells which are lowered to various depths. Such studies assist in the determination of currents and provide clues to biological influences.

A–4 Chemical Oceanography.—The field of chemical oceanography is concerned with the determination of the various constituents of sea water and their distribution. The salinity of sea water is required in computing densities and dynamic currents as well as sound velocities. Analyses to determine nutrient concentration (phosphate, nitrate, silicate, etc.), pH (acidity), and concentration of dissolved gases (oxygen and carbon dioxide) provide information which aids in determining age, origin, and movement of water masses and their influences upon marine life. Some of these analyses must be made immediately after water sampling. Other samples may be stored and analyzed ashore at a later date if the facilities of the ship are not adequate.

A–5 Meteorological Oceanography.—The interaction of sea and air and the influence of each medium upon the other is a necessary part of most oceanographic studies. In certain areas prevailing winds affect ocean currents, whereas in others the sea water modifies air temperature. Solar radiation affects the heat budget and influences the biological environment. Thus, meteorological information that must accompany all oceanographic observations includes: Air temperatures, wind direction and speed, atmospheric pressure, cloud types and amount, and visibility.

A–6 Biological Oceanography.—Biological oceanography is concerned with both plant and animal life in the sea. All marine life may be divided into three general groups—the *benthos* (bottom living), the *nekton* (swimming), and the *plankton* (wanderers or floating and drifting life). The plankton are further divided into *phytoplankton* (plant forms) and *zooplankton* (animal forms). Little is known of most of the life cycles of marine life and of pelagic populations. We are interested in the distribution of plankton populations, from both quantitative and qualitative points of view, as well as the distribution and habits of the benthos and nekton. Different types of nets are towed in an effort to sample marine life, and panels of various materials are placed in the sea for specified periods of time to determine growth rates of fouling organisms. It is considered that studies in this field may solve many physical problems which are believed to be of biological origin. Among these are the influence that marine life may have on the transmission of underwater sound.

A–7 Geological Oceanography.—Another aspect of oceanography is submarine geology, especially the nature of the bottom. The techniques of echo sounding, seismic exploration, underwater photography, and bottom sampling and coring are gradually providing a picture of the shape, character, and history of the ocean bottom.

A–8 Oceanographic Platforms.—Principal platforms now being used by oceanographers are surface ships such as those in figures A–1 and A–2. In addition, submarines and ocean towers have served as satisfactory platforms, and recently considerable progress has been made in developing the potential of unmanned buoys, airplanes and satellites, and undersea vehicles as oceanographic data collection platforms. But the surface ship is still the principal survey platform used by the U.S. Naval Oceanographic Office.

A–9 Shipboard Equipment and Facilities.—The most basic requirement for an oceanographic ship to meet is the provision of a stable platform from which observations at sea can be made. The more stable the platform the greater the number of working days possible under adverse weather and sea conditions, with the resulting greater return of more accurate data. Coupled with stability is the ability to remain on station with a minimum amount of drift. Thus, a deep-draft ship with a minimum amount of freeboard to give windage is desirable. Other basic requirements for an oceanographic ship include adequate deck working space and machinery, laboratory facilities, extended cruising range, and living accommodations for the scientists and crew. Desirable features include control of the ship's heading at very slow speeds and while lying-to on station, ability to maintain silent ship conditions (with batteries substituting for generators) for periods up to at least 12 hours, and adequate weight-handling equipment such as booms and cranes.

A–10 Deck Space and Machinery.—Open and uncluttered deck space is needed to handle the numerous pieces of large oceanographic equipment, of which some are very heavy while others are long and awkward to handle. Deck machinery essential to the oceanographer includes specially designed winches, booms, and cranes.

A–11 Shipboard Winches.—The largest of the winches used by oceanographic research ships are the *deep-sea anchoring winch and the deep-sea coring winch.* These winches carry more than 45,000 feet of ⅜- to ¾-inch tapered wire rope or 20,000 to 35,000 feet of ½-inch nontapered wire rope. These winches are used for anchoring the ship, in addition to lowering cameras, towing bottom dredges and larger midwater trawls, and obtaining large bottom cores.

The winch the oceanographer probably uses most is the oceanographic-hydrographic winch. This is a medium size winch which holds 20,000 to 30,000 feet of 5/32- or 3/16-inch wire rope or approximately 12,000 feet of 7-conductor electrical cable. The winch is a high-speed type and is the one from which the majority of oceanograpic instruments are lowered. It is used for water sampling bottles, current meters, underwater cameras, small coring devices, small dredges, plankton nets, various temperature

Figure A–1. USS *San Pablo* (AGS–30) Oceanographic survey ship.

Figure A–2. USNS *Silas Bent* (AGS–26) Oceanographic survey ship.

measuring instruments, and numerous other types of equipment (fig. A–3).

One of the smallest winches is the *bathythermograph (BT) winch.* This winch is used to lower the BT, both while underway and when lying-to on station. The winch carries 2,500 to 3,000 feet of $\frac{3}{32}$-inch diameter stainless steel wire. It is sometimes used in shallow water for taking small bottom samples when underway with a specially designed bottom sampler called a "scoopfish." Mechanical current meters and vertical hand plankton nets are sometimes lowered from the BT winch.

A *special-purpose electrical cable winch* equipped with 9,000 feet of 4–HO electrical cable is carried on some survey ships. This winch is used for lowering the transmitting current meters and the sound velocimeter.

The newer research ships with the Shipboard Oceanographic Survey System aboard also carry an *intermediate winch.* This winch will hold 30,000 feet of 0.380-inch diameter electrical cable in lieu of original $\frac{1}{2}$-inch cable. The Shipboard Survey System on-station fish is operated from this winch.

A–12 Laboratory and Storage Facilities.—An oceanographic survey ship should have laboratory, office, and storage spaces. A deck laboratory is necessary in which instruments are prepared for operation and some analyses are carried out. It should be located near the oceanographic winch. Other laboratory spaces are needed where chemical, biological, and geological analyses can be performed, where electronic recording equipment can be installed, and where photographic developing and printing can be done. In addition to these laboratories, office and drafting room space is needed to carry out the reduction of data and preparation of preliminary reports. Dry storage space for oceanographic equipment and storage for samples obtained during the cruise are a necessity. Racks to stow cases of sea water samples, cases of biological specimen jars, and core samples also are required.

A–13 Taking Oceanographic Observations.—Oceanographic observations are made from a ship while underway, while lying-to on station, and on occasion while the ship is anchored. An expedition for the collection of these data comprises an oceanographic cruise. Observations taken underway include bathythermograph lowerings, occasional shallow water bottom samplings, magnetometer tows, gravity measurements, seismic profiles, current observations, plankton tows, pyrheliometer readings, meteorologic observations, and sea and swell observations. For special surveys, hull-mounted recording devices are installed for obtaining

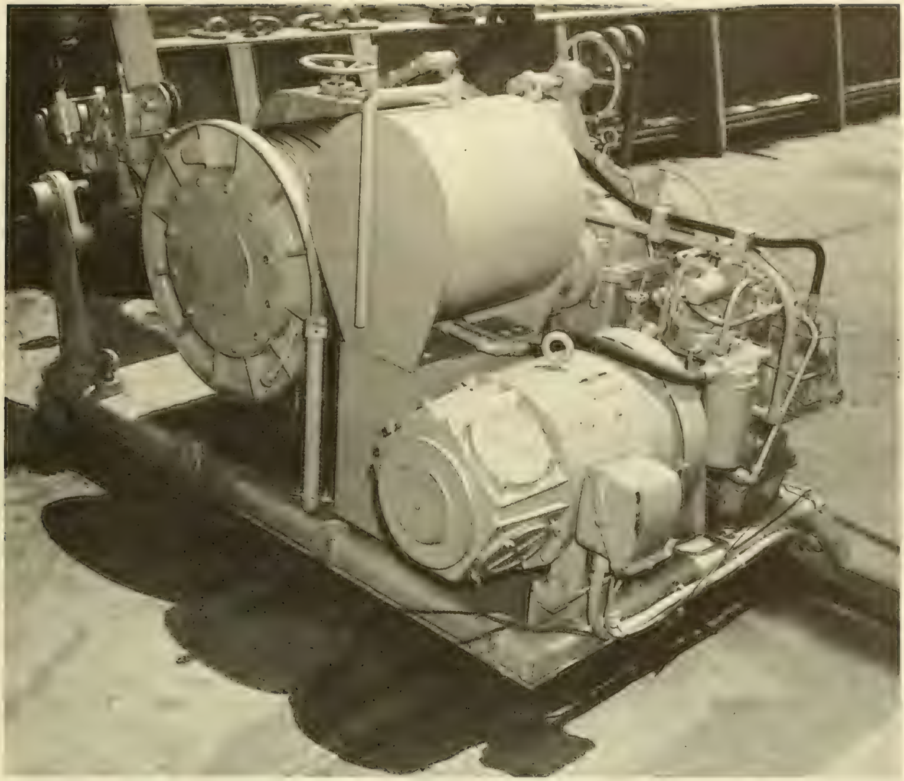

Figure A–3. **Oceanographic-hydrographic winch.**

continuous data on water temperature, salinity, or conductivity. Seismic and acoustic measurements are made with two ships—one lying-to and the other underway.

The greater portion of oceanographic work at sea is carried out while occupying an oceanographic station in which the ship is lying-to. An oceanographic station is any group of oceanographic observations made at the same, or virtually the same, geographic position at nearly the same time. An oceanographic station most commonly comprises a group of observations such as Nansen casts, bottom sediment samplings, bathythermograph lowerings, and associated observations made at one location. One of the primary objectives of occupying an oceanographic station is to determine the temperature and salinity of the water at various depths in the ocean.

In planning an oceanographic cruise, oceanographers plot the locations where information is to be sought on a station location chart. It is the responsibility of the oceanographer in charge of the cruise to insure that the proper thermometers are supplied to observe the temperatures in the desired working area. He can accomplish this purpose by studying the water masses of the area in material already published. He also must insure that the ship has all the necessary equipment and accessories for properly conducting assigned observations during the cruise.

A–14 Occupying an Oceanographic Station.—The instruments and equipment to be used are put in readiness before arriving on station. When the navigator has determined that the ship is at the desired location, the ship is maneuvered so that the winch to be used is to windward. (In this position the ship will usually drift away from the cable that is suspended in the water.) The ship's engines then are stopped.

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Outboard from the oceanographic winch is a platform, similar to that used for heaving a leadman's chains. Over the platform is an A-Frame or davit, from which is suspended a special block called a meter wheel. This meter wheel has a stainless steel sheave of an exactly measured circumference, which is connected by a special cable to a counter block (fig. A-4). The oceanographic wire is passed over the meter wheel sheave, and the amount of wire paid out over the side is indicated by the counter dials. A lead weight of about 100 pounds then is attached to the end of the wire. This is lowered over the side, outboard of the platform, after the ship is dead in the water. Water sampling bottles, usually of the Nansen type, equipped with deep-sea reversing thermometers, are attached to the wire at predetermined intervals as the wire is lowered into the water. After the Nansen bottle cast (or casts) has been completed, the oceanographic winch may be used to lower other sampling devices such as the bottom sediment corer, underwater camera, or plankton nets.

The time involved in taking a series of observations as described above, in water 4,000 to 5,000 meters deep, would be approximately 7 hours. If a large coring device, such as the half-

Figure A-4. Platform, A-Frame, meter wheel, and counter block.

ton Ewing piston corer, were lowered by the anchoring winch to this depth, some 5 hours would be required to lower and raise it for a single core.

Many observations can be taken simultaneously. Thus, bathythermograph lowerings, vertical plankton tows, subsurface visibility measurements, and associated meteorological observations can be taken while other lowerings are in progress without adding to the time on station.

The efficiency with which the observations and measurements are obtained during the time the ship is occupying the oceanographic station naturally depends upon the number of personnel available and the degree of training they have had. On U.S. Navy survey ships, there may be three to 12 men assisting the oceanographers, depending upon the requirements for a particular station. For example, several men are required to rig and put the Ewing piston corer over the side, and three men are required to make Nansen bottle casts (a winch operator, a bottle passer, and a bottle hanger).

After the last piece of equipment is back aboard, the ship gets underway for the next station, which may be a few miles or possibly a hundred miles away. While the ship is steaming to the next station, water samples taken on the previous station are analyzed and recorded on log sheets, the samples to be returned to laboratories are properly labeled and stowed, and equipment and instruments are cleaned and prepared for the next station. Meanwhile, underway measurements and observations may be taken. In the drafting room or scientific office and in the laboratories, the data recently collected are processed and analyzed.

In the following chapters of this instruction manual for obtaining oceanographic data, the instruments, observation techniques, sample analysis techniques, and data processing methods used at the U.S. Naval Oceanographic Office are described in further detail.

CHAPTER B

METEOROLOGICAL, SEA AND SWELL, AND SPECIAL OBSERVATIONS

B–1 General.—The interaction of sea and air is extremely important in the studies of various oceanographic problems. Almost all oceanographic observations must be accompanied with simultaneous meteorological and sea surface observations. Spaces for such observations usually are provided on oceanographic log sheets, and codes and tables to assist in recording these observations are included in this chapter.

An oceanographic observer must be able to take and record marine meteorological observations that are called for by the various log sheets. The tables and methods used in this chapter are adapted from manuals used by the U.S. Weather Bureau for recording marine meteorological observations.

B–2 Types of Meteorological and Sea and Swell Observations.—The types of meteorological and sea and swell observations required with the oceanographic log sheets include: Weather, cloud type and amount, visibility, wind speed and direction, dry- and wet-bulb air temperatures, barometric pressure, and wind wave (sea) and swell. On certain surveys, other meteorological and/or sea surface measurements are required, and these are obtained with special instruments. For example, solar radiation studies are made with data recorded by the pyrheliometer. Also, precise temperature measurements taken and recorded simultaneously at different levels on the ship are made with a temperature-lapse-rate indicator. Such measurements are valuable in explaining varying conditions in the upper layers of the ocean. Much of the information that follows has been extracted from the U.S. Weather Bureau's Manual of Marine Meteorological Observations, Circular M, and Manual of Cloud Forms and Codes for States of the Sky, Circular S. For more complete instructions, reference should be made to the above manuals.

B–3 Weather.—Table B–1 is used to indicate and record on the A-Sheet (see ch. E) the state of the weather at the time of observation. The 100 descriptive terms include most weather phenomena that will be encountered. *Code figures should not be used to record weather on the A-Sheet.* If a code figure is used to describe a weather condition in reporting or recording any observation, the code designation must be plainly indicated on all log sheets and rigorously adhered to; otherwise, the data are of no value. Terms selected should describe the weather at the time of observation or during the preceding hour. Neither when selecting the general description nor in determining the complete description of the weather must account be taken of weather phenomena which occurred more than 1 hour preceding the observation time.

B–4 Clouds.—The type of the significant cloud layer should be recorded on the A-Sheet using the descriptions given in table B–2 and figures B–1 through B–26. If fragments of a cloud layer (i.e., covering less than $\frac{1}{10}$ of the sky) are observed under a cloud layer covering $\frac{1}{10}$ or more of the sky with bases below 8000 feet, the fragments will be disregarded. The height of the cloud is the distance from sea level to the base of the cloud. The amount of total cloud cover should be recorded on the form in tenths of sky covered. In the thin types of mackerel sky there are almost always gaps or spaces through which clear sky can be seen. When these conditions prevail, the amount of cloud should never be recorded as greater than $\frac{9}{10}$ even though such clouds are spread over the entire sky.

B–5 Visibility.—Horizontal visibility often is very useful as an indicator of the condition of the lower atmosphere, which in turn has effects on the sea surface. As a general rule, the visibility is good when the air temperature is lower than the sea temperature and very poor when higher. The reason for this is that, in the former condition, the lowest layers of the atmosphere are being heated by the sea. This tends to make the atmosphere thermally unstable and favors

Table B–1. Descriptive terms for present weather (extracted from WMO Code 4677)

Group	Code figure	Description	
No meteors except photometeors	00	Cloud development not observed or not observable	characteristic change of the state of sky during the past hour
	01	Clouds generally dissolving or becoming less developed	
	02	State of sky on the whole unchanged	
	03	Clouds generally forming or developing	
Haze, dust, sand or smoke	04	Visibility reduced by smoke, e.g. veldt or forest fires, industrial smoke or volcanic ashes	
	05	Haze	
	06	Widespread dust in suspension in the air, not raised by wind at or near the station at the time of observation	
	07	Dust or sand raised by wind at or near the station at the time of observation, but no well developed dust whirl(s) or sand whirl(s), and no duststorm or sandstorm seen	
	08	Well developed dust whirl(s) or sand whirl(s) seen at or near the station during preceding hour or at the time of observation, but no duststorm or sandstorm	
	09	Duststorm or sandstorm whithin sight at the time of observation or at the station during the preceding hour	
	10	Mist	
	11	Patches of	shallow or ice fog at the station, whether on land or sea, not deeper than about 2 metres on land or 10 metres at sea
	12	More or less continuous	
	13	Lightning visible, no thunder heard	
	14	Precipitation within sight, not reaching the ground or the surface of the sea	
	15	Precipitation within sight, reaching the ground or the surface of the sea, but distant (i.e. estimated to be more than 5 km) from the station	
	16	Precipitation within sight, reaching the ground or the surface of the sea, near to, but not at the station	
	17	Thunder storm, but no precipitation at the station	
	18	Squalls	at or within sight of the station during the preceding hour or at the time of observation
	19	Funnel cloud(s)*)	
	20	Drizzle (not freezing) or snow grains	not falling as shower(s)
	21	Rain (not freezing)	
	22	Snow	
	23	Rain and snow or ice pellets, type (a) (sleet)	
	24	Freezing drizzle or freezing rain	
	25	Shower(s) or rain	
	26	Shower(s) of snow, or of rain and snow	
	27	Shower(s) of hail,** or of rain and hail**	
	28	Fog or ice fog	
	29	Thunderstorm (with or without precipitation)	
	30	Slight or moderate duststorm or sandstorm	has decreased during the preceding hour
	31		no appreciable change during the preceding hour
	32		has begun or has increased during the preceding hour
	33	Severe duststorm or sandstorm	has decreased during the preceding hour
	34		no appreciable change during the preceding hour
	35		has begun or has increased during the preceding hour
	36	Slight or moderate drifting snow	generally low (below eye level)
	37	Heavy drifting snow	
	38	Slight or moderate drifting snow	generally high (above eye level)
	39	Heavy drifting snow	
	40	Fog or ice fog at a distance at the time of observation, but not at the station during the preceding hour, the fog or ice fog extending to a level above that of the observer	
	41	Fog or ice fog in patches	
	42	Fog or ice fog, sky visible	has become thinner during the preceding hour
	43	Fog or ice fog, sky invisible	
	44	Fog or ice fog, sky visible	no appreciable change during the preceding hour
	45	Fog or ice fog, sky invisible	
	46	Fog or ice fog, sky visible	has begun or has become thicker during the preceding hour
	47	Fog or ice fog, sky invisible	
	48	Fog, depositing rime, sky visible	
	49	Fog, depositing rime, sky invisible	

Code figure		
50	Drizzle, not freezing, intermittent	slight at time of observation
51	Drizzle, not freezing, continuous	
52	Drizzle, not freezing, intermittent	moderate at time of observation
53	Drizzle, not freezing, continuous	
54	Drizzle, not freezing, intermittent	thick at time of observation
55	Drizzle, not freezing, continuous	
56	Drizzle, freezing, slight	
57	Drizzle, freezing, moderate or heavy (dense)	
58	Drizzle and rain, slight	
59	Drizzle and rain, moderate or heavy	
60	Rain, not freezing, intermittent	slight at time of observation
61	Rain, not freezing, continuous	
62	Rain, not freezing, intermittent	moderate at time of observation
63	Rain, not freezing, continuous	
64	Rain, not freezing, intermittent	heavy at time of observation
65	Rain, not freezing, continuous	
66	Rain, freezing, slight	
67	Rain, freezing, moderate or heavy	
68	Rain or drizzle and snow, slight	
69	Rain or drizzle and snow, moderate or heavy	
70	Intermittent fall of snow flakes	slight at time of observation
71	Continuous fall of snow flakes	
72	Intermittent fall of snow flakes	moderate at time of observation
73	Continuous fall of snow flakes	
74	Intermittent fall of snow flakes	heavy at time of observation
75	Continuous fall of snow flakes	
76	Ice prisms (with or without fog)	
77	Snow grains (with or without fog)	
78	Isolated starlike snow crystals (with or without fog)	
79	Ice pellets type (a)	
80	Rain shower(s), slight	
81	Rain shower(s), moderate or heavy	
82	Rain shower(s), violent	
83	Shower(s) of rain and snow mixed, slight	
84	Shower(s) of rain and snow mixed, moderate or heavy	
85	Snow shower(s), slight	
86	Snow shower(s), moderate or heavy	
87	Shower(s) of snow pellets or ice pellets, type (b),	—slight
88	with or without rain or rain and snow mixed	—moderate or heavy
89	Shower(s) of hail, with or without rain or rain	—slight
90	and snow mixed, not associated with thunder	—moderate or heavy
91	Slight rain at time of observation	thunderstorm during the preceding hour but not at time of observation
92	Moderate or heavy rain at time of observation	
93	Slight snow, or rain and snow mixed or hail** at time of observation	
94	Moderate or heavy snow, or rain and snow mixed or hail** at time of observation	
95	Thunderstorm, slight or moderate, without hail**, but with rain and/or snow at time of observation	thunderstorm at time of observation
96	Thunderstorm, slight or moderate, with hail** at time of observation	
97	Thunderstorm, heavy without hail**, but with rain and/or snow at time of observation	
98	Thunderstorm combined with duststorm or sandstorm at time of observation	
99	Thunderstorm, heavy, with hail** at time of observation	

*Tornado cloud or water spout

**Hail, ice pellets, type (b) small hail, snow pellets

CLOUD TYPES

(Compiled by the U.S. Weather Bureau to aid in the interpretation of cloud observations.)

FAMILY "A" HIGH CLOUDS: CIRRUS (Ci), CIRROCUMULUS (Cc). MEAN LOWER LEVEL, 6,000 METERS (20,000 FEET).

FAMILY "B" MIDDLE CLOUDS: ALTOCUMULUS (Ac), ALTOSTRATUS (As). MEAN UPPER LEVEL, 6,000 METERS (20,000 FEET); MEAN LOWER LEVEL, 2,000 METERS (6,500 FEET).

FAMILY "C" LOW CLOUDS: STRATOCUMULUS (Sc), STRATUS (St), NIMBOSTRATUS (Ns). MEAN UPPER LEVEL, 2,000 METERS (6,500 FEET); MEAN LOWER LEVEL, CLOSE TO SURFACE.

FAMILY "D" CLOUDS WITH VERTICAL DEVELOPMENT; CUMULUS (Cu), CUMULONIMBUS (Cb).

Figure B–1. Cirrus.

Figure B–2. Filaments or strands of cirrus scattered and not increasing.

Figure B–3. Dense cirrus in patches or twisted sheaves usually not increasing.

Figure B–4. Cirrus, often anvil-shaped.

Figure B–5. Cirrus (often hook-shaped) gradually spreading over the sky.

Figure B–6. Cirrus and cirrostratus, often in bands converging toward the horizon.

Figure B–7. Cirrus and cirrostratus often in bands converging toward the horizon.

Figure B–8. Cirrostratus covering the entire sky.

Figure B–9. Cirrostratus not increasing and not covering the whole sky.

Table B–2. Descriptive terms of WMO Code 0500 for recording cloud type (genus)

Name of Cloud Type	*Abbreviation*
Cirrus	Ci
Cirrocumulus	Cc
Cirrostratus	Cs
Altocumulus	Ac
Altostratus	As
Nimbostratus	Ns
Stratocumulus	Sc
Stratus	St
Cumulus	Cu
Cumulonimbus	Cb
Clouds not visible owing to darkness, fog, duststorm, sandstorm, or other analogus phenomena.	

Figure B–10. Cirrocumulus.

Figure B–11. Thin altostratus (semitransparent everywhere) through which the sun or moon can be dimly seen.

Figure B–12. Thick altostratus or nimbostratus.

active vertical mixing, which in turn tends to disperse haze or fog particles that may have accumulated at low levels. An unstable atmosphere is characterized by cumuliform clouds and a showery type of weather.

On the other hand, when the sea temperature is lower than the air temperature, it follows that the sea cools the lowest layers of the atmosphere.

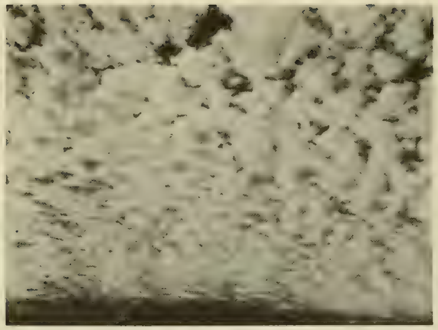

Figure B–13. Thin (semitransparent) altocumulus.

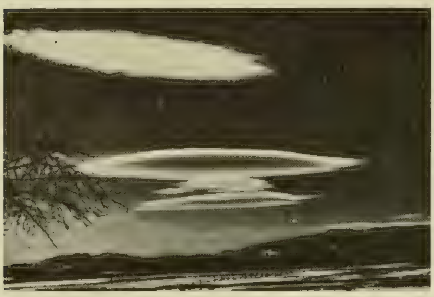

Figure B–14. Altocumulus in patches.

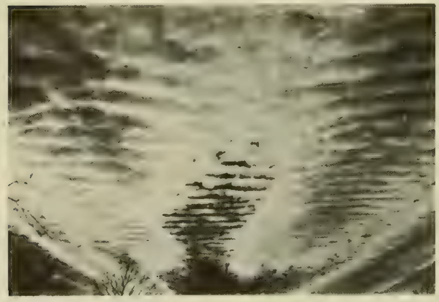

Figure B–15. Altocumulus in bands.

This tends to make the atmosphere thermally stable and prevents active vertical mixing, which in turn favors the production of haze and fog at low levels. A stable atmosphere, therefore, is characterized by poor visibility and, if it is sufficiently moist, by fog, low stratus clouds, and drizzle.

Observations of visibility should be recorded on the A-Sheet in either meters and kilometers

Figure B–16. Altocumulus formed by spreading out of cumulus.

Figure B–17. Altostratus and altocumulus.

Figure B–18. Altostratus and altocumulus.

or yards and nautical miles. *Always indicate the units of measurement.*

B–6 Wind Speed and Direction.—When a ship is equipped with an anemometer the true wind speed is recorded in knots and the direction in degrees true rather than magnetic. When observing aboard a ship without an anemometer, estimate the wind speed in knots from the Beau-

Figure B–19. Altocumulus.

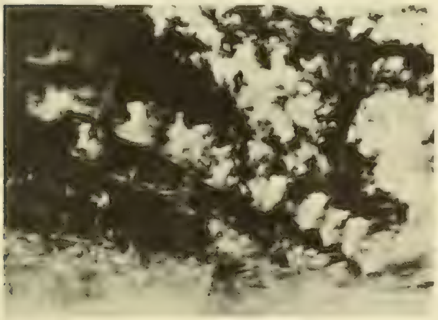

Figure B–20. Altocumulus.

Figure B–21. Cumulus with little vertical development and seemingly flattened.

fort's scale given in table B–3 or use a portable wind measuring set shown in figure B–27.

The appearance of the sea surface serves as the best means of estimating the true wind speed, just as it affords the best means of estimating true wind direction. The direction can be determined by making use of the fact that the crest

Figure B–22. Cumulus of considerable development, generally towering.

Figure B–23. Cumulonimbus.

Figure B–24. Stratocumulus formed by spreading out of cumulus.

lines of the smallest ripples on the sea surface are perpendicular to the direction of the wind. These ripples are very sensitive to sudden changes in character of the wind. Accentuation of them by a localized increase in wind velocity produces an apparent darkening of the sea surface, which serves to show the rate of travel of individual gusts or puffs. With wind forces of 6 (Beaufort) or more, the wind direction also may be estimated correctly from the direction

Figure B–25. Stratocumulus not formed by spreading out of cumulus.

Figure B–26. Cumulus and stratocumulus.

of the streaks of foam which are formed. *Do not use the Beaufort's Force numbers when recording wind speed on the A-Sheet.*

B–7 Temperature of the Air.—The air temperature should be read from the dry bulb of a sling psychrometer and recorded on the A-Sheet to the nearest tenth degree. The wet-bulb reading of the sling psychrometer should be read and recorded to the same degree of accuracy. It is important that the temperature of the dry-bulb and also the wet-bulb temperature be measured by a sling psychrometer since this method is more accurate than that of stationary thermometers. Furthermore, the formula employed for determining the relative humidity from the readings of a psychrometer is not applicable to the readings of a stationary wet-bulb thermometer. If a sling psychrometer is not available, the free-air temperature should be read from an ordinary thermometer exposed to the free air on the windward side of the ship under conditions that eliminate as completely as possible the effects of extraneous sources of heat.

Table B–3. Wind force descriptive scale and velocity from WMO Code 1100

Beaufort Number	*Descriptive Term*	*Mean Velocity In Knots*
0	Calm	Less than 1.
1	Light air	1 to 3.
2	Light breeze	4 to 6.
3	Gentle breeze	7 to 10.
4	Moderate breeze	11 to 16.
5	Fresh breeze	17 to 21.
6	Strong breeze	22 to 27.
7	Near gale	28 to 33.
8	Gale	34 to 40.
9	Strong gale	41 to 47.
10	Storm	48 to 55.
11	Violent storm	56 to 63.
12	Hurricane	64 and over.

Figure B–27. Measuring wind speed and direction with Wind Measuring Set (AN–PMQ–5A).

The mercury bulb of the wet-bulb thermometer in the sling psychrometer is covered with a muslin wick. The wick must be wet with *fresh* water before each observation. The wick must be kept clean and free of salt.

B–8 Barometric Pressure.—Atmospheric pressure usually is measured aboard ship with a precision aneroid barometer. Barometric pressure should be recorded on the A-Sheet in inches of mercury or millibars after applying the correction to the barometer reading. The correction tag for the barometer usually is posted in a convenient place near the barometer. *Be sure to indicate the units of measurement.*

B-9 Wind Waves (Sea) and Swell.—Table B-4, Sea State, presents a word description of the state of the sea and the corresponding height of the wave in feet and meters, and is used for recording the wave conditions on the A-Sheet. Because of the almost complete lack of quantitative reports concerning wave conditions in all parts of the world, it is most important to take observations of wind waves and swell whenever possible while afloat or airborne. These data may be used for the following: planning air-sea rescue or aircraft carrier operations; selecting seaplane landing areas; studying local and distant wind systems and their effect on sea conditions; determining drift and breakup of ice floes; and the movement of supplies and personnel through surf zones.

Table B-4. Sea state from the WMO Code 3700 for recording sea state

Description	*Height*	
	Feet	*Meters*
Calm-glassy	0	0.
Calm-rippled	0 to ⅓	0 to 0.1.
Smooth-wavelets	⅓ to 1⅔	0.1 to 0.5.
Slight	1⅔ to 4	0.5 to 1.25.
Moderate	4 to 8	1.25 to 2.5.
Rough	8 to 13	2.5 to 4.
Very rough	13 to 20	4 to 6.
High	20 to 30	6 to 9.
Very high	30 to 45	9 to 14.
Phenomenal	Over 45	Over 14.

Every effort should be made to standardize visual observational procedure so that different observers studying similar waves will reach the same conclusions as to what they see, and will record the same data. Unless a standardized procedure is agreed upon, an observer might also have difficulty in comparing two of his own observations made at different times, or in deciding if the waves had changed since the last observation. Conscientious attention to the observations will therefore be required.

A standardized method for recording visual sea and swell observations on a log sheet has been developed. Instructions for making these observations are given in H.O. Pub. No. 606–e, *Sea and Swell Observations.* The log sheet used to record these observations is the *Shipboard Wave Observation Log*, PRNC–NHO–1192 (fig. B–28).

B–10 Sea and Swell Terms.—To enable the observer to have a better understanding of the various factors involved in sea and swell observations, definitions of certain oceanographic terms are given below.

1. Wind Waves.—The character of the sea surface caused by action of the local wind can be described in terms of height, period, length, and direction of the wind waves being formed. Waves which are still growing under the force of the wind are known as wind waves. These waves travel in a direction within about 20° of the local wind, and their dimensions are determined by three factors:

a. The STRENGTH of the wind.

b. The DURATION of time the wind has been blowing.

c. The FETCH or distance of the sea surface over which the wind has acted.

If the waves are newly formed and have not had a chance to consolidate themselves in a series of regularly connected crests and troughs, the sea surface will be choppy and make description difficult. As the waves grow, they form themselves into a regular series of connected troughs and crests with the H/L ratio (wave height/wave length) customarily ranging from 1/12 to 1/35, or 12 to 35 times their height.

2. Swell.—Swell is a system of waves that has moved out of the generating area into a region of weaker or opposing winds, or a calm. Swells decrease in height with travel, and although there may be difficulty in distinguishing between wind waves and swell, the latter usually possesses a more or less smooth, well-rounded profile, has greater wave length and period, and disturbs the water to a greater depth. The H/L ratio for swell normally ranges from 1/35 to 1/200. Under certain conditions, extremely long and high swells will cause a ship to take solid water over its bow regularly in a glassy sea.

The reporting of a swell is exceedingly important, for its presence in the local area indicates that recently there may have been a very strong wind, possibly even a severe storm, hundreds or thousands of miles away. The direction from which the swell is coming tells in what direction the strong wind was located. In certain instances the onset of a swell is the first indication of an approaching storm.

3. Wave Height.—The vertical distance from the trough to the crest is termed the wave height. In view of the considerable variation in height between waves observed in a 7-minute period, reference is conveniently made to the significant wave height. This wave height is the average of the higher, well-defined waves present during the observation. Statistically, significant waves are defined as the average of the 1/3 highest waves observed in a given time. As the height is the most important wave characteristic from the operational point of view, care should be taken to observe and report it accurately. While this value for height is about the best that can be expected from visual observation, efforts are being made to perfect the power spectrum analysis of instrument records which will be more valuable for forecasting purposes.

4. Wave Period, Length, Velocity, and Direction.—The *wave period* is defined as the time interval between successive wave crests as the wave passes a fixed point. *Wave Length* is the horizontal distance between successive crests.

OCEANOGRAPHIC LOG SHEET - H
PRNC-NAVOCEANO-3167/8 (Rev. 1-63)

U. S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON 25, D. C.

SHIPBOARD WAVE OBSERVATIONS
FOR USE WITH H. O. PUB. NO. 606-E

VESSEL	CRUISE	MONTH	YEAR

LOCATION							WIND			WIND WAVES (SEA)					SWELL					SWELL					REMARKS	OBS. INITIAL
MO.	DAY	YR.	OCT.	LAT.	LONG.	TIME	DIR.	SPEED	ELEV.	SEA	DIR.	HEIGHT	PERIOD	LENGTH		DIR.	HEIGHT	PERIOD	LENGTH		DIR.	HEIGHT	PERIOD	LENGTH		
MM	dd	yy	Q	$L_aL_aL_a$	$L_oL_oL_o$	GG	dd	ff	E	S	d_wd_w	H_wH_w	P_wP_w	$L_wL_wL_w$	x	d_wd_w	H_wH_w	P_wP_w	$L_wL_wL_w$	x	d_wd_w	H_wH_w	P_wP_w	$L_wL_wL_w$		
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See reverse side for explanation of column.

Figure B-28. **Oceanographic Log Sheet-H (Front).**

MMddy

$yQL_aL_aL_a$ $L_oL_oL_oGG$ $ddffE$

$Sd_wd_wH_wH_w$ $P_wP_wL_wL_wL_w$

$Xd_wd_wH_wH$ $P_wP_wL_wL_wL_w$

MM
MONTH OF THE YEAR

	CODE
January	01
February	02
March	03
April	04
May	05
June	06
July	07
August	08
September	09
October	10
November	11
December	12

dd
DAY OF THE MONTH

Use two figures in reporting day of the month. For example: the fifth day is reported as 05.

yy
YEAR

Report only the last two figures. For example: 1949 is reported as 49.

Q
OCTANT OF THE GLOBE

	CODE
North latitude:	
0° to 90° W	0
90° W to 180°	1
180° to 90° E	2
90° E to 0°	3
South latitude:	
0° to 90° W	5
90° W to 180°	6
180° to 90° E	7
90° E to 0°	8

$L_aL_aL_a$
LATITUDE

Report in degrees and tenths, the tenths being obtained by dividing the number of minutes by 6 and neglecting the remainder.

$L_oL_oL_o$
LONGITUDE

Report in degrees and tenths. Omit hundreds when the longitude is greater than 100°.

GG
HOUR OF THE DAY (Greenwich Mean Time)

dd or d_wd_w
TRUE DIRECTION FROM WHICH SURFACE WIND IS BLOWING OR FROM WHICH WAVE SYSTEM IS APROACHING, IN 10's OF DEGREES.

	CODE
Calm	00
5° to 14°	01
15° to 24° NNE	02
25° to 34°	03
35° to 44°	04
45° to 54° NE	05
55° to 64°	06
65° to 74° ENE	07
75° to 84°	08
85° to 94° E	09
95° to 104°	10
105° to 114° ESE	11
115° to 124°	12
125° to 134°	13
135° to 144° SE	14
145° to 154°	15
155° to 164° SSE	16
165° to 174°	17
175° to 184° S	18
185° to 194°	19
195° to 204° SSW	20
205° to 214°	21
215° to 224°	22
225° to 234° SW	23
235° to 244°	24
245° to 254° WSW	25
255° to 264°	26
265° to 274° W	27
275° to 284°	28
285° to 294° WNW	29
295° to 304°	30
305° to 314°	31
315° to 324° NW	32
325° to 334°	33
335° to 344° NNW	34
345° to 354°	35
355° to 4° N	36
Direction Variable or Unknown	99

ff
WIND SPEED

Report speed in knots using two figures. For example: a 9-knot wind is reported as 09. Use the Beaufort Scale below when no anemometer is available. Speeds above 99 knots and unusual gustiness should be noted in "Remarks" column.

		BEAUFORT NUMBER
Calm	Less than 1 knot	00
Light airs	1-3	01
Light breeze	4-6	02
Gentle breeze	7-10	03
Moderate breeze	11-16	04
Fresh breeze	17-21	05
Strong breeze	22-27	06
Moderate gale	28-33	07
Fresh gale	34-40	08
Strong gale	41-47	09
Whole	48-55	10
Storm	56-63	11
Hurricane	64 and above	12

E
ELEVATION OF WIND MEASUREMENT ABOVE SEA SURFACE

	CODE
0-9 feet	0
10-19	1
20-29	2
30-39	3
40-49	4
50-69	5
70-89	6
90-130	7
Greater than 130	8
Wind strength by Beaufort Scale (no anemometer)	9

S
STATE OF SEA—WIND WAVES (WMO Code 75)

CODE	DESCRIPTION	HEIGHT (Feet)
0	Calm—glassy	0
1	Calm—rippled	0-1/3
2	Smooth—wavelets	1/3-1 2/3
3	Slight	1 2/3-4
4	Moderate	4-8
5	Rough	8-13
6	Very rough	13-20
7	High	20-30
8	Very high	30-45
9	Phenomenal	over 45

NOTE: The bounding height is to be assigned to the lower code, that is, a height of 4 feet is coded as 3.

H_wH_w
HEIGHT OF THE SIGNIFICANT WIND WAVES OR SWELL

Report height in feet using two figures. For example a 5-foot wave is reported as 05.

P_wP_w
PERIOD OF THE SIGNIFICANT WIND WAVES OR SWELL

Report period in seconds using two figures. For example a 6-second wave is reported 06.

$L_wL_wL_w$
LENGTH OF THE SIGNFICANT WIND WAVES OR SWELL

Report length to nearest 10 feet, using three figures, with final zero omitted. For example, a 50-foot wave length is reported 005, a 210-foot wave length is reported 021, etc.

If observations are made to nearest foot, drop final figure if less than 5, and add one to 10's figure if 5 or more. For example, a 63-foot wave length is reported 006, a 155-foot wave length is reported 016, etc.

X
SWELL INDICATOR. SHOWS THAT NEXT TWO GROUPS REFER TO SWELL.

Figure B–28. (Continued). Oceanographic Log Sheet-H (Back).

The *wave velocity* is the rate of travel of the wave form through the water. Here again, as in the case of height, there is considerable variation in these characteristics in any given wave train. For observation purposes, one should determine the average values for the significant waves. *Wave direction* is the direction, in degrees true, from which the waves come.

If wave systems cross each other at a considerable angle, the result is a very irregular sea surface comprised of apparently unrelated peaks and hollows and is termed a *cross sea*. Waves are said to be *short-crested* when the crests are short compared to the wave length and *long-crested* when crests are long compared to the wave length. Waves are commonly short crested in cross seas and in the early stages of generation, while swell is generally long crested. In deep water, where the orbital motion of water particles is uninhibited by the bottom while the waves proceed through the water, the wave period is related mathematically to the wave length and wave velocity in such a manner that they travel at different speeds, and are constantly overtaking or pulling away from their neighbors. If the crests of two waves happen to be at the same point at the same time, their combination results in a crest that is higher than either of the component crests. This phenomenon, know as *wave interference*, accentuates the variability in wave height. Conversely, interference also can cause flat zones when the trough of one wave meets the crest of another. The hydrodynamics of surface wave motion is such that as the period increases, the speed and wave length increases as well. The following approximate formulas show this relation, where the units are knots, feet, and seconds,

Wave speed $=3.0$ (Period)

Wavelength $=5.12$ (Period)^2

Wave Period $=0.3$ (Wave Speed)

5. Whitecaps.—In deep water, the wind may blow strong enough to raise steep and choppy wind waves. When the ratio of height to length becomes too large, the water at the crest moves faster than the crest itself, causing the water to topple forward and form *whitecaps*. The term whitecap is confined to deep water waves while the term *breaker* is used to describe waves breaking in shoal water or in strong-tidal currents which oppose wave motion. Whitecaps owe their instability to a too rapid addition of energy from the wind to the wave form and breakers to the restrictive effect of the sea bottom or opposing currents upon the water movement in the wave form.

6. Breakers.—A *breaker* is an ocean wave, either wind wave or swell, which has traveled over a gradually shoaling bottom and reached the point in its transformation where it is no longer stable and plunges over or breaks. As a rule, when swell is definitely predominant, the breakers are regular with smooth profiles. When wind waves are predominant, the breakers are choppy and confused. Swell coming into a beach increases in height up to the point of breaking. Wind waves, on the other hand, are already so steep that there is little if any increase in height just before breaking. Thus, swell often defines the period of the breakers even though the wind waves appear to predominate in deep water. A long, low swell in deep water may be obscured by choppy wind waves and be detectable only on the beaches.

7. Surf.—The zone of breakers, termed *surf*, includes the region of white water between the outermost breaker and the waterline on the beach. During a storm, it may be difficult to differentiate between surf inshore and whitecaps in deep water just beyond.

8. Wave Refraction and Longshore Currents.—When waves approach a coastline at any angle, they tend to swing around and break parallel to the beach. The waves are slowed down as they come into shallow water by the inhibiting effect of the bottom, and owing to the change in velocity and contour of the bottom, are deflected, or refracted from their original parts. Consequently, refraction is only noticeable on beaches with gradual profiles since the bottom must influence the waves over several wavelengths. When waves do not swing all the way around before breaking and break at an angle with the shoreline, a current in the direction of the open angle is generated. The strength of this current depends chiefly on the height, period, angle of approach of the waves, and beach configuration. If a longshore current develops during unloading operations, it may swing vessels sideways and broach them.

B–11 Effect of Tidal Currents.—If tidal currents acquire velocities of two or three knots or greater, they affect the waves which travel into the area of their influence. Waves opposing currents tend to steepen and increase in height; those moving with currents flatten and decrease in height. Unless the current is effective over a considerable area with a moderate to high velocity, wave changes are not usually noticeable. Near headlands and in tidal races, however, they may be appreciable, and zones of whitecaps where the waves are breaking because of this effect occur at many places.

B–12 Effect of Shoals.—Waves (either sea or swell) in passing over shoals or bars tend to steepen and increase slightly in height. Long swells feel the effect of a deeper shoal more than wind waves and may steepen more noticeably, but will not break as quickly because their height to length ratio is initially very low. Wind waves, on the other hand, may suddenly steepen and break.

B–13 Wave Reflection.—At steep coasts, where there is no beach and deep water is close inshore, wind waves and swell will travel to the coast without undergoing shallow water transformation. Under these conditions, the waves will be reflected from the shoreline and proceed seaward, causing an interference pattern. If this phenomenon is pronounced, one can see pyramidal waves shooting upward where the crest of a reflected wave meets the crest of an oncoming wave. Beach gradients generally must be steeper than 1 in 10 before reflection occurs.

B–14 Wave Forecasting.—Recent developments in wave forecasting theory indicate that a much more thorough description of the sea surface is needed than is possible by visual observations alone. Consequently, automatic wave recorders of various types are being evaluated as they are developed. This equipment eventually will enable the Oceanographic Forecasting Central of the Oceanographic Office to improve the prediction of sea conditions over large portions of the ocean on a round-the-clock basis. The immediate need, however, is for accurate observational data, preferably instrument data, to be used in checking and improving forecasting procedures.

B–15 Bottom Pressure Fluctuations.—In shallow water, pressure devices have been used successfully to measure waves. For example, a differential pressure gage that produces an electrical signal proportional to the pressure variation can be placed on the bottom and connected to a recording system on an anchored ship. Analog tapes of time versus amplitude will yield bottom pressure fluctuations which are caused by wave motions at the surface and are related to wave periods and heights.

B–16 Solar Radiation Measurements.—Solar radiation measurements are made using a recording pyrheliometer system. The pyrheliometer is an instrument designed primarily for the measurement of direct solar radiation at normal incidence. When mounted on a boom in an inverted position, reflected radiation also may be measured. The type pyrheliometer generally used by the Oceanographic Office is a thermopile enclosed in a spherical glass bulb. The receiving surface consists of two flat concentric disks, a black disk forming an absorbing surface and a white disk forming a reflecting surface. The resulting temperature difference between the two disks acts on the thermopile and produces an electromotive force (EMF) which is proportional to the intensity of the radiation. This signal then is transmitted to a recording potentiometer. Each pyrheliometer is given a sensitivity value to convert the EMF to gram-calories per square centimeter per minute. This value is usually stamped on the pyrheliometer identification tag.

B–17 The Pyrheliometer Installation.—The pyrheliometer installation is dependent upon the pyrheliometer used and the type radiation to be measured; however, the following statements are applicable in all instances and are included as a guide. In order to obtain an accurate measurement of the radiation, mount the instrument in a location where shadows are at a minimum. The pyrheliometer bulb and sensor are extremely fragile and must be treated carefully both in use and in shipping. Whenever possible, shock mounts and/or rubber gasketing should be used to reduce the vibration and shock normally encountered on shipboard. Two-conductor insulated cable should be used to connect the pyrheliometer with the recorder. Any type instrument that will record EMF can be used for recording pyrheliometer data, but the recorder manual should be consulted for operating instructions for the particular instrument used.

An installation for measuring total incoming solar radiation and the radiation reflected from the sea surface includes one topside pyrheliometer and two inverted (180° shielded) outboard pyrheliometers (fig. B–29).

B–18 Taking Pyrheliometer Measurements.—At the beginning of the operation and at frequent intervals thereafter, the pyrheliometer should be calibrated by placing the bulb in total darkness and zeroing the recorder. The recorder should be turned on approximately 1 hour before sunrise and turned off approximately 1 hour after sunset. Recorder speed should be relatively slow; 1 or 2 inches per hour usually is sufficient.

B–19 Marking the Recorder Chart.—The following information is entered on the recorder chart:

1. At the beginning of the roll, enter ship's name, date (GMT), pyrheliometer bulb number and sensitivity value, recorder speed (inches per hour), and recorder range (in millivolts).

2. When the recorder is turned on enter time and date (GMT), position and heading.

3. Time should be annotated every 2 to 4 hours during the measurements, or whenever significant events occur; e.g., station, recalibration, cleaning bulb, etc.

4. When recorder is turned off, enter time and date (GMT), and position.

B–20 Maintenance.—The pyrheliometer bulbs may become encrusted with salt spray or engine soot from the stack and must be wiped

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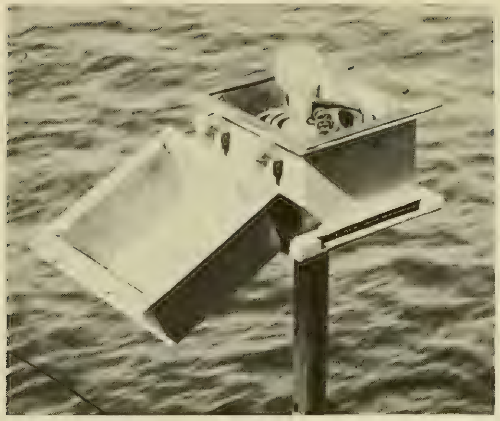
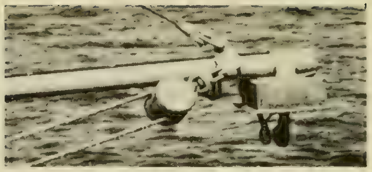


A pyrheliometer mounted in gimbals and shielded from reflected radiation.



Above, inverted painted bulb-type unit, and below, the shielded-type unit, both measuring one half the total radiation reflected from the ocean surface. The boom is extended while underway.

Figure B–29. **Shipboard installation of pyrheliometer cells.**

clean at least once each day, and more often if necessary. Since numerous recorders can be used to collect pyrheliometer data the operator should be familiar with the calibration, maintenance, and troubleshooting of the particular instrument being used.

The pyrheliometer assembly is durable enough to withstand fairly heavy sea conditions; however, it is advisable to rig in and secure the equipment if bad storms and abnormally heavy seas are encountered. On naval vessels, the pyrheliometer should be secured and the bulbs removed and stored before any large caliber guns are fired as the bulbs will be shattered by the concussions.

Chart paper should be checked daily to insure sufficient paper for the day's operation, and the ink reservoir should be checked occasionally to insure a sufficient supply of ink to the pen.

B–21 Storing and Shipping Pyrheliometer Records.—Used chart paper rolls are labeled indicating the ship, cruise number, and dates of beginning and ending of the roll. If the original roll boxes are retained, the rolls may be stored and shipped in them. If there are no such boxes available, the rolls should be fanfolded, inserted in heavy manila envelopes, and shipped in covering envelopes or heavy wrapping paper. These records should be forwarded at the end of a cruise to: U.S. Naval Oceanographic Office, Washington, D.C. 20390.

B–22 Water Transparency and Light Absorption Measurements.—The physical relationships governing the penetration and absorption of light and the color and transparency of the sea are of prime importance to physical and biological oceanography. For such measurements, four general types of instruments or devices are in use: The submarine photometer (irradiance or K meter), the hydrophotometer (transmissometer or α meter), the Secchi disc, and the Forel scale.

The submarine photometer detects ambient luminous flux in foot-candles and records a ratio of surface illuminance to the illuminance existing at various depths down to approximately 150 meters. From this ratio, the diffuse attenuation (K) constant per unit length is obtained.

The hydrophotometer has a self-contained constant light source and measures the attenuation coefficient (α) of a beam of light per unit length.

From these two hydrological factors (K and α) obtained with the irradiance meter and the transmissometer, the range at which a submerged swimmer can detect certain underwater objects can be p edicted.

The Secchi d sc with its simplicity of theory becomes difficult in operation owing to currents, drift, and light reflection from the sea surface and provides only an approximate average index of transparency of sea water.

Color measurements with the Forel scale provide a color index which gives an indication of the transparency of sea water.

B–23 Transparency Measurements With the Secchi Disc.—The Secchi disc (fig. B–30) is a circular plate, having a standard diameter of 30 centimeters. One side is white and the other is black. A ring attached at the center of the disc allows a graduated line to be secured. A 5 to 7½-pound lead weight is attached to the disc so the device will sink rapidly and vertically. The line

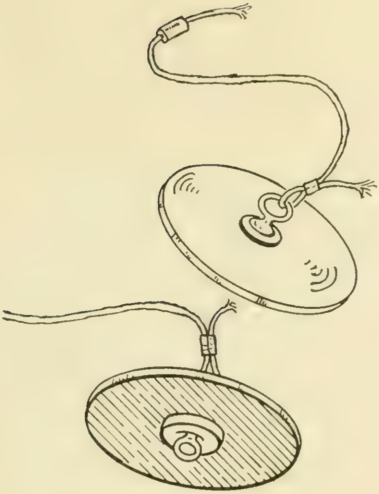


Figure B–30. The Secchi disc.

attached to the Secchi disc should be marked off in 1-meter intervals to at least 50 meters. It is recommended that ¼-inch tiller line with a phosphor bronze core, which minimizes stretching, be used.

The Secchi disc is designed to measure transparency and is dependent upon the available illumination which varies with the time of day, cloud formation, and amount of cloud cover. The Secchi disc observations are recorded at the top of the A-Sheet and must be taken at the same time the associated meteorological data is taken for that sheet.

To obtain Secchi disc observations, the Secchi disc with the white side up should be lowered into the water from the shaded side of the ship until the disc is just perceptible, and the depth in meters noted. The lowering is then continued until the disc is no longer visible. The disc is then slowly raised until it is again barely visible. The depth reading of this point is then averaged with the reading obtained on lowering and is recorded as given above. This same procedure is repeated using the black side of the disc. White and black Secchi disc observations for 15 and 10 meters are recorded as White 15 Black 10.

B–24 Determining Water Color with the Forel Scale.—The standard Forel scale consists of a series of 11 small vials containing ammoniacal copper sulphate and neutral potassium chromate in such proportions that a different graduation of color is imparted to each vial. These vials are numerically designated and are compared directly with the water in the manner described below.

The water color is most easily determined in conjunction with the Secchi disc (fig. B–31). After completion of the transparency measurement described in B–23, raise the white Secchi disc until it lies approximately 1 meter below the surface. The number of the vial that blends most closely with the water color against the Secchi disc is recorded on the A-Sheet. The whiteness of the disc provides the background to which the color is referred; this color may not be the color of the sea surface visible away from the ship. The vials must be shaded from open sunlight when the determination is being made.

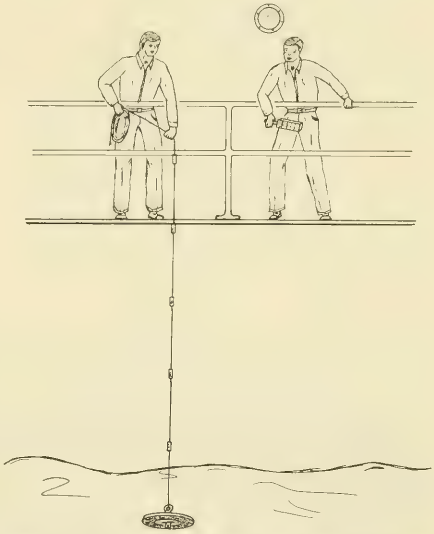


Figure B–31. Obtaining water color with the Forel scale.

B–25 Ice Observations.—Ice observations are made from aboard ship, from land stations, and from aircraft, with each type observation offering specified information.

Shipboard observers are in a position to examine closely the ice immediately around their vessel. From this vantage, they can determine the texture and solidity of the ice, variations in thickness, state of deterioration, and other features requiring actual contact with the ice.

Estimated ice coverage, or concentration, in the immediate vicinity of the ship is recorded to the nearest tenth on the A-Sheet; however, for comprehensive ice observations, H.O. Pub. No. 606–d, *Ice Observations*, should be used as a reference, and observations should be recorded on the Ship Ice Log.

CHAPTER C

MEASURING WATER TEMPERATURE AND DEPTH WITH A BATHYTHERMOGRAPH

C–1 The Bathythermograph or BT.—The BT (fig. C–1) is an instrument for obtaining a record of the temperature of sea water at moderate depths. The BT is lowered into the sea and retrieved by means of a wire rope. It can be operated while the ship is underway at speeds up to 18 knots. It works more satisfactorily, however, at speeds of 12 knots or less.

C–2 How a BT Works.—The thermal element of the BT, corresponding to the mercury column in a glass thermometer, consists of about 45 to 50 feet of fine copper tubing filled with xylene (fig. C–2). As the xylene expands or contracts with the changing water temperature, the pressure inside the tubing increases and decreases. This pressure change is transmitted to a Bourdon tube, a hollow brass coil spring, which carries a stylus at its free end. The stylus records, on a coated glass slide, the movements of the Bourdon tube as it expands or contracts with changes of temperature. The slide is held rigidly by the depth element assembly which is on the end of a coil spring enclosed in a copper bellows or sylphon. The temperature range of the BT is 28° to 90° F.

Water pressure, which increases with depth, compresses the sylphon as the BT sinks. This pulls the slide toward the nose of the BT, at right angles to the direction in which the stylus moves; thus, the trace scratched on the coated surface of the glass slide is a combined record

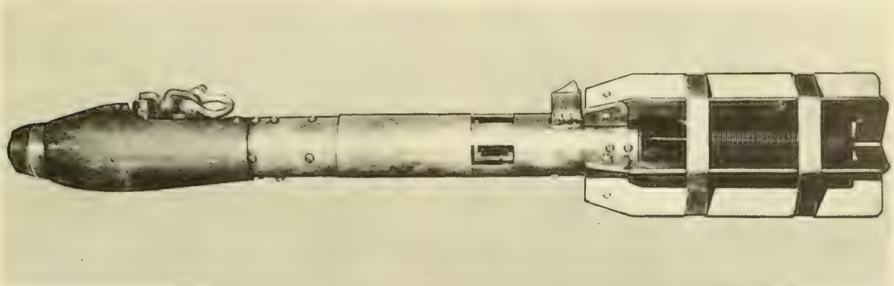


Figure C–1. The Bathythermograph (BT).

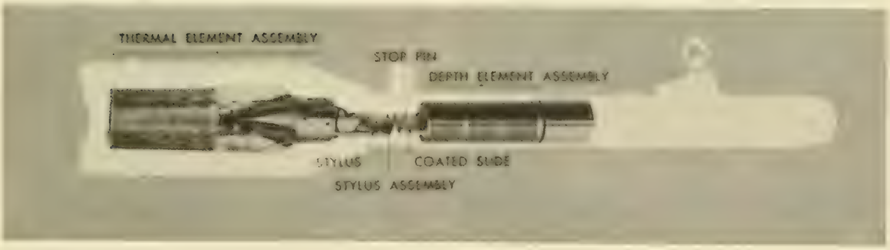


Figure C–2. BT thermal element, depth element, and styllus assemblies.

of temperature and depth. The depth range is stamped on the nose of the BT. It is either 200, 450, or 900 feet.

C–3 Equipment Needed to Operate the BT.—In addition to the BT, the following list of equipment is required to operate the instrument:

1. A BT winch. Examples of winches include: The E6/S Winch (fig. C–3) and the ACCO Equipment Division Winch (fig. C–4).
2. A BT boom.
3. A BT towing block, counterbalanced.
4. Wire rope. $\frac{3}{32}$-inch diameter, 7 x 7 stainless steel, in 3,000-foot length per reel.
5. A grid mount assembly.
6. Metallic-coated glass slides.
7. A slide viewer.
8. A thermometer for measuring surface water temperature.
9. Tools (8-inch pliers, medium screwdriver, and a $\frac{3}{32}$-inch Nicopress).
10. Nicopress sleeves, thimbles, swivels, wire clips, and shackles.

One other tool, which is not essential but is always handy if the wire should jump the block sheave or backlash, is a cable-grip (come-along).

Shown in figure C–5 are the Nicopress tool and sleeves, wire rope, thimbles, swivels, wire clips, and shackles.

C–4 Recording BT Data.—BT data are recorded on the National Oceanographic Data Center *Bathythermograph Log*, NODC–EXP-3167/10 (Rev. 3–66) (fig. C–6). It is designed to provide NODC with information required for BT analog and digital processing and to provide a standard message format for radio transmission of synoptic BT data for automatic data processing. Instructions for completing the items on the Bathythermograph Log are printed inside the cover of each pad of log sheets.

C–5 Taking a BT.—Making a BT lowering is described by the term "Taking a BT." It is a relatively simple operation; nevertheless, a new operator should practice lowerings and recoveries with a dummy BT before undertaking the lowering with an actual instrument.

Certain operations are necessary to assure that good data are obtained. Taking a BT includes the following procedures:

Step 1. Check the operating instruction manual for the model winch to be used. The hand lever on the E6/S winch (fig. C–3) serves both as a brake and clutch. It has three positions: (1) When it is vertical, the winch is in neutral and the drum can be turned in either direction; (2) When it is pushed outboard to the engaged (hoist) position, the motor turns the drum and spools on the wire; (3) When the lever is pulled inboard toward the operator, to the brake position, the drum is locked and cannot be rotated. On other models the operation is different. The operating lever and the brake are separate.

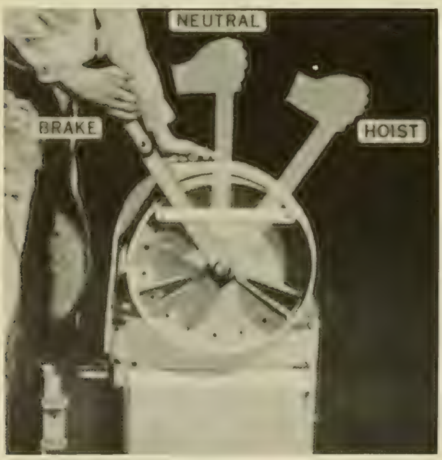


Figure C–3. E 6/S BT winch operating positions.

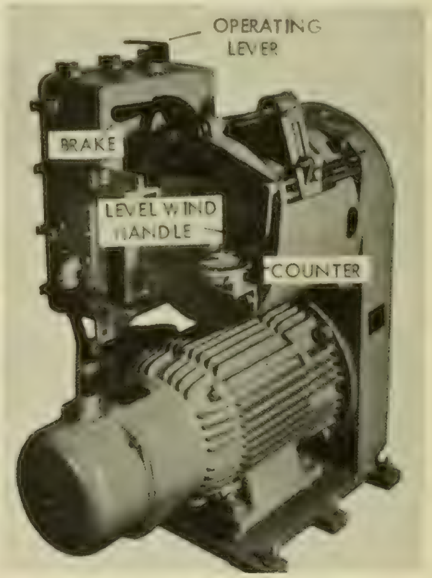


Figure C–4. ACCO Equipment Division BT winch.

Figure C–5. The Nicopress tool and sleeves, wire rope, thimbles, swivels, wire clips, and shackles.

Examine the winch installation to assure that the wire comes across the top of the drum. Run the free end of the wire through the towing block at the end of the boom. This block is of a special counterbalanced design for BT use. Make certain that the winch drum and block are properly lubricated.

Step 2. Connecting BT to Lowering Wire.—Cut off rusted, kinked, or frayed wire and make a new connection using a thimble with three Nicopress sleeves or wire clips. Check the swivel and if the BT does not have a built in swivel include one in the connection. Connect the lowering wire thimble to the BT swivel with a shackle. *NOTE:* More BT's are lost by poor connections than from any other cause. Another important precautionary measure is to paint the last 50 feet of the BT wire a bright color. This will signal the operator during retrieval to be on the immediate lookout for the BT, preventing accidental "two-blocking" and loss of the instrument. It is unwise to trust the counter dial on any BT winch.

Step 3. Inserting Slide in BT.—It is important that the slide is inserted in the BT properly.

Slide the BT sleeve forward toward BT nose (fig. C–7). This will uncover the stylus assembly and slide holder.

Hold slide between thumb and index finger with coated side up.

Insert the slide into the hole on the side of the BT, and push the slide into its bracket. The edge of the slide with the beveled corner goes in first, with bevel towards the nose of the BT.

Push the slide all the way in. Occasionally check the grooves of the slide holder to make sure they are clean and free of glass chips. Also, check the spring to assure that the slide is being held firmly in position.

Move the sleeve back to cover the opening prior to putting the BT over the side. This will bring the stylus assembly in contact with the glass slide.

Step 4. Putting the BT Over the Side.—When permission has been obtained from the bridge, the BT can be put over the side.

Hold the BT at the rail; take up the slack wire.

Lower the BT into the water to such a depth that it rides smoothly just below the surface (fig. C–8).

Put on the brake and hold the BT at this depth for at least 30 seconds to enable the thermal element to come to the temperature of the surface water.

Turn on the motor, so that power is available instantly for the rest of the operation.

Set the counter on the winch to zero.

Step 5. Taking the Sea Surface Reference Temperature.—While the BT is being towed at the surface, the sea surface reference temperature is taken. Any reliable thermometer can be used. The most common method of obtaining the temperature is to collect a bucket of surface water, immediately immerse the thermometer in the water, stir the thermometer with a circular motion, and read the thermometer with the stem still immersed in the water. Make several readings to assure a valid observation (fig. C–9).

Record the sea surface reference temperature on the Bathythermograph Log.

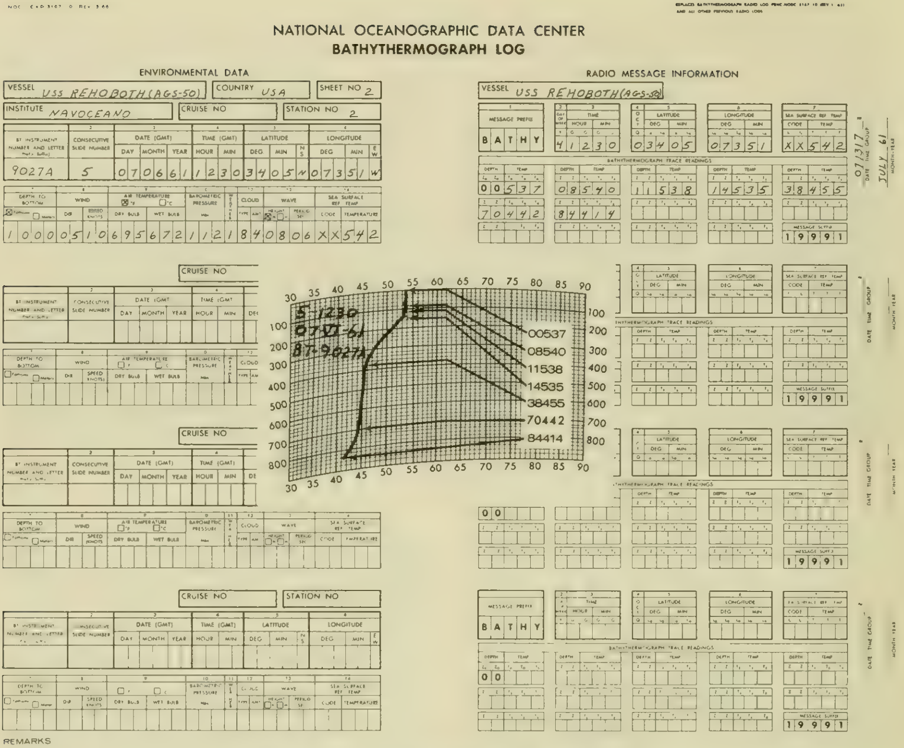


Figure C–6. **Bathythermograph Log with slide inset.**

Step 6. Lowering the BT.—After the sea surface reference temperature has been taken the BT can be lowered. The operator should provide himself with a round stick about 15 inches long to be used to control the speed of the drum. The following instructions apply to underway lowering:

CHECK THE DEPTH OF WATER JUST BEFORE MAKING EACH LOWERING.

Release the brake, and allow the wire to pay out freely. Success in reaching the maximum desired depth depends on paying out the wire as quickly as possible.

Watch the wire and the drum carefully, and gently slow the drum with the stick if excessive slack appears. Do not apply too much pressure to the drum with the stick. Once the diving motion of the BT is arrested it will not dive deeper regardless of the amount of wire payed out.

The proper amount of wire to be payed out will depend upon the speed of the ship, the type of BT, whether or not the nose sleeve is attached, and operator experience. Several lowerings should be made to obtain ship-speed/wire-out ratio for BT used.

Stop the winch when the counter indicates the proper length of wire has been payed out. Apply the brake smoothly; avoid excessive jerk, it may part the wire. *NOTE:* Never pay out the last layer of wire on the drum.

Step 7. Retrieving BT.—As soon as the brake is applied, the BT will stop diving and return to the surface far astern.

Haul in the BT at full speed.

Guide the wire back and forth in even layers on the drum. If the winch does not have a level wind, use the wooden stick for proper spooling.

Decrease the winch speed when BT is close astern. Continue to haul in until BT begins to porpoise (breaking clear of the surface and swinging forward as the ship rolls or as wave crests pass). *NOTE:* This the most critical

Figure C–7. Inserting glass slide into BT.

Figure C–8. BT just below the surface.

point in the operation. To bring the BT alongside and raise it without too much swing requires practice.

Stop the winch with the BT 2 or 3 feet from the towing block. If the BT skips or swings forward of the boom, allow the BT to sink freely until it has passed clear astern, and try again.

Turn off the winch motor and commence bringing the BT aboard. The BT can be brought aboard in various ways, depending on how the boom is rigged. With the standard gate boom, the use of a retrieving line and ring is recommended (fig. C–10). This consists of a metal ring an inch and a half in diameter through which the wire is passed between the towing block and the BT. The ring is attached to a retrieving line which is secured to the lifeline

Figure C–9. Reading the sea surface reference temperature.

or rail. With the proper amount of slack, the ring will ride freely when the BT is being lowered and retrieved. By hauling in on the retrieving line while easing the brake, the BT can be brought to hand.

Step 8. Removing the BT Slide.—As soon as the BT is in hand, slack off the wire, set the brake, and remove the BT slide in the following manner:

Move the sleeve forward toward the BT nose to lift the stylus off the slide. Partially eject the slide by pushing against its edge with the forefinger, or a pencil, through the slide-ejecting part (fig. C–11).

Carefully, grip the slide by the thumb and forefinger (fig. C–12) holding the slide only by the edges. Be careful not to obscure the trace with smudges or fingerprints.

Place the BT in its deck rack, and notify the bridge that the BT is on deck.

Step 9. Securing Equipment.—If another lowering is to be made soon and there is no danger of overheating the BT, it may be left in the deck rack connected to the wire; otherwise, unshackle it and stow in a cool place. *CAUTION:* Never let the temperature of the BT exceed 105° F. (40.56° C). If this temperature is exceeded, the instrument will be damaged and the calibration will be invalid. Never leave the BT on deck without protection from hot sun. Suitable protection to the thermal element can be afforded by keeping the BT covered with wet cloths.

Step 10. Labeling the BT Slide.—As soon as the BT slide is removed from the BT, examine

Figure C–10. **Bringing BT aboard with a retrieving line and ring.**

it to be sure that a suitable trace has been obtained. With a sharp instrument or pencil, write the following information on the slide, being careful not to obscure or touch the temperature-depth trace (fig. C–13).

Slide number and time group. Number slides consecutively. Use Greenwich Mean Time (0000 to 2359), giving the hour and minute at which the BT entered the water. Enter a dash between slide number and time. Slide number five taken at 2240 is marked : 5–2240.

Day, month, and year. Use Roman numerals for the month. 29 November 1966 is written: 29–XI–66.

BT instrument serial number. The serial number of the BT is stamped near the nose of the instrument. This number is very important as each BT has a calibrated grid, a duplicate of which is on file at the laboratory that will process the slide. Without the proper serial number, the information on your slide is valueless. Include any letter which precedes or follows the serial numbers; e.g., BT A–1257 or BT–1216A.

Always enter the information on the slide in the order given above. Avoid the temptation to improve an apparently faint trace by enlarging or tracing over it at the time you enter the data. The processing laboratory can copy an actual trace, however faint, by the delicate photographic processes it uses, but a retouched trace will invariably be detected and rejected. After the slide is labeled, rinse in fresh water, read the slide, and record the data on the log sheet.

C–6 Reading the BT Slide.—The BT grid (fig. C–14) is connected to a magnifying grid mount viewer which facilitates holding and reading the BT slide.

Clean the grid with a cloth or tissue. Place the slide in the viewer with the coated surface toward the grid and the beveled edge toward the set screw. Gently push the slide down against the spring and into place so the coated surface lies flat against the grid and snugly against the set screw.

Figure C–11. Ejecting the BT slide.

Figure C–12. Holding the BT slide.

To remove the slide from the grid depress the spring to loosen the slide from the grid mount.

The trace scratched by the stylus is a temperature-depth record. Each point on the trace represents a value of temperature and depth which can be read off the appropriate line of the grid. The lines on the grid are established by actual

Figure C–13. Labeling the BT slide.

test of the instrument. Each BT has its own grid for converting the stylus trace to temperature and depth readings. *These grids are not interchangeable between instruments.* Serial numbers of both grid and BT must agree. The surface temperature is read from the BT slide by noting the temperature of the point at which the trace starts downward from the surface. Temperatures should be read to tenths of a degree and depth to within 10 feet (see inset of fig. C–6).

C–7 Storing and Shipping BT Slides.—After the BT slide has been read, place it in the plastic storage box. *Do not dip slide in lacquer.*

Whenever a full box of slides is accumulated during the course of a survey, it should be packed securely and shipped to the National Oceanographic Data Center (NODC). To protect your slides so that NODC has the necessary information to process them, proceed as follows:

1. Replace slides in issue box.
2. Put no material between slides.
3. Pad top of slides (use issue pad) before replacing cover.

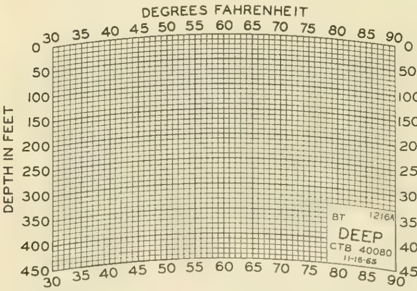


Figure C–14. BT grid.

4. Paste on standard mailing label NODC 3167/11 (9–61) giving ship's name, date(s) of cruise, and BT log sheet number.
5. Pad box well and pack in cardboard box.
6. Wrap securely and label clearly repeating information in item 4.
7. Fold and staple the bathythermograph log so that the mailing format printed on the reverse side is displayed.
8. Mail BT slides and log sheets to:
   National Oceanographic Data Center
   Washington, D.C. 20390 U.S.A.

All grids from BT's lost during operations at sea shall be forwarded to the NODC on return to port or at the end of a survey cruise.

C–8 BT Maintenance.—The BT requires very little maintenance, but careful handling is essential to maintain the accuracy of the delicate internal mechanisms.

After survey operations, the BT should be rinsed with fresh water. Never store a BT that is being withdrawn from use without thoroughly rinsing it.

Do not disassemble the BT. It is a precision instrument with delicate internal mechanisms, and even with the greatest care possible it is difficult to avoid damage if disassembling is attempted aboard ship. If for any reason the BT fails to operate satisfactorily, it should be turned in for repair with a report indicating the symptoms to aid the repair facility in correcting the trouble. A replacement BT can be obtained by filling out the standard forms and mailing them to Naval Ship Systems Command Headquarters Washington, D.C. 20360. This also applies to those BT's lost during operations. Standard failure reports also should be submitted in accordance with current directives.

NAVOCEANO BT's should be replaced after 6 months or after 200 drops, whichever occurs first. These BT's should be returned to:

Supply Officer
U.S. Naval Oceanographic Office
Washington, D.C. 20390

C–9 Malfunctions.—The BT normally is a very reliable instrument; however, the operator should be alert to several common malfunctions. Shocks which occur to the instrument during the handling and lowering may cause hysteresis, temperature error, and/or depth error.

(1) Hysteresis.—The stylus scratches its trace while the BT is diving and as it rises to the surface. Water conditions where it dives may be slightly different from where it rises. These conditions are usually negligible; however, the instrument may have hysteresis; i.e., there may be a slight lag in the movement of its thermal and depth elements. If the up and down traces are essentially similar, a slight divergence of the traces usually is immaterial. *If the traces differ widely, change to another BT*. The temperature reading at the given depth (if the water conditions are not changing) would be a point midway between the two traces. Nothing can be done aboard ship for hysteresis. *Note*: Closely spaced traces (less than 0.5° F.) and double traces in strong gradients (layers of rapid change of temperature) are not considered as hysteresis.

(2) Temperature Error.—It is advisable to make frequent comparisons between the BT surface temperatures and the sea surface reference temperatures. These temperatures should be approximately the same. If they differ slightly, the difference should remain constant over a long period of time. If this difference changes and if the amount of the difference then found continues for subsequent lowerings, it is an indication that the calibration has shifted. A shift in calibration, sometimes called a "shift in the zero points," should not affect the shape of any given trace. The operator should make a note on the log sheet showing the slide number and time at which this shift in calibration was detected.

If the zero shift is more than 4° F., or if it shifts from one lowering to another, the BT needs adjustment and should be turned in for repair. If the instrument must be used, the following procedures can be used to determine the amount of temperature correction to apply.

Load the BT with a slide and leave the brass sleeve up so the stylus does not rest on the slide. Immerse the tail fins, thermal element, and the sleeve in a bucket of water for several minutes. Then push the sleeve down to bring the stylus in contact with the slide. At that instant obtain the water temperature in the bucket with a thermometer. Then raise the sleeve and trip the automatic stylus lifter without taking the BT out of the bucket. Add hot water to raise the temperature a few degrees. Stir the water and allow time for the BT to come to temperature and then make another mark as before and read the thermometer. Repeat the process several times to establish a series of temperature points across the slide, along the zero depth line. The values of the points are read with the viewer and may be plotted on a graph against the temperatures obtained by the thermometer.

(3) Depth Error.—The BT, when on deck, usually has a different temperature than when in the water. The BT thermal element assembly moves the stylus assembly along the zero depth line to the surface water temperature position during the period the BT is being towed at the surface (see par. C–5, Step 4). Thus, the top of the trace is almost always a horizontal line which should be on the zero depth line of the grid when the slide is viewed. If the trace appears more than 3 feet above or below the zero line, the depth readings must be corrected by

the amount of this error for accurate results. In order to determine the amount of correction to apply to depth for accurate work, the following procedures can be used in an emergency:

> With the sleeve all the way back, immerse the thermal element in a cold and then in a warm (less than 105° F.) bucket of water. This will cause a long zero depth line to be drawn across the slide. The slide is then placed in the viewer and the difference, in feet, of the trace above or below the zero depth line on the grid is the error for which corrections must be made at all depth readings.

BT's that have a depth error of more than 10 feet for a 200-foot instrument, 20 feet for a 450-foot instrument, or 40 feet for a 900-foot instrument should be replaced.

CHAPTER D

NANSEN BOTTLES AND REVERSING THERMOMETERS

D–1 General Remarks.—Sea water samples are collected from various depths in the ocean by means of specially adapted water sampling bottles. The first bottle was invented by Hooke in 1611. Since then, more than 50 types have been developed and used by different oceanographic institutions throughout the world, however, the types of bottles in general use have been reduced to a few of simple but rugged design. This is so because only a few are designed to withstand the rigorous working conditions and have specific or desirable features. The type used by the Oceanographic Office is a modification of the one developed by the Norwegian arctic explorer and oceanographer, Fridtjof Nansen, in the latter part of the 19th century. This type is known as the Nansen bottle.

Water temperatures at various depths are obtained with deep sea reversing thermometers. These special thermometers are attached to the exterior of the Nansen bottle. Reversing thermometers were first developed by the firm of Negretti and Zambra, of London, in 1874. Presently used deep sea reversing thermometers are precision instruments and have changed very little since first developed.

D–2 Deep Sea Reversing Thermometers.—Deep sea reversing thermometers are delicate, highly accurate, mercurial thermometers specially designed for determining *in situ* water temperatures. There are two types of reversing thermometers: Protected and unprotected. The temperature scale is Celsius (centigrade) and is carefully etched on the glass stem. Each thermometer is calibrated by the manufacturer, and all thermometers used by the Oceanographic Office also are calibrated by the U.S. Naval Oceanographic Instrumentation Center before they are used at sea. In addition, thermometers are recalibrated at periodic intervals throughout their life. The scale is read with a thermometer reader or viewer. Each thermometer actually consists of two instruments: One, the reversing thermometer which is called the *main thermometer;* the other, an ordinary thermometer which is called the *auxiliary thermometer.*

D–3 The Main Thermometer.—The main thermometer is essentially a double-ended thermometer (fig. D–1). In the upright or lowering position, it has a large reservoir of mercury at the lower end connected by means of a fine capillary to a small bulb at the upper end. The capillary is constricted and branched just above the reservoir. This branching point is called the appendix dead arm. The function of the appendix is to provide a means of separating the mercury in the stem from the mercury in the reservoir. Above the appendix, the thermometer is bent in a 360° loop, called the pigtail, from which it continues straight and terminates with the bulb at the upper end. The thermometer is so constructed that in the upright or lowering position mercury fills the reservoir, the capillary (pigtail and stem), and sometimes part of the bulb, depending upon the temperature. When the thermometer reverses, the mercury column breaks at the appendix and descends into the bulb, filling it and part of the stem, thus indicating the temperature at the depth of reversal. The mercury remains at this reading until the thermometer is returned to the upright position when the mercury drains from the bulb and back into the reservoir.

D–4 The Auxiliary Thermometer.—The auxiliary thermometer is a small, ordinary mercurial thermometer that is mounted alongside the main thermometer (fig. D–1). It is used to obtain the air temperature at the time the main thermometer is read. The auxiliary temperature is needed as corrections must be applied to the main thermometer reading to compensate for the change in volume of the mercury in the main stem. This volume of mercury changes owing to the difference between the *in situ* water temperature and the air temperature.

D–5 Protected Reversing Thermometers.—The main and auxiliary thermometers of protected reversing thermometers are enclosed in a heavy glass jacket (fig. D–1). The jacket is sealed at both ends and the air within is partially evacuated. The space surrounding the reservoir of the main thermometer is filled with mercury. This mercury serves as a thermal conductor and gives the instrument greater sensitivity to temperature change. The sealed jacket protects the thermometer from hydrostatic pressure thereby giving a true reading of the

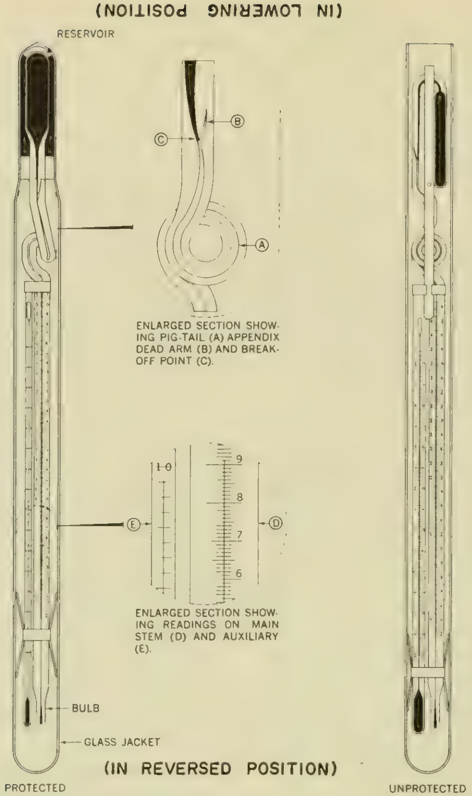


Figure D–1. **Protected and unprotected deep sea reversing thermometers.**

water temperature *in situ.* The temperature scales of main protected reversing thermometers range from –2° C. to as high as 32° C.

D–6 Unprotected Reversing Thermometers.—An unprotected reversing thermometer is similar to the protected except that the heavy glass jacket that encloses the main and auxiliary stems is open at one end, and it has no mercury surrounding the reservoir. Since the unprotected thermometer is in direct contact with the water and is subject to hydrostatic pressure, it does not give a true temperature reading; instead, it gives a reading which is increased approximately 1° C. for each 100 meters of depth. The unprotected thermometer, when used with a protected thermometer, is a pressure gage for determining the exact depth of the thermometers at the time of reversal. The temperature scales of main unprotected reversing thermometers range from –2° C. to as high as 60° C. For extremely deep measurements (ocean trenches), specially developed thermometers with expanded scales to as high as 80° C. are used.

D–7 Handling, Storing, and Transporting Deep Sea Reversing Thermometers.—Deep sea reversing thermometers are delicate precision instruments and must be handled with care. Special carrying cases are used for storing and transporting thermometers. Thermometers always are hand carried to and from the survey ship.

When handling a reversing thermometer, *never lay it on its side.* The construction of the thermometer is such that in a horizontal position the mercury in the main thermometer may become separated. This separation can trap gas in the stem and cause the instrument to malfunction. NAVOCEANO oceanographers always store and transport thermometers in the specially constructed carrying cases shown in figure D–2. These cases are padded with shock absorbent material and have compartments for 48 to 60 thermometers. Thermometers are placed in the carrying case with the pigtail-end down; however, if air temperatures of –10° C. (14° F.) or lower are expected to be encountered, the thermometers should be reversed; otherwise, the auxiliary thermometer may be damaged. Always transport the carrying case in an upright position. While aboard ship, store extra thermometers in the case and protect from excessive vibration and shock. In the laboratory ashore and while at sea, thermometers should be reversed once each 24 hours to insure satisfactory functioning of the instrument.

D–8 The Nansen Bottle.—The Nansen bottle is a metal reversing water sampler with a 1.25-liter capacity (fig. D–3). This bottle is used to obtain an uncontaminated water sample and to reverse the attached deep sea thermometers at any desired depth. The bottle is fitted at both ends with tapered plug valves; the valves are joined with a connecting rod. The lower end of the bottle is securely attached to the oceanographic wire with a clamp, and the upper end is hooked to the wire by a tripping mechanism. The device is lowered with the tapered plug valves in an open position, thus flushing itself during lowering.

When a series of Nansen bottles on a wire has been lowered to a predetermined depth (a cast), a brass weight (messenger) is attached to the wire and dropped. The messenger triggers the tripping mechanism to disconnect the top of the bottle from the wire; the bottle then reverses, making a 180° arc with the wire (fig. D–4). The valves close when reversal occurs, entrapping a water sample, and a second messenger is released which in turn effects the reversal of the next deeper bottle, and so on until all bottles on the cast have reversed.

Each Nansen bottle is fitted with a detachable deep sea reversing thermometer frame (fig.

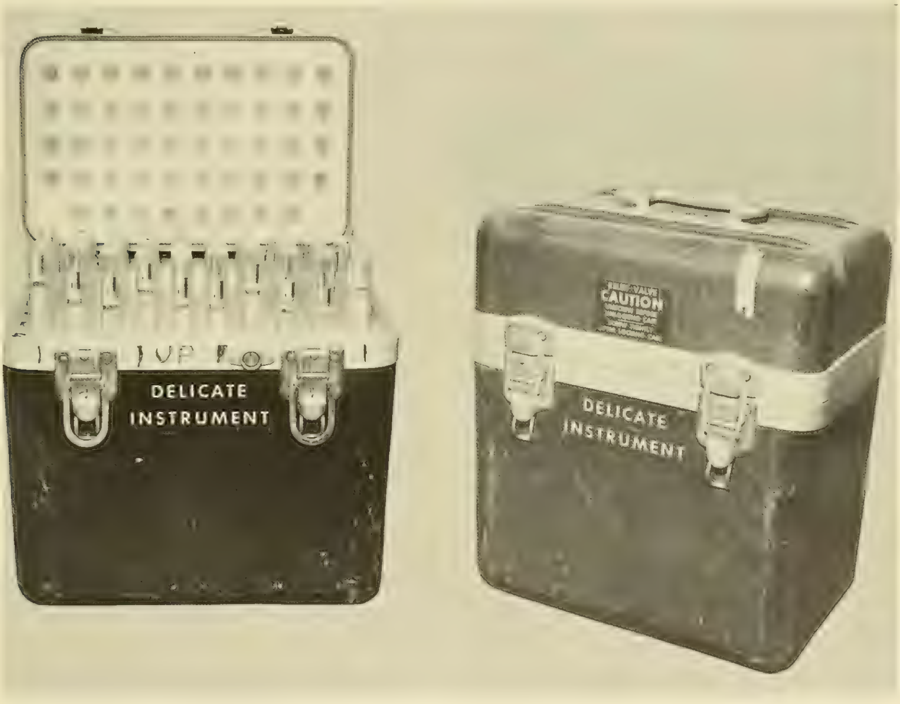


Figure D–2. Special carrying cases for storing and transporting thermometers.

223-812 O - 68 - 4

Figure D–3. Nansen bottle with reversing thermometers.

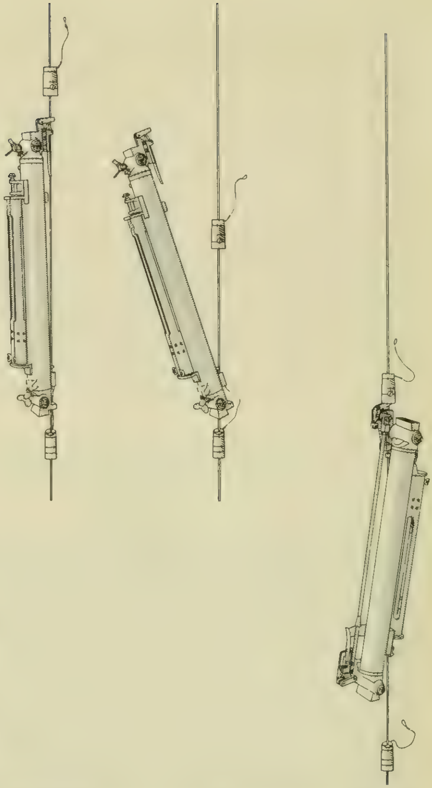


Figure D–4. Nansen bottle in three positions—before tripping, during tripping, and after tripping.

D–3). Frames for two, three, or four thermometers are used. The tubes of the frame are slotted and perforated so thermometers can be read without removing them from the tubes and to permit water circulation so the thermometers will come to temperature more rapidly. The tubes contain coil springs and rubber pads to hold the thermometers securely in place and to provide protection against shock. When a Nansen bottle is reversed at a given depth, the thermometer frame is inverted.

D–9 Nansen Bottle Racks.—An arrangement for racking the Nansen bottles is essential for proper conduct of operations. The Nansen bottle rack should be fabricated to hold 12 or more bottles side by side. It must be constructed so that the Nansen bottles are held securely in a vertical position and yet can be removed readily. Immediately below each Nansen bottle the rack should have compartments to hold several water sample bottles. The rack should be mounted on a bulkhead near the platform and A-Frame in a location protected from the sun and weather. It should be at a height for easy reading of the reversing thermometers (fig. D–5).

D–10 Standard Depths.—In 1936, the International Association of Physical Oceanography proposed the following standard depths at which observations should either be taken directly or the data adjusted by interpolation from the distribution at other levels. These standard depths, in meters below the sea surface are: 0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, 400, 500, 600, (700), 800, 1,000, 1,200, 1,500, 2,000, 2,500, 3,000, 4,000, and thence every

Figure D–5. Nansen bottle rack.

1,000-meter interval to the bottom. The depths in parentheses are optional. All data obtained by Nansen bottles and used at the Oceanographic Office are interpolated to standard depths.

D–11 Nansen Bottles in Series.—To expedite work at sea, Nansen bottles are used in series; several bottles are attached at intervals along the wire during a single lowering or cast. In this way, nearly simultaneous water samples and temperatures at different depths are obtained with one lowering. As many as 18 bottles may be used on one cast, depending on the size of the wire and the depth of the lowering. The depth to which bottles will be lowered is determined prior to starting a cast. Generally, the bottles are spaced at close intervals near the surface since the temperature and chemical properties are often more variable in this region. One or more casts may be required to sample the water column. This operation is described by the term "Taking an oceanographic station."

D–12 Preparing the Nansen Bottles for Operation.—Before a Nansen bottle is used on a station, check it carefully for proper operation of parts. Lubricate the valves with a silicone stopcock grease to insure smooth movement and watertight seal. Lubricate all other moving parts with penetrating oil to give free action. Test springs and pins of the messenger- and bottle-releasing mechanisms for proper action. If they are too weak, the bottle may trip prematurely or the messenger may release while the bottle is being lowered. If they are too stiff, they will not release properly when struck by the messenger. Check the action of the air vent screw and the condition of the washer. The two air vent holes must not be clogged. The drain petcock valve should turn smoothly.

A Nansen bottle spare-parts kit is provided those ships which maintain Nansen bottles for a period of time over several cruises. The kit contains spare clamps, springs, washers, pins, and the necessary tools to effect minor repairs and general maintenance. After the bottles have been checked and are in good operating condition, place them in the Nansen bottle rack with the air vent screw at the top.

When the thermometers for the bottles are selected, place them in a thermometer frame and attach the frame to the bottle. Use two protected thermometers on each Nansen bottle. It is customary to place the protected thermometers to the left in the thermometer frame and the unprotected to the right. This enables the reading of the thermometers and recording of the data in the proper order for applying the corrections. Thus, errors in computations are reduced.

It usually is not necessary to have unprotected thermometers on every Nansen bottle used in a cast. They should be placed strategically, however, so that the depths of reversal of other bottles in the cast can be interpolated readily.

On shallow casts, i.e., those commencing with bottles at the surface, it is best to group the unprotected thermometers on the lower bottles as this type thermometer will not record accurately at depths less than 200 meters.

On deep casts, i.e., those commencing with bottles at depths below those of the shallow cast, it is most important that unprotected thermometers be placed on the top and bottom bottles. The remaining unprotected thermometers should be on bottles spaced at as nearly equal distances along the wire as possible.

After the Nansen bottles have been checked and equipped with thermometers, invert the bottles and arrange them in the Nansen bottle rack in the order they will be placed on the wire.

D–13 Spacing the Nansen Bottles.—Several factors influence the spacing of Nansen bottles along the wire and these vary from station to station with the types of data sought. While it is desirable to obtain data at or near standard depths, this is accomplished only under conditions of zero or near zero wire angles. Such conditions are relatively rare at sea. Iso-conditions of temperature and chemical properties may warrant wider spacing of bottles. In order to better delineate gradients of temperature and chemical properties, closer spacing may be required. Often, to determine proper bottle spacing on the shallow cast, a bathythermogram is taken and bottles are spaced on the wire in relation to the existing thermal conditions.

D–14 Sea Water Sample Bottles.—The type analysis to be performed on a sea water sample determines the type sample bottle to be used (fig. D–6).

1. The sample bottle for salinity determination is the (so called) Citrate of Magnesia bottle, 12 oz. (360 ml.), with glass stopper and rubber gasket.

Figure D–6. Water sample bottles.

2. The sample bottle for oxygen determination by the regular Winkler titration method is the amber glass bottle, 250 ml., ground glass stoppered.

3. The sample bottle for oxygen determination by the Micro titration method is the Erlmeyer Flask, 125 ml., with a ground glass stopper.

4. The sample bottle for oxygen determination by the Gas Chromatography method is the glass serum bottle, 60 ml., with a rubber serum stopper.

5. The sample bottle for nutrient, pH, and alkalinity determination is the Polyethelene Boston Round Narrow Mouth bottle, 6 oz. (180 ml.), with screw cap.

One sea water sample bottle for each determination to be made should be placed in the Nansen bottle rack compartment beneath each Nansen bottle.

CHAPTER E

TAKING AN OCEANOGRAPHIC STATION

E–1 Oceanographic Log Sheet–A.—The Oceanographic Log Sheet–A (NAVOCEANO-EXP–3167/1 (Rev. 9–64)), usually referred to as the A-Sheet, is the basic record of an oceanographic station (fig. E–1). It is used to record the Nansen bottle observations, sea water sample bottle numbers of the salinity, oxygen, and nutrient samples, water temperature and depth calculations, and related meteorological and sea and swell information obtained while occupying an oceanographic station. The analyses and calculations of the station data are derived from the information recorded on this sheet. Extreme care must be taken when making all entries, which should be printed neatly. Upon completion of all entries and calculations, the A–Sheet should be filed in a manila oceanographic station folder (fig. E–2).

E–2 Setting Up the A–Sheet.—After the Nansen bottles, with their thermometers and sea water sample bottles, are arranged in the Nansen bottle rack in the order they are to be placed on the oceanographic wire, set up the A–Sheet for the first Nansen cast so no delay will be encountered once the ship arrives on station. Instructions for recording observations on the Log Sheet A (fig. E–1) follow:

Step 1. Record the following information in the appropriate blocks of the A–Sheet heading:

Project No. Each cruise is assigned a project number. This number is in the survey specifications.

Assigned Station No. This is a number and/or letter designating stations. It may be assigned prior to the cruise by the survey specifications.

Vessel. Record full name and number of ship.

Step 2. Record the number of each Nansen bottle to be used in the cast in *Nansen Bottle No.* column. List from shallow to deep, allowing an extra line for those bottles equipped with more than two thermometers.

Step 3. Record the following information in the various columns as appropriate:

Serial No. Salinity Sample Bottle No. Nansen bottle observations taken during a cruise are numbered consecutively beginning with the first Nansen bottle of the first station. Use this same number for the Salinity Sample Bottle Number. Mark the number on each salinity sample bottle with a waterproof marker.

Sample Bottle Number. Three columns are provided for recording additional sea water sample bottle numbers. In column (1) O_2, record oxygen sample bottle number. Use columns (2) and (3) for other chemical water samples.

Step 4. Identify each cast with a Roman numeral, and enclose the serial numbers of the cast with a bracket.

Step 5. In *Therm No.* columns, record the thermometer numbers for each Nansen bottle. The thermometer number is the manufacturer's number. It is inside the thermometer jacket on a metal band. Record this number carefully. Indicate unprotected thermometers by placing a triangular mark in the corner of the *Therm No.* block. *NOTE:* Two, three, and sometimes four thermometers are used on a Nansen bottle, and it is accepted practice to indicate their position in the thermometer frame as left and right. Also, when protected and unprotected thermometers are used on the same Nansen bottle, record the protected thermometers on one line and unprotected thermometer(s) on one line.

Step 6. Enter in the *Wire Length Depth (L)* column the length of wire in meters for the desired depth of each Nansen bottle.

Step 7. Compute the down meter wheel reading for each Nansen bottle by subtracting its wire length depth (L) from the wire length depth (L) of the deepest bottle, and record these values in the appropriate *Meter Wheel Reading Down* column; e.g.,

For Nansen Bottle number 1,
$600-0=600$
For Nansen Bottle number 10,
$600-400=200$
For Nansen Bottle number 12,
$600-600=0$

Write the meter wheel readings for the cast on a card, and give it to the winch operator so he will know where each Nansen bottle is to be placed on the wire.

Step 8. Invert the Nansen bottles and place them in the Nansen bottle rack with valves open and petcock up.

Step 9. After the ship arrives on station,

OCEANOGRAPHIC LOG SHEET–A
NAVOCEANO-EXP-3167/1 (Rev. 9-64)

RETURN TO:
U.S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

DO NOT CODE OBSERVATIONS

STATION AND THERMOMETER DATA
For use with H.O. Pub No. 607 (Amended)

Project No.	Assigned Station No.	Vessel	Date	Time Zone	Latitude	Longitude	Navigation	Weather	Barometer	Consecutive Station No.	Station Observers	Completed by	Checked by
201 - 01	4A	USS San Pablo	24 April 1965	+4	30° 30′ 0″ N.	69° 04′ 2″ W	LORAN C	Partly Cloudy	1017 9 MBS	3	LE JORDAN	KBP	FD

Nansen Cast	Wire Angle (1)	Wire Angle (2)	Start	Down	Mess	Up	In	Sonic Depth Meters
First	13°	15°	1010	1038	1048	1053	1115	5065
Second	20°	20°	1155	1242	1252	1320	1415	5070
Third	14°	17°	1505	1620	1615	1645	1815	5073

Wind Speed	Wind Dir	Ice Coverage	Air Temp. Dry	Air Temp. Wet	Clouds Type	Clouds Amt.	Visibility	Sea Dir	Sea Height	Swell Dir	Swell Height	Swell Length	Water Color	Water Transparency	Remarks
07	300	—	20 1°C	16 7°C	cumulus	4/10	7 miles	280	1	—	—	—	III	15 white	

Cast	Serial No. Salinity Sample Bottle No.	Sample Bottle Number (1) O_2	(2)	(3)	Nansen Bottle No.	Meter Wheel Reading Down (604)	Meter Wheel Reading Up	Wire Length Depth (L)	Left Therm. No.	Left Main (T′)	Left Aux. (t)	Left V_0	Left I	Left C_p / C_u	Left T_w	Right Therm. No.	Right Main (T′ or T′$_U$)	Right Aux (t or t_U)	Right V_0	Right I	Right C_p / C_u	Right T_w or T_u	Accepted or Average T_w	Diff. (T_U-T_W)	(T_w-T_w) Diff / 1/pm	Q Factor	Thermometric Depth (Z)	L-Z Obs	L-Z Used	Accepted Depth (D)	Remarks
I	49	1	49		1	600	601	0	366-64	19.81 / 19.82	18.6 / 18.8	97 9	.01 / .01	.02 / .02	19 84 / 19 85	210-62	19 88 / 19 89	18 8, 18 7 / 19 1, 19 0	110 4	.05 / .05	.02 / .02	19 85 / 19 86	19 85		.02				0	0	At slide numbers 48, 49, 50
	50	2	50		2	590	591	10	487-64	19 85 / 19 86	18 7, 18 5 / 18 8, 18 6	101 2	.02 / .02	.02 / .02	19 85 / 19 86	496-64	19 88 / 19 89	18 6 / 18 7	93 7	.05 / .05	.02 / .02	19 85 / 19.86	19 86		.00				0	10	
	51	3	51		3	580	581	20	485-64	19 20 / 19 22	18 7 / 18 9	85 8	.03 / .03	.01 / .01	19.18 / 19 20	539 64	19 19 / 19 20	18 6 / 19 0	98.7	.01 / .01	.01 / .00	19 19 / 19 19	19 19		.01				1	19	
	52	4	52		4	570	571	30	484-64	18 98 / 18 98	18 6 / 18 8	99 5	.01 / .01	.01 / .00	18 98 / 18 97	254 63	18 94 / 18 95	18 7 / 19 0	106 2	.00 / .00	.01 / 00	18 95 / 18 95	18.96		.03				1	29	
	53	5	53		5	550	551	50	268-63	19 05 / 19 04	18 8 / 19.0	101 0	.03 / .03	.01 / .00	19 09 / 19 08	674 65	19 10 / 19 11	18 7 / 19 1	95.0	.01 / .01	.01 / 00	19 10 / 19 10	19 09		.01				2	48	
	54	6	54		6	500	501	100	653-64	18 80 / 18 82	18.4 / 18 7	107 2	.02 / .02	.01 / 00	18 83 / 18 84	640-64	18 80 / 18 81	18 6 / 19 1	100 0	.04 / .04	.00 / .01	18 84 / 18 84	18.84		.01				3	97	
	55	7	55		7	450	451	150	637-64	18 72 / 18 74	18 4 / 18.7	97 0	.03 / .03	.01 / .00	18 76 / 18 77	642-64	18 79 / 18 80	18 4, 18 3 / 18 8, 18 7	110.0	.03 / .03	.01 / .00	18 77 / 18 77	18.77		.01				5	145	
	56	8	56		8	400	400	200	396-64	18 60 / 18 60	18 3 / 18.7	97 0	.02 / .02	.01 / .00	18 59 / 18 58	643-64	18 62 / 18 63	18 4 / 18 7	110 0	.04 / .04	.00 / 00	18 58 / 18 59	18.58		.00				6	194	
	57	9	57		9	300	300	300	641-64	17 84 / 17 83	18 3 / 18.5	97 7	.02 / .02	.01 / .01	17 85 / 17 84	708-64	17 88 / 17 88	18 4 / 18 7	104 6	.00 / 00	.01 / .02	17.87 / 17.86	17 86		.03			9	9	291	
									WAI No 1	14° DR200°						55-1321	20 63 / 20 64	18 1 / 18 2	106 3	.06 / 06	.00 / 01	20 57 / 20.57		2.71	.9737	.0090729	291				
	58	10	58		10	200	200	400	636-64	17 52 / 17 52	18.3 / 18.6	94 8	.01 / .01	.01 / .02	17 50 / 17.49	475-65	17 54 / 17 53	18 3 / 18 5	92 7	.01 / 01	01 / 02	17 54 / 17 52	17.51		.05			13	12	388	
																423-63	21 02 / 21 02	18 1, 18 2 / 18 2, 18 3	120.9	.00 / 00	.01 / 02	21 01 / 21.00		3 49	.9733	.0087893	387				
	59	11	59		11	100	100	500	510-64	16.92 / 16 91	18 4 / 18 6	101 0	.05 / .05	.03 / 03	16 84 / 16 83	157-64	16.81 / 16 82	18 3, 18 4 / 18 4, 18 5	103.7	.02 / .02	.03 / .03	16 80 / 16.81	16.82		.04			14	14	486	
									WAI No 2	5° DR210°						419-63	20.96 / 20.96	18.5 / 18 6	120.8	.01 / 01	.04 / .04	20.91 / 20 91		4.09	.9730	.0081841	486				
	60	12	60		12	0	0	600	327-64	15 17 / 15 18	18 3 / 18 4	94 2	.02 / .02	.06 / .06	15 13 / 15.14	701-64	15 20 / 15 20	18 4 / 18 5	105.4	.03 / 03	.06 / .07	15 11 / 15.10	15 12		.04			15	15	585	
																196-64	20 04 / 20.05	18 4, 18 5 / 18 5, 18 6	139 6	.01 / .01	.09 / .09	19.96 / 19.97		4.84	.9727	.0080448	585				

Summary T_w–T_w Diff.		Pair	Ind.
Total T_w =		12	
Diff °C	.00	2	
	.01	4	
	.02	1	
	.03	2	
	.04	2	
	>.04	1	
One T_w Acc	1A		
None Acc	X		

Figure E–1. Oceanographic Log Sheet–A.

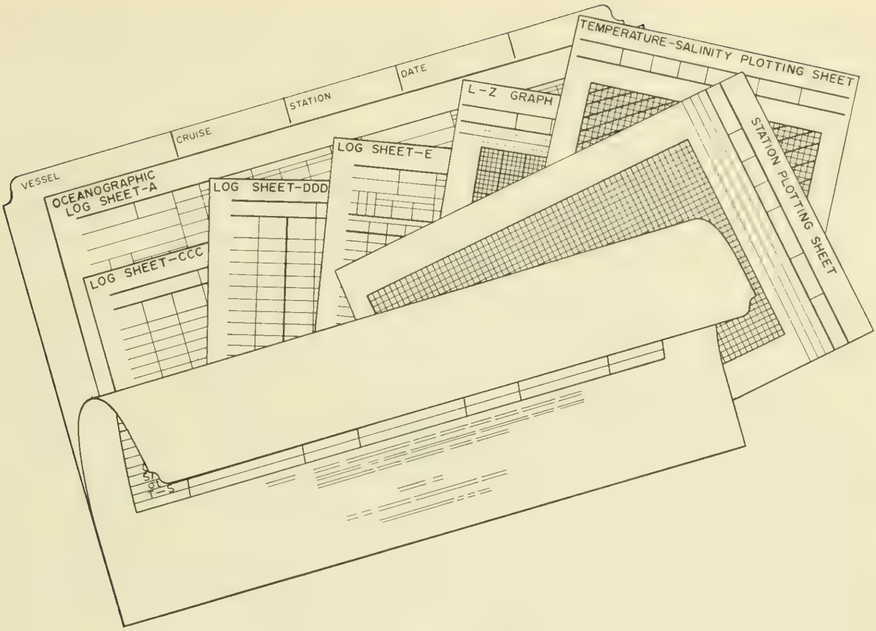


Figure E–2. **Oceanographic Station Folder.**

complete the following items on the heading of the A–Sheet:

Time Zone. Record time zone, e.g., +4

Sonic Depth. Immediately after the ship has stopped on station and at the time of additional casts, obtain the sonic depth and record it in meters.

Latitude, Longitude, and Navigation. The position of the station is obtained from the bridge. Later correct this position from the adjusted ship's track or the smooth plotting sheets. The messenger time of the first cast is used to determine the time of the position. Record in degrees, minutes, and seconds (North or South, East or West). Indicate type navigation used.

Weather. Record a description of the weather, *do not code.* If more space is required use remarks section.

Barometer. Record the barometer reading and the units of measurement.

Wind Speed (knots). When ship is equipped with an anemometer, or a portable anemometer is used, record wind speed in knots. Record the height of the ship's anemometer above the water under *Remarks.* If an anemometer is not available, record a description, *do not code.*

Wind Direction, °T. Record the direction from which the wind is blowing in degrees true, *do not code.*

Ice Coverage. Where ice exists, record type and coverage in tenths; e.g., Pancake 5/10.

Air Temperature. Dry- and wet-bulb air temperatures are recorded in degrees and tenths. Indicate Celsius (°C.) or Fahrenheit (°F.).

Cloud Type. Record a description of the significant clouds, *do not code.*

Cloud Amount. Record the total amount of cloud coverage in tenths; e.g., 0/10, 2/10, 10/10. If sky is obscured or amount cannot be estimated, so state in *Remarks.*

Visibility. Record visibility in feet, yards, meters, or nautical miles; e.g., 1,000 ft., 1,000 yds., 3,000 meters, 4 miles, *do not code.*

Sea and Swell Direction. Record direction from which waves and/or swell are coming in degrees true, *do not code.*

Sea and Swell Height (feet). Record estimated height of waves and/or swell in feet, *do not code.*

Swell Length (feet). Record estimated number of feet between crests, *do not code.*

Water Color (Forel). At daylight stations only, record water color by Forel Scale numeral when scale is used; otherwise, record a description.

Water Transparency. Record Secchi disc observations only.

E–3 Testing and Inspecting the Oceanographic Winch and Accessories.—Before taking the first oceanographic station, the oceanographic winch, wire, A-Frame, and platform should be tested and inspected.

1. Winch and Wire.

a. Inspect the winch to insure that all parts are properly lubricated, especially the level wind mechanism. Check the hydraulic fluid level. Check electrical connections.

b. Check the operation of the winch after the ship has come to a complete stop in the water by slowly paying out wire, with 100-pound Nansen cast weight, to near bottom depths. During the lowering, carefully inspect wire for broken strands, splices, kinks, corrosion, nicks, and unlayed areas. The condition of the wire will determine the need to replace wire or to limit loads and depths of subsequent operations. A continuous wire rope history should be maintained. As the wire is brought in, vary winch speeds from creeping to full and check braking action.

2. A-Frame and Platform.

a. Inspect A-Frame mounting to insure that all pins are properly seated and safety-wired.

b. Check A-Frame inboard-outboard travel.

c. Inspect rigging of meter wheel to insure shackle is well seated and safety-wired. A good practice also is to install a safety wire (⅜- to ½-inch) through the sheave, beneath the eye, and around the top of the A-Frame.

d. Inspect mounting of counter block and flexible cable to insure adequate slack to permit free lateral travel of block. Inspect pointers on counter block to make sure they are firmly attached. Tighten flexible cable connecting nuts only finger tight.

e. Check that platform fittings, braces, and stays are properly seated and in good condition. Make sure life rails or chains are adequate and well secured.

In addition to testing and inspecting the above items, the following preparations should be considered before arriving on station:

a. Assure adequate overhead and over-the-side lighting for night time operations, and arrange for communications with the bridge.

b. Rope off area to exclude nonoperational personnel traffic.

c. Clear area of unnecessary objects and equipment, and remove all grease and/or oil from the deck. Sand if necessary.

d. Have available life jackets and/or life rings; hard hats, safety shoes, safety glasses, safety belts, and gloves also are desirable. A boat hook and a "Come Along" wire gripper should be available in the area.

On stations when water samples are to be collected, the ship should refrain from backing down and from pumping bilges, releasing laundry wastes, and discarding trash and garbage into the surface water.

E–4 Taking a Nansen Cast.—When the ship is on station and permission to proceed with the operation has been received from the bridge, the Nansen bottles are placed on the wire. This operation requires three persons: A winch operator, a bottle passer, and a bottle hanger (fig. E–3).

Step. 1. Final Inspection.—Give the Nansen bottles a final inspection for proper adjustment of main valves and connecting rods and secure attachment of thermometer frame.

Step 2. Placing the Nansen Bottles on the Wire.—Lower the lead weight over the side and into the water several meters to steady the wire. Set the counter dials at zero; record the time (GMT) in the *START* column of the *Greenwich Mean Time* block of the A-Sheet; and enter the day, month, and year (GMT) in the *Date (GMT)* block of the A-Sheet. The bottle passer should remove the first bottle from the rack; reverse it and return it to the inverted position to check for proper functioning of the mercury columns in the thermometers, and then pass it to the bottle hanger. Repeat this procedure for each successive bottle. It should be noted that the first Nansen bottle to be placed on the wire will go to the greatest depth; thus, the bottom bottle of the cast is the first bottle placed on the wire. At this time, the bottle hanger should attach the safety line (a snap-hook on the end of a light line) to the Nansen bottle connecting rod. The safety line prevents possible loss of the bottle over the side. Next, clamp the lower end of the bottle to the wire and tighten the wing nut; then, depress the messenger trigger of the tripping mechanism and attach the upper end of the bottle to the wire, making sure the messenger trigger returns to the "up" position and the pin holding the bottle to the wire returns to the closed position (fig. E–4). Next, check to insure that the drain petcock at the upper end of the bottle and the air vent at the lower end of the bottle are closed. Finally, check that the mercury has drained from the upper portion of the main stem bulb of the thermometers. Then remove the safety line.

Step. 3. Attaching the Messenger to the Bottle.—The messenger is a small brass weight constructed in such a manner that it can be attached to and detached from the wire quickly and can slide freely along the wire. When released, it slides down the wire and trips the next bottle below. Attached to the messenger is a 6- to 8-inch wire with a small loop at the end. To attach

Figure E–3. Winch operator (1), bottle passer (2), and bottle hanger (3).

the messenger to the Nansen bottle, depress the messenger release arm, and insert the messenger wire loop in the hold slot on the underside of the clamp assembly. After making sure the messenger release pin has seated itself through the loop, attach the messenger to the wire, check that it is properly closed and slides freely, then signal the winch operator to lower away. *NOTE:* If the wire angle of the cast is 35° or more and on all deep casts use two messengers on each bottle to assure tripping. *On all bottles except the first bottle placed on the wire, messenger(s) must be attached.* To avoid the accidental tripping of bottles that have been lowered, the safety line may be attached to the oceanographic wire while the messenger(s) is being attached.

Step 4. Lowering the Nansen Bottle.—Lower the Nansen bottle slowly until it has entered the water. When the bottle is one or two meters below the surface gradually increase the speed of the winch to its normal lowering speed. If the bottle is lowered into the water too rapidly, the messenger may release prematurely or the bottle may trip. In the first instance, any bottles below will be tripped, and in the second,

Figure E–4. Nansen bottle being placed on wire.

the bottle may be crushed if any air should be trapped in it and the lowering continued (fig. E–5). Stop the winch at each down meter wheel reading, and attach the next bottle until all bottles are on the cast. Then lower the last bottle to just below the surface, stop the winch, and set the brake. It is important that winch operations, starting and stopping, be conducted as *smoothly* as possible to prevent pretripping of bottles and malfunctioning of thermometers. On the A-Sheet, record time (GMT) in *DOWN* column, and record the meter wheel reading at the top of the *Down Meter Wheel Reading* column. On the 2d and 3d casts, after the last bottle is attached, lower the cast to the wire length depth of the deepest bottle plus the distance from the water surface to the level of attachment by the bottle hanger.

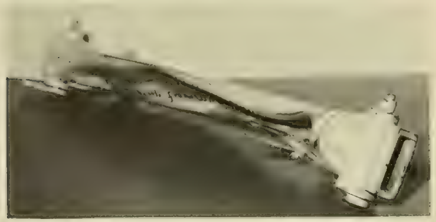


Figure E–5. A crushed Nansen bottle.

Step 5. Measuring the Wire Angle and Dropping the Messenger.—Before the messenger is dropped to trip the bottles on the cast, a minimum of 10 minutes should be allowed for the reversing thermometers to come to the temperature of the water. Measure the wire angle with the wire angle indicator—a simple device for measuring the angle of the oceanographic wire with the vertical (fig. E–6). Take the average of several readings to allow for roll of the ship; then, drop the messenger. On the A-Sheet record the wire angle in *Wire Angle (1)* column and the time (GMT) the messenger was dropped in the *MESS* column.

The time required for a Nansen bottle messenger to reach the last bottle of the cast may be computed at 200 meters per minute for wire angles less than 35° and at 150 meters per minute for wire angles greater than 35°. Time can be saved when deep casts are down by deducting messenger time for the distance to the shallowest bottle from the time the bottles are allowed to remain *in situ*. For example, if it takes 3 minutes for a messenger to reach and trip the shallowest bottle, the messenger may be dropped 7 minutes after the cast is down instead of waiting 10 minutes.

Step 6. Retrieving the Nansen Bottles.—After sufficient time has lapsed for the deepest bottle to be tripped, remeasure the wire angle, start the winch, and commence hoisting. On the A-Sheet, record the second wire angle measurement in *Wire Angle (2)* column and the time

Figure E–6. Wire angle indicator.

(GMT) the hoisting commenced in the *UP* column. Post a lookout during the entire retrieval operation. The lookout should signal the winch operator when the bottle is *in sight*, at which time the winch operator slows the winch. When the bottle breaks the *surface*, the lookout again signals the winch operator, who then slows the winch to a creeping speed. After carefully hoisting the bottle to the platform, stop the winch, snap the safety line onto the bottle (fig. E–7), and remove the messenger(s) and bottle from the wire. Remove the safety line, and keeping the bottle in a vertical position, return it to its original place in the rack. *NOTE:* Avoid excessive shock to the thermometers. Record the meter wheel reading in the *UP* column of the A-Sheet opposite each bottle as the cast is brought in. When all Nansen bottles have been returned to the rack, record the time (GMT) in the *IN* column of the A-Sheet.

The process of transferring water from Nansen bottles to sea water sample bottles is described as "drawing water samples" (fig. E–8); samples drawn for a certain chemical determination are referred to as a salinity sample, oxygen sample, etc. See chapter D, paragraph D–14, for types of sea water sample bottles.

Step 7. Drawing the Oxygen Sample.—The first sample to be drawn should be the oxygen sample. Use either the amber bottle, the flask, or the serum bottle depending on the type analysis. Loosen the air vent thumb screw at the top of the Nansen bottle. Attach a delivery tube (a piece of soft-wall tygon tubing about 8 inches long) to the petcock. Open the petcock and draw a small amount of water (1 inch in bottle). Thoroughly rinse the bottle by swirling. Rotate bottle in a horizontal position, pouring the rinse water over the stopper. Rinse at least twice. When bottle is rinsed, insert tip of delivery tube to the bottom of the sample bottle. Open the drain petcock slowly to prevent air bubbles. As the bottle fills, gradually withdraw the delivery tube, always keeping the tip of the tube below the surface of the sample. Allow the bottle to overflow slightly, withdraw the delivery tube; then turn off the petcock. Insert the stopper into the mouth of the bottle in such a way that no bubbles of air are trapped, and allow it to seat. Invert the bottle and check for presence of bubbles. If air bubbles are present in the sample, discard it and draw another. Oxygen samples for titration analysis must be treated immediately after they have been drawn. *NOTE:* Replicate samples are collected if analysis is to be by the (Micro) Winkler method.

Step 8. Drawing the Nutrient and Trace Metal Sample.—After the oxygen sample is drawn, draw nutrient and trace metal samples. Use the polyethelene bottle. Open the petcock (the delivery tube is not required), and fill the bottle

Figure E–7. Snapping the safety line onto the bottle.

Figure E–8. Drawing water samples.

about one-fourth full. Thoroughly rinse the bottle by shaking vigorously and pour the rinse water over the screw cap. Rinse at least twice. When the bottle is rinsed, open the petcock, fill the bottle to about 1 inch from the top, and close the petcock. Cap the bottle and replace in rack. If the nutrient sample is to be analyzed at a later date, it should be quick frozen within 30 minutes.

Step 9. Drawing the Salinity Sample.—After the oxygen and nutrient samples are drawn, draw the salinity samples. Use a clean citrate of magnesia bottle with a well seated stopper and washer. Open the petcock (the delivery tube is not needed) and fill the bottle about one-fourth full. Thoroughly rinse the bottle by shaking vigorously and pouring the rinse water over the stopper and the rubber washer. Rinse at least twice. When the bottle is rinsed, open the petcock, fill the bottle to within 1 inch of the top, and close the petcock. A 1-inch air space must be left to allow for expansion. Seal the bottle and return to the rack.

Step 10. Checking Water Sample Bottle Numbers and A–Sheet.—After the water samples are drawn, check to make certain that the numbers on the water sample bottles are legible, that they agree with A–Sheet entries, and that they have been drawn from the Nansen bottles indicated on the A–Sheet. Move samples to the laboratory for analysis or storage.

Step 11. Reading and Recording Temperatures.—After the cast is in and the water samples are drawn, allow time for the reversing thermometers to come to air temperature before reading temperatures. This usually takes from 10 to 15 minutes. For optimum results, the ship should remain on station until thermometers are read. When all auxiliary thermometers in both the protected and unprotected thermometers read approximately the same, the thermometers can be presumed to have come to air temperature.

A special thermometer viewer, with a 6–× lens mounted in a brass tube, is used for reading the thermometers (fig. E–9). The front end of the tube has two V notches for alining the viewer against the glass jacket of the thermometer. In addition, a flashlight may be required when reading the thermometers. Exercise care in reading the position of the mercury column (fig. E–10). If the ship is rolling and the mercury column is fluctuating, read at "midroll." Two persons are required for reading and recording temperatures (fig. E–11). Observer number one reads all thermometers while number two records; then, they change, and number two reads while number one records. The main

Figure E–9. Reading the reversing thermometer with viewer.

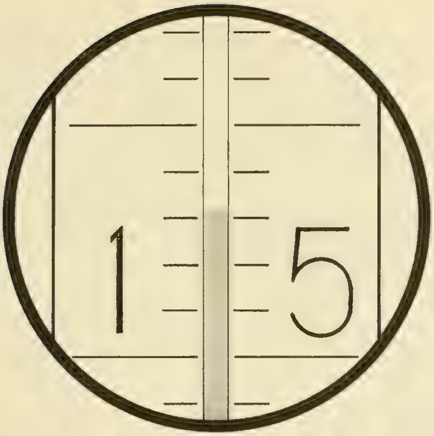


Figure E–10. The scale divisions and the mercury column of the reversing thermometer main stem as seen through the thermometer viewer. *Note:* The meniscus of the mercury column is arched. For proper reading, center the top of the mercury in the viewer, and read the top of the meniscus on the scale; e.g., 15.32.

Figure E–11. Reading and recording reversing thermometers.

stem is read to the nearest one-hundredth degree; the auxiliary to the nearest tenth degree. The recorder enters the value on the A-Sheet in the appropriate columns. Space is available for recording both readings (*1*) and (*2*) of the main (*Main* (T')) and auxiliary (*Aux.* (t)). Record the auxiliary temperatures with small numbers in the lower half of the spaces provided. If a thermometer malfunctions by flooding, separating, etc., enter type of malfunction in the *Main* (T') column. If the two main temperature readings for a thermometer differ by more than .02°, reread the main and auxiliary thermometers and agree on the correct reading. After the temperatures have been read and recorded, drain the bottles, invert in the rack, and rearrange as necessary for the next cast or station. Inspect thermometers for mercury drainage from the main stems. Notify the bridge that the operation is completed.

E–5 Maintenance and Storage of Nansen Bottles, Reversing Thermometers, and Water Sample Bottles.—At the end of the survey and during extended periods of downtime or adverse sea conditions, Nansen bottles, thermometers, and water sample bottles should be cleaned and stored as follows:

Step 1. After removing thermometers, rinse Nansen bottles with warm fresh water. Lubricate all moving parts with oil, and lubricate valves with silicone grease. Store Nansen bottles in Nansen bottle rack or in their shipping cases.

Step 2. Wash thermometers thoroughly with fresh water. Be sure to flush out the jacket of the unprotected thermometers. Dry thermometers and store in the carrying case *placing the reservoir end down*, unless the stored thermometers will be subjected to temperatures colder than −10°. *Note:* When handling and storing, avoid placing thermometers in a horizontal position.

Step 3. Rinse water sample bottles with fresh water and place in storage cases.

E–6 Subsurface Wire Angle Indicator.—Numerous devices have been designed to measure the Nansen cast subsurface wire angle. One of these devices is the subsurface wire angle indicator shown in figure E–12. This device indicates the angle of the wire and the direction it is tending. Instructions for operating the subsurface wire angle indicator follow:

E–7 Instructions for Operating the Subsurface Wire Angle Indicator.—When subsurface wire angle indicators are to be used on the Nansen cast, space for recording the data should be provided when the Log Sheet–A is being prepared. For example, if three wire angle indicators are to be used on a cast, determine the wire length depth for each indicator and make the following entries on the log sheet:

Nansen Bottle No. column. Leave one line on the A–Sheet between the two Nansen bottles where the wire angle indicator (WAI) will be placed. Enter WAI No.1, 2, or 3 and mark the number on the instrument with waterproof ink.

Wire Length Depth (L) column. Enter wire length depth.

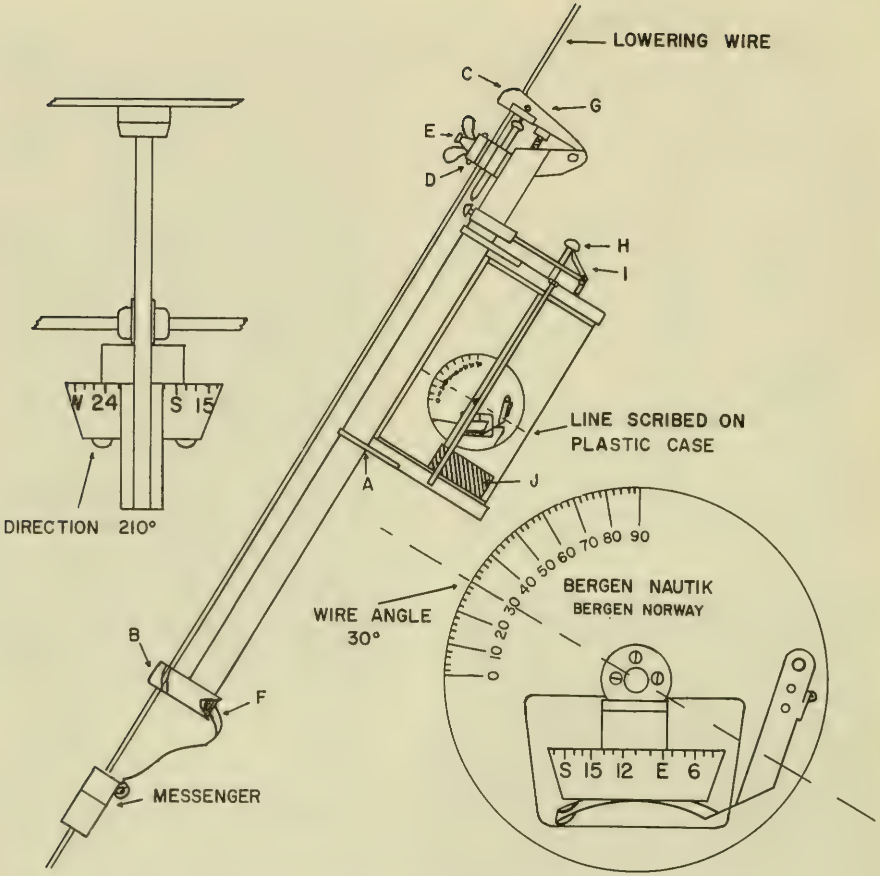


Figure E–12. Subsurface wire angle indicator (designed by Dr. J. N. Carruthers.)

Meter Wheel Reading Down column. Calculate this value in the same manner as though the wire angle indicator was a Nansen bottle (see par. E–2).

When the cast is being lowered, stop the winch when the counter dials indicate the down meter wheel reading for the WAI, and attach the device to the wire as follows:

Step 1. Snap the safety line clip to rod (A) on the indicator, and engage the oceanographic wire in wire groove (B) at the bottom of the indicator.

Step 2. Then engage the oceanographic wire in upper wire slot (C) and wire clamp (D) and tighten the thumb screw (E) until the WAI is secured to the oceanographic wire.

Step 3. Unclip the safety snap and hook to the oceanographic wire below the indicator.

Step 4. Place a messenger with wire and loop on the lowering cable below the indicator and connect the loop of the wire to the messenger release mechanism (F) by pressing down on the tripping mechanism (G).

Step 5. Cock the indicator mechanism by lifting spring plunger (H) with fingers and engaging trigger (I).

Step 6. The WAI is now set to operate. Remove the safety clip from the lowering wire, and lower the indicator into the water.

E–8 Retrieving the Wire Angle Indicator.— Keep a sharp lookout for the subsurface wire angle indicators when hoisting the Nansen cast. Signal the winch operator when the indicator is *in sight* and again when it is at the *surface* of the water. When the indicator is at platform level, check the UP meter wheel reading and record it, connect the safety line to rod (A) on the indicator, and remove the tripping messenger and indicator from the wire.

E–9 Reading the Wire Angle Indicator.—To read the wire angle indicator hold the instrument at eye level and read the wire angle directly from the zero to 90° scale. A line scribed on the plastic case that encloses the angle indicator and compass is the horizontal reference line for the angle indicator. Enter the wire angle in the *Therm. No.* column. The direction the wire was tending at the time the indicator was tripped can be read directly from the compass. Enter this direction under the wire angle reading in the *Therm. No.* column; e.g., DR 210°.

CHAPTER F

A-SHEET COMPUTATIONS

F–1 General.—A-Sheet computations include correcting protected thermometer readings, averaging water temperatures, correcting unprotected thermometer readings, calculating thermometric depths, and determining accepted depths. To perform these calculations, the Reversing Thermometer Calibration and History Record PRNC–NAVOCEANO–3167/53 (Rev. 2–64) for each thermometer used is required, and an L–Z Graph NAVOCEANO 3167/62 (Rev. 2–64) for each cast of the oceanographic station is required. The A-Sheet is described in chapter E.

F–2 Reversing Thermometer Calibration and History Record.—After a deep sea reversing thermometer is manufactured and before it is used in taking an oceanographic station, the thermometer must be calibrated. This calibration process determines the deep sea reversing thermometer corrections to be applied to the temperature scales etched on the main and auxiliary stems of the thermometers. It also establishes the volume of mercury (V_0), at zero degrees Centigrade, in the thermometer reservoir and main stem capillary. In addition, the calibration determines the "Q" Factor, or pressure factor, for unprotected thermometers at 1,000-, 2,000-, 3,000-meter, etc., depth increments. "Q" Factors for 500-meter depth increments are determined when required. Thermometers are calibrated at the U.S. Naval Oceanographic Instrumentation Center, and the results are recorded on the Reversing Thermometer Calibration and History Record (fig. F–1). The record includes the following information: The thermometer number, make (manufacturer's name), V_0 in °C., makers V_0 in °C., "K" value (glass-mercury coefficient of expansion constant), range (main stem scale), smallest scale division, protected or unprotected, owner, purchased new or used, purchased from, cost, and date acquired. In addition, the record includes Deep Sea Reversing Thermometer Corrections at various temperatures for both main and auxiliary thermometers and "Q" factors for unprotected thermometers. The record also includes an interpolation table for temperature corrections. This table is completed by the thermometer user. Instrumentation personnel performing and certifying the calibration, the date calibrated, the adherence to contract specifications, and the functioning of the instrument are shown on the record. The bottom of the form contains a Thermometer History Record for the user to record cruise, dates thermometer was used, and performance (see ch. G).

F–3 The Main and Auxiliary Interpolation Table.—The values for the Main and Auxiliary Interpolation Tables can be computed graphically or algebraically as follows:

(1) Graphically:

Step 1. Construct a graph making the main thermometer correction as one coordinate and the main thermometer temperature as the other (fig. F–2).

Step 2. At the plus and minus 0.005, 0.015, 0.025, etc., correction values, determine the corresponding temperature, and enter the values in the Main Interpolation Table (round to the nearest hundredth degree).

Step 3. Construct a similar graph for the auxiliary corrections and temperatures and determine the plus and minus 0.05, 0.15, 0.25, etc., correction values and enter in the Auxiliary Interpolation Table (round to the nearest tenth degree).

(2) Algebraically:

Step 1. Compute the temperatures (T_c) that correspond to the "I" (I_c) by the following formula:

$$\frac{T_2-T_1}{C_2-C_1}=\frac{T_c-T_1}{I_c-C_1}$$

where I_c is plus or minus 0.005, 0.015, 0.025, etc., correction values and T_1 and T_2 and C_1 and C_2 are the thermometer main temperatures and corrections on the calibration card.

Example:

$$\frac{5-0}{+0.011-(-0.002)}=\frac{T_c-0}{+0.005-(-0.002)}T_c=2.69$$

$$\frac{10-5}{+0.028-(+0.011)}=\frac{T_c-5}{+0.015-(+0.011)}T_c=6.18$$

Step 2. Round I_c to hundredth in direction of C_1 and enter in the Main Interpolation Table.

Step 3. Repeat step 1 substituting plus or minus 0.05, 0.15, 0.25, etc., correction values I_c, and the auxiliary temperatures and corrections for T_1 and T_2 and C_1 and C_2.

Step 4. Round I_c to tenth in direction of C_1 and enter in the Auxiliary Interpolation Table.

223-812 O - 68 - 5

NUMBER	MAKE	V_0 = 139.6 °C / MAKERS $V°$ = 146 °C	"K" VALUE = 6098	RANGE	SMALLEST SCALE DIVISION	
195-64	Kessler			-2 °C TO + 30 °C	0.1 °C	[ ] PROTECTED [X] UNPROTECTED

OWNER			
U. S. NAVAL OCEANOGRAPHIC OFFICE		[X] PURCHASED NEW [ ] PURCHASED USED	PURCHASED FROM: KESSLER CO. PRICE: $92.30 DATE ACQUIRED: June 1964

DEEP SEA REVERSING THERMOMETER CORRECTIONS

MAIN THERMOMETER		AUXILIARY THERMOMETER		"Q" FACTOR
TEMPERATURE	CORRECTION	TEMPERATURE	CORRECTION	1000 METERS
0 °C	-0.002	0 °C	0.00	1=0.0080448
5 °C	+0.011	10 °C	-0.10	2=0.0080272
10 °C	+0.028	20 °C	-0.08	3=0.0080364
15 °C	+0.032	30 °C	-0.10	4=
20 °C	+0.012	40 °C	-0.08	5=
25 °C	-0.009	50 °C	-0.08	6=
30 °C	-0.040	°C		7=
°C		°C		8=
°C		°C		9=
°C		°C		10=
CALIBRATED BY E.H. Blackwell/S		ADHERENCE Ex		11=
CERTIFIED BY Louis Martin/S		FUNCTIONING Ex		12=
DATE 5 Oct 1964				

MAIN — INTERPOLATION TABLE — AUXILIARY
APPLY THERMOMETER CORRECTIONS ALGEBRAICALLY

T°	CORR	T°	CORR	T°	CORR	T°	CORR	T	CORR	T'	CORR
0		21.67								0	
	0		0								0
2.69		24.05								5	
	+.01		-.01								-.1
6.18		25.96								50	
	+.02		-.02								
9.12		27.58									
	+.03		-.03								
16.75		29.19									
	+.02		-.04								
19.25		30.00									
	+.01										
21.67											

1. Always store thermometer in the carrying case with the large reservoir DOWN, unless the stored thermometer will be subjected to temperatures colder than -10°C.

2. Reverse the thermometer at least once every day.

3. Keep a complete history of this thermometer. Explain condition as accurately as possible under remarks below.

THERMOMETER HISTORY RECORD

CRUISE	DATE	SEPARATES	DOESN'T BREAK	BREAKS IMPROPERLY	FLOODS	TOTAL CASTS USED	REMARKS	EST. OF COND.	OBSERVER'S NAME
MICHELSON	3-65/7-65				1	32	28-Ex 2-High 1-Low	EXC.	T.A.B.
SAN PABLO	10-65/11-65				1	36	32-Ex, 4-Low	EXC.	D.H.H.
REHOBOTH	12/65			BA			NOT USED		F.A.A.

RANGE °C TO °C
UN PRO. [ ]
PRO. [ ]
MAKE
NUMBER

REVERSING THERMOMETER CALIBRATION AND HISTORY RECORD PRNC-NAVOCEANO-3167/53 (Rev. 2-64)

Figure F-1. Reversing Thermometer Calibration and History Record.

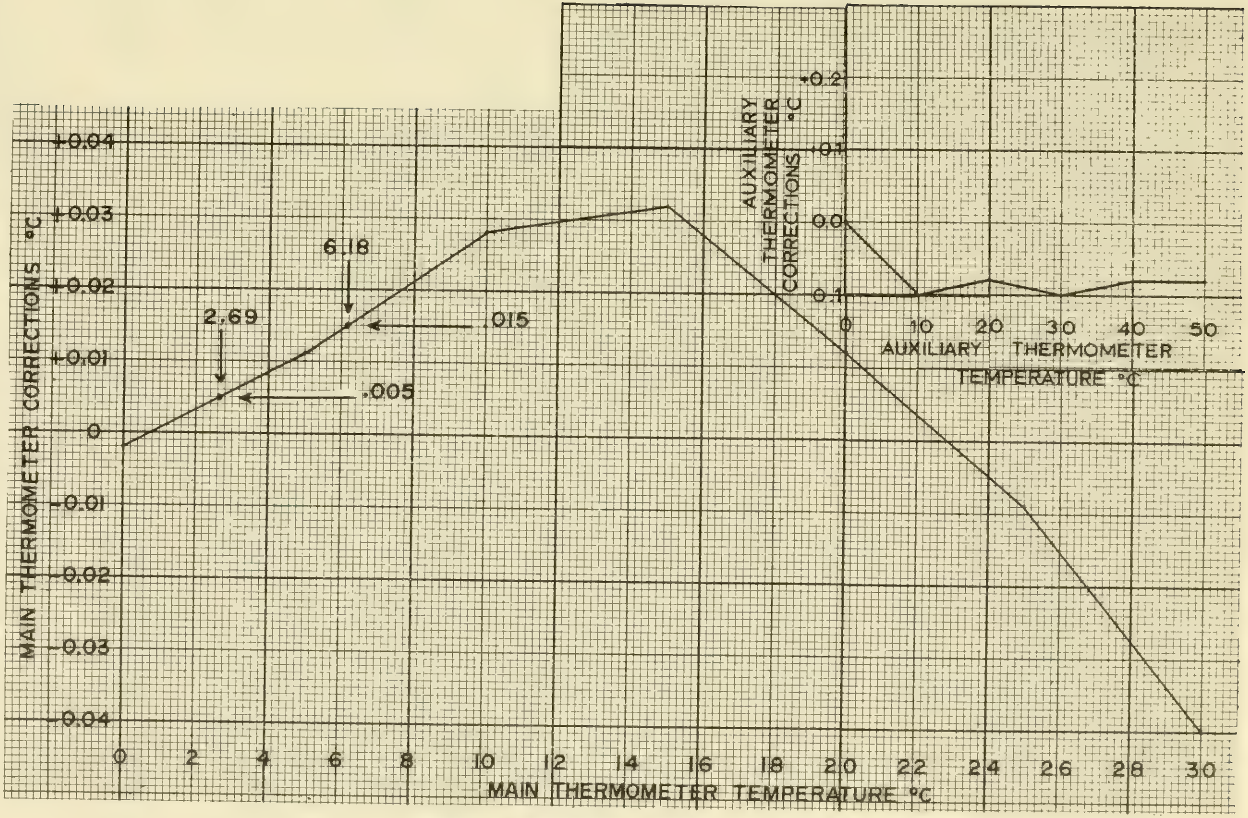


Figure F-2. **Thermometer correction graphs.**

NUMBER	MAKE	V°	"K" VALUE	RANGE	SMALLEST SCALE DIVISION	
510-64	Kessler	101.0 °C; MAKERS V° 100 °C	6098	-2 °C TO + 20 °C	.1 °C	[X] PROTECTED; [ ] UNPROTECTED

OWNER		
U.S. Naval Oceanographic Office	[X] PURCHASED NEW; [ ] PURCHASED USED	PURCHASED FROM Kessler; PRICE $92.30; DATE ACQUIRED Sept 1964

DEEP SEA REVERSING THERMOMETER CORRECTIONS

MAIN THERMOMETER		AUXILIARY THERMOMETER		"Q" FACTOR
TEMPERATURE	CORRECTION	TEMPERATURE	CORRECTION	1000 METERS
-2 °C	-.040	°C	-.06	1=
0 °C	-.040	10 °C	.00	2=
5 °C	-.052	20 °C	+.02	3=
10 °C	-.046	30 °C	.00	4=

MAIN INTERPOLATION TABLE AUXILIARY
APPLY THERMOMETER CORRECTIONS ALGEBRAICALLY

T	CORR	T°	CORR	T°	CORR	T°	CORR	T	CORR	T	CORR
-2.										0	
2.08	-.04									1.7	-.1
11.66	-.05									500	.0
16.40	-.04										
20.0	-.05										

NUMBER	MAKE	V°	"K" VALUE	RANGE	SMALLEST SCALE DIVISION	
157-64	Kessler	103.7 °C; MAKERS V° 105 °C	6098	-2 °C TO + 20 °C	.1 °C	[X] PROTECTED; [ ] UNPROTECTED

OWNER		
U.S. Naval Oceanographic Office	[X] PURCHASED NEW; [ ] PURCHASED USED	PURCHASED FROM: Kessler Co.; PRICE $92.30; DATE ACQUIRED: 3/24/64

DEEP SEA REVERSING THERMOMETER CORRECTIONS

MAIN THERMOMETER		AUXILIARY THERMOMETER		"Q" FACTOR
TEMPERATURE	CORRECTION	TEMPERATURE	CORRECTION	1000 METERS
0 °C	.014	0 °C	.00	1=
5 °C	.042	10 °C	-.08	2=
10 °C	.006	20 °C	-.08	3=

MAIN INTERPOLATION TABLE AUXILIARY
APPLY THERMOMETER CORRECTIONS ALGEBRAICALLY

T°	CORR	T°	CORR	T	CORR	T°	CORR	T	CORR	T	CORR
0		8.75								.0	
.18	+.01	12.62	+.01							6.2	.0
1.97	+.02	20.00	+.02							40.5	-.1
3.76	+.03									45.2	0
	+.04										

NUMBER	MAKE	V°	"K" VALUE	RANGE	SMALLEST SCALE DIVISION	
419-63	Kessler	120.8 °C; MAKERS V° 125 °C	6098	-2 °C TO + 30 °C	.1 °C	[ ] PROTECTED; [X] UNPROTECTED

OWNER		
U.S. Naval Oceanographic Office	[X] PURCHASED NEW; [ ] PURCHASED USED	PURCHASED FROM: Kessler Co; PRICE $92.30; DATE ACQUIRED 1/13/64

DEEP SEA REVERSING THERMOMETER CORRECTIONS

MAIN THERMOMETER		AUXILIARY THERMOMETER		"Q" FACTOR
TEMPERATURE	CORRECTION	TEMPERATURE	CORRECTION	1000 METERS
0 °C	+.008	0 °C	+.02	1=.0081841
5 °C	-.012	10 °C	-.08	2=.0082618
10 °C	-.018	20 °C	-.04	3=.0082440
15 °C	-.016	30 °C	-.04	4=
20 °C	-.014	40 °C	-.10	5=
25 °C	+.006	50 °C	-.20	6=
30 °C	+.011	°C		7
°C		°C		8=
°C		°C		9=

MAIN INTERPOLATION TABLE AUXILIARY
APPLY THERMOMETER CORRECTIONS ALGEBRAICALLY

T°	CORR	T°	CORR	T°	CORR	T°	CORR	T	CORR	T	CORR
0		24.76								0	
.75	+.01	30.00	+.01							7.0	.0
3.25	.00									17.6	-.1
7.50	-.01									31.5	.0
17.50	-.02									45.0	-.1
22.25	-.01									50.0	-.2
24.75	.00										

1. Always store thermometer in the carrying case with the large reservoir DOWN, unless the stored thermometer will be subjected to temperatures colder than -10°C.

Figure F-3. Reversing Thermometer Calibration and History Records for thermometers used on Nansen bottle number 11.

SHOWN BELOW ARE PORTIONS OF AN A-SHEET (FOR A COMPLETE A-SHEET REFER TO CHAPTER E).

NANSEN BOTTLE NO.	METER WHEEL READING		WIRE LENGTH DEPTH (L)	LEFT THERMOMETER							RIGHT THERMOMETER							ACCEPTED OR AVERAGE T_w
	DOWN	UP		THERM. NO.	MAIN (T')	AUX. (t)	V_0	I	C_p C_u	T_w	THERM. NO.	MAIN (T' OR T'_U)	AUX (t OR t_U)	V_0	I	C_p C_u	T_w OR T_u	
11	100	100	500	510-64	16 92	$\overline{18\ 4}$	101 0	-05	-03	16 84	152-64	16 81	18 3 18 4	103.7	+02	-.03	16.80	16 82
					16 91	$\overline{18.6}$		-05	-.03	16 83		16 82	18.4 18 5		+02	-03	16.81	
											419-63	20.96	$\overline{18.5}$	1208	-.01	-.04	20 91	Tu
												20.96	$\overline{18.6}$		-.01	-.04	20.91	20.91

Figure F–4. **Portion of an A-Sheet showing reversing thermometer corrections.**

F–4 Correcting the Reversing Thermometer.—To correct reversing thermometers, the following calculations are made on the A-Sheet:

Step 1. From the calibration records (fig. F–3) for the thermometers used on Nansen bottle No. 11 (fig. F–4), enter the V_0 in the V_0 block.

Therm. No.	510–64	V_0 is 101.0°
	157–64	103.7°
	419–63	120.8°

Step 2. Find the main and auxiliary thermometer corrections in the interpolation table of the calibration records (fig. F–3); enter the main correction in the *I* block; enter the corrected auxiliary value above the recorded value in *Aux.* (*t*) block (if correction is zero mark a line above the recorded value).

Therm. No. 510–64: Main temperature readings 16.92° and 16.91° fall between 16.40° and 20.00° in the interpolation table with a correction value —.05. Enter —.05 in block *I*.

Auxiliary temperature readings 18.4° and 18.6° fall between 1.7° and 50.0° in the interpolation table with a correction value of zero. Indicate by drawing a line over 18.4 and 18.6.

Therm. No. 157–64: Main temperature readings 16.81° and 16.82° fall between 12.62° and 20.00° in the interpolation table with a correction value of +.02. Enter +.02 in block *I*.

Auxiliary temperature readings 18.4° and 18.5° fall between 6.2° and 40.5° in the interpolation table with a correction value of —.1. Write 18.3 over 18.4 and 18.4 over 18.5 in *Aux.* (*t*) block.

Therm. No. 419–63: Main temperature readings 20.96° fall between 17.50° and 22.25° in the interpolation table with a correction value of —.01. Enter —.01 in block *I*.

Auxiliary temperature readings 18.5° and 18.6° fall between 17.6° and 31.5° in the interpolation table with a correction value of zero. Indicate by drawing a line over 18.5 and 18.6.

Step 3. Compute C_p (correction for protected thermometers) by the formula:

$$(1)\quad C_p = \frac{(T'-t)(T'+V_o)}{K-\frac{1}{2}(T'-t)-(T'+V_o)}$$

or

$$(2)\quad C_p = \frac{(T'-t)(T'+V_o)}{K-100}$$

Where $\frac{1}{2}(T'-t)-(T'+V_o)$ is rounded off to 100.

Where T′ is the main thermometer reading, t is the corrected auxiliary thermometer reading, and K (6098) is the "K" value from the calibration record rounded to 6100. *NOTE:* Most oceanographers prefer to calculate thermometer corrections with a special oceanographic slide rule (see par. F–10) and to check the computation with a calculator.

Using formula number (2), compute C_p and enter in block C_p.

LEFT THERMOMETER

Therm No. 510–64

$$C_p=\frac{(16.92-18.4)(16.92+101.0)}{6100-100}=-.03°$$

RIGHT THERMOMETER

Therm No. 157–64

$$C_p=\frac{(16.81-18.3)(16.81+103.7)}{6100-100}=-.03°$$

Step 4. Add T′, I, and C_p algebraically to obtain corrected protected thermometer reading T_w.
Therm. No. 510–64:

(1) $T'+I+C_p=T_w=16.92+(-.05)+(-.03)=16.84°$
(2) $T'+I+C_p=T_w=16.91+(-.05)+(-.03)=16.83°$

Therm. No. 157–64:

(1) $T'+I+C_p=T_w=16.81+(+.02)+(-.03)=16.80°$
(2) $T'+I+C_p=T_w=16.82+(+.02)+(-.03)=16.81°$

Step 5. Repeat steps 1 through 4 for each protected thermometer on the Nansen bottle, and average the T_w's to obtain the accepted or average water temperature. Enter in *Accepted or Average T_w* block. *NOTE:* If the T_w's of paired thermometers differ by more than $\pm.06°$, defer the calculation of the average T_w because one or the other or both T_w's are not within the range of acceptability.

Average $T_w=16.82°$

Step 6. After the average T_w for a Nansen bottle observation has been determined, compute C_u (correction for unprotected thermometers) by the formula:

$$(1)\quad C_u=\frac{(T_w-t_u)(T_u'+V_o)}{K-\frac{1}{2}(T_w-t_u)}$$

or

$$(2)\quad C_u=\frac{(T_w-t_u)(T_u'+V_o)}{K}$$

Where $\frac{1}{2}(T_w-t_u)$ is rounded off to zero.

Where T_w is the average from step 5 above, t_u is the corrected unprotected auxiliary thermometer reading, T_u' is the unprotected main thermometer reading, and K is rounded to 6100.

Using formula (2), compute C_u and enter in C_u block.

RIGHT THERMOMETER

Therm. No. 419–63

$$C_u=\frac{(16.82-18.5)(20.96-120.8)}{6100}=-.04°$$

Step 7. Add T_u', I, and C_u algebraically to obtain corrected unprotected thermometer reading T

Therm. No. 419–63:

(1) and (2) $T_u'+I+C=T_u=20.96+(-.01)+(-.04)=20.91°$

Transfer T_u to *Accepted or Average T_w* column and enter T_u above the value.

F–5 Thermometric Calculations.—Thermometric calculations (fig. F–5) are performed to determine the depth at which Nansen bottles equipped with unprotected thermometers were reversed.

Step 1. Enter the "Q" factor from the calibration record (fig. F–3) in the *"Q" Factor* block. If wire depth (L) is less than 1,000 meters, and "Q" factor is not available for 500 meters, use "Q" factor for 1,000 meters. *Use the value nearest to the wire depth (L) or estimated accepted depth.* Interpolation between "Q" factors usually is not performed.

"Q" factor for Therm. No. 419–63 is .0081841 at 1,000 meters.

Step 2. Compute T_u-T_w difference.

$20.91°-16.82°=4.09°$

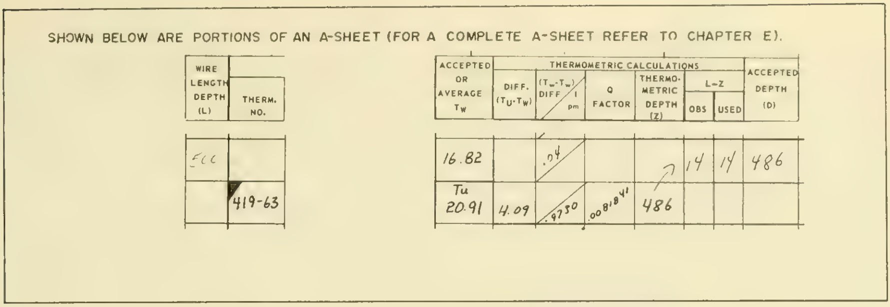


Figure F–5. Portion of A-Sheet showing thermometric calculations.

Step 3. Enter Table F–1 and determine 1/ρm for wire length (L), using nearest oceanic region. Enter value in *1/ρm* block.

1/ρm for wire length depth (L) 500 meters, North Atlantic Ocean is .9730.

Step 4. Compute thermometric depth (Z) in meters from formula, and enter result in *Thermometric Depth* (Z) column.

$$Z=\frac{(T_u-T_w)}{\rho m \text{ ``Q'' Factor}}=\frac{1/\rho m\ (T_u-T_w)}{\text{``Q'' Factor}}=\frac{.9730\times 4.09}{.0081841}=486$$

Step 5. Compute L–Z Obs (observed) by subtracting Z from L (wire length depth). Enter *L–Z Obs* column of A-Sheet.

$L-Z=500-486=14$

Table F–1. Mean density of sea water column above estimated depth

Estimated depth (meters)	North Atlantic		Northeast Pacific		Arctic [1]		Antarctic [2]		Mediterranean	
	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$
0	1. 0262	0. 9745	--------	--------	1. 0279	0. 9729	1. 0275	0. 9732	1. 0282	0. 9726
100	1. 0264	. 9743	1. 0248	0. 9758	1. 0281	. 9727	1. 0277	. 9730	1. 0286	. 9722
200	1. 0267	. 9740	1. 0255	. 9751	1. 0283	. 9725	1. 0281	. 9727	1. 0289	. 9719
300	1. 0270	. 9737	1. 0261	. 9746	1. 0285	. 9723	1. 0284	. 9724	1. 0293	. 9715
400	1. 0274	. 9733	1. 0267	. 9740	1. 0288	. 9720	1. 0287	. 9721	1. 0296	. 9712
500	1. 0278	. 9730	1. 0272	. 9735	1. 0290	. 9718	1. 0290	. 9718	1. 0300	. 9709
600	1. 0281	. 9727	1. 0276	. 9731	1. 0292	. 9716	1. 0292	. 9716	1. 0302	. 9707
700	1. 0285	. 9723	1. 0280	. 9728	1. 0295	. 9713	1. 0295	. 9713	1. 0305	. 9704
800	1. 0288	. 9720	1. 0283	. 9725	1. 0297	. 9712	1. 0297	. 9712	1. 0307	. 9702
900	1. 0291	. 9717	1. 0286	. 9722	1. 0299	. 9710	1. 0300	. 9709	1. 0310	. 9699
1,000	1. 0294	. 9714	1. 0289	. 9719	1. 0302	. 9707	1. 0302	. 9707	1. 0312	. 9697
1,500	1. 0308	. 9701	1. 0304	. 9705	1. 0314	. 9696	1. 0314	. 9696	1. 0324	. 9686
2,000	1. 0321	. 9689	1. 0318	. 9692	1. 0326	. 9684	1. 0326	. 9684	1. 0335	. 9676
2,500	1. 0334	. 9677	1. 0331	. 9680	1. 0338	. 9673	1. 0338	. 9673	1. 0346	. 9665
3,000	1. 0346	. 9666	1. 0344	. 9667	1. 0351	. 9661	1. 0350	. 9662	1. 0358	. 9655
3,500	1. 0358	. 9654	1. 0356	. 9656	1. 0363	. 9650	1. 0362	. 9651	--------	--------
4,000	1. 0370	. 9643	1. 0369	. 9644	1. 0375	. 9638	1. 0375	. 9638	--------	--------
4,500	1. 0383	. 9631	--------	--------	1. 0387	. 9627	1. 0387	. 9627	--------	--------
5,000	1. 0395	. 9620	--------	--------	1. 0400	. 9615	1. 0400	. 9615	--------	--------

[1] Norwegian and Greenland Seas.
[2] Ross and Weddell Seas.

F–6 Determining Accepted Depth (D).— The accepted depth (D) is determined by the L–Z graphical method. The L–Z Graph, NAVOCEANO–3167/62 (Rev. 10–64) (fig. F–6) is used to facilitate the calculations. The procedures used to construct the L-Z graph follow:

Step 1. On the vertical side of the graph, lay off wire length depth (L), starting with zero at

OCEANOGRAPHIC LOG SHEET–A
NAVOCEANO-EXP-3167/1 (Rev. 9-64)

STATION AND THERMOMETER DATA
For use with H.O. Pub No. 607 (Amended)

Nansen Cast	Wire Angle	
First	13°	15°
Second		
Third		

Consecutive Station No. 3
Station Observer: LS Jordan
Computed by: KBP Checked by: LW

Wire Length Depth (L)	Thermometric Depth (Z)	L–Z Obs	L–Z Used	Accepted Depth (D)	Remarks
0			0	0	48, 49, 50
10			0	10	
20			1	19	
30			1	29	
50			2	48	
100			3	97	
150			5	145	
200			6	194	
300	291	9	9	291	
400	387	13	12	388	
500	486	14	14	486	
600	585	15	15	585	

SUMMARY $T_u - T_p$ DIFF.

TOTAL T=	12
DIFF °C .00	2
.01	4
.02	1
.03	2
.04	2
> .04	1
ONE T= Acc	1A
NONE Acc	X

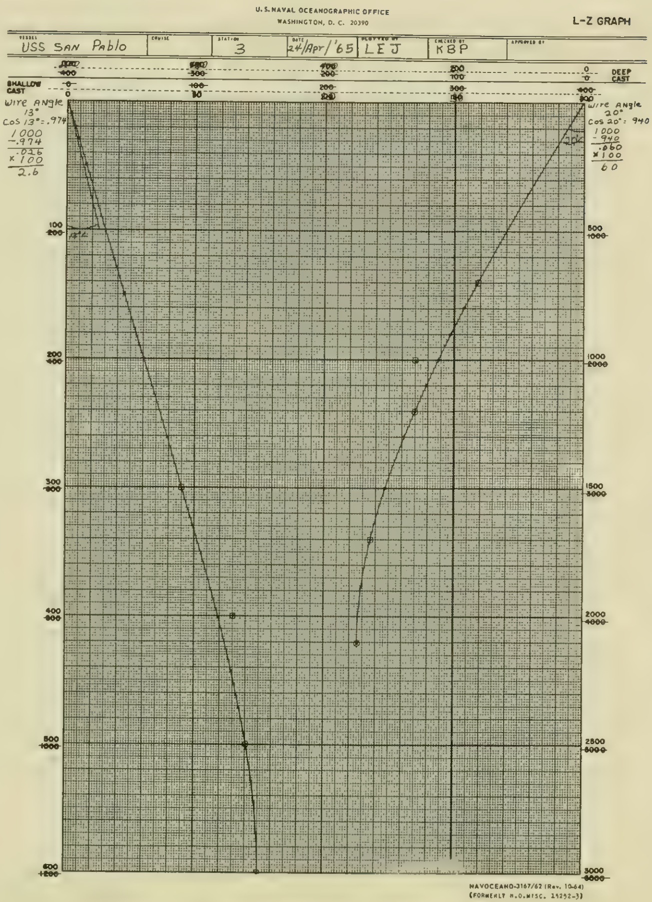


Figure F–6. **The L–Z graph with typical curves.**

OCEANOGRAPHIC LOG SHEET–A
NAVOCEANO-EXP-3167/1 (Rev. 9-64)

STATION AND THERMOMETER DATA
For use with H.O. Pub No. 607 (Amended)

Nansen Cast	Wire Angle	
First		
Second	20°	20°
Third		

Consecutive Station No. 3
Station Observer: L.S Jordan
Computed by: KBP Checked by: LW

Wire Length Depth (L)	Thermometric Depth (Z)	L–Z Obs	L–Z Used	Accepted Depth (D)	Remarks
700	659	41	41	659	
800			46	754	
900			51	849	
1000	935	65	56	944	
1100			61	1039	
1200	1135	65	65	1135	
1300			69	1231	
1500			76	1424	
1700	1618	82	82	1618	
1900			86	1814	
2100	2013	87	87	2013	

SUMMARY $T_u - T_p$ DIFF.

TOTAL T=	11
DIFF °C .00	1
.01	2
.02	3
.03	3
.04	2
ONE T= Acc	1A
NONE Acc	X

the upper left for the shallow cast and upper right for the deep cast. Use a convenient depth increment for each cast which will allow sufficient space for the maximum wire depth sampled.

Step 2. Across the top of the graph, lay off the depth difference (L–Z) scale for each cast. Use a convenient L–Z increment for each cast which will allow sufficient space for the maximum L–Z observed.

Step 3. From the origin (upper left or right zero depth), construct a line making an angle from the vertical which represents the wire angle. This is done as follows:

From a table of trigonometric functions, find the cosine of wire angle (1). Subtract the cosine from 1.000. Multiply the remainder by 100. Plot the product as L–Z at L equals 100, and construct a line passing through the origin and this point.

Cosine of 13° is .974
$1.000-.974=.026$
$.026\times 100=2.6$

Step 4. Plot *L–Z Obs* values at *Wire Length Depth* (*L*) values; make a circle around each point plotted.

Step 5. Construct a reasonably smooth curve through the origin of the graph and as many points as possible.

Step 6. From the curve, pick off L–Z values for every Nansen bottle of the cast. Enter these values in the appropriate *L–Z Used* block.

Step 7. To determine the accepted depth, subtract *L–Z Used* value from *Wire Length Depth* (*L*) value and enter the remainder in *Accepted Depth* (*D*) column.

F–7 Wire Angle (2) Measurements.—*Wire Angle* (*2*) measurement is used by the oceanographer to assist him in verifying accepted depth calculations obtained for a Nansen cast. For example, if *Wire Angle* (*1*) and *Wire Angle* (*2*) are nearly equal as in figure F–6, the ship-wire system was probably relatively stable during the descent of the messenger down the wire. If the two wire angles, however, differ significantly (5° or more), the probability exists that either the ship was undergoing accelerated drift, or the wire and bottles were influenced by subsurface currents, or that both conditions existed.

Figure F–7 depicts examples of two deep cast L–Z curves which do not follow the typical classical pattern shown in figure F–6. Credence to the validity of the atypical L–Z curves is given by the observation of the second wire angle measurement which in these examples differed significantly from Wire Angle (1).

F–8 Subsurface Wire Angle Measurements.—Subsurface wire angle measurements, obtained with the subsurface wire angle indicator (WAI) described in paragraph E–6, chapter E, are used to check accepted depth differences between Nansen bottles on a cast. For example, if the WAI reading between two Nansen bottles is $\theta°$ and the bottles are Y meters apart on the wire, the L–Z values for the two bottles should differ by approximately Y Sin θ. The WAI is especially valuable between the top two and the bottom two Nansen bottles on deep casts. The other parameter, direction wire is tending, that is obtained with the WAI, is used as an indication of the true configuration of the wire and may assist in the determination of accepted depths.

F–9 Checking A-Sheet Computations.—After the A-Sheet computations have been completed and the initials of the computer are entered in the *Computed By* block, another person should check the A-Sheet. To do this begin with paragraph F–4, Correcting the Protected Thermometer, and recompute the A-Sheet step by step. Using a red pencil, indicate that an item has been checked and is correct by placing a small dot over the checked value. To make corrections, line out the incorrect value and enter new value. When the A-Sheet is completely checked, enter initials in *Checked By* block.

F–10 Correcting Reversing Thermometer Temperatures with the Culbertson Slide Rule.—The Culbertson slide rule is designed to facilitate calculations of temperature corrections and thermometric depths. In addition, the rule has several other useful features, including conversion scales, and a Temperature Depth Salinity rule. The slide rule is circular, 8⅜ inches in diameter, and has two movable arms on one side and one on the other. Figure F–8 shows the side with two arms. This is the side of the rule used for correcting reserving thermometer temperatures. To calculate protected and unprotected thermometer corrections (C_p and C_u) with a Culbertson slide rule, proceed as follows:

Step 1. Using the values for thermometer number 327–64 in Figure F–9, set (see footnote) the arms on T′ and t on the linear temperature scale surrounding the striped graph. Set the long arm on the larger value and the short arm on the smaller value, e.g., T′ (15.18°) and t (18.4°) (fig. F–10).

Step 2. Move the arms until the short arm is at 0° (fig. F–11).

Step 3. Under 109.38° (V_o+T') (94.2+15.18) on the long arm, read .06° (C_p) on spiral stripes. If T′ is less than t, the correction (C_p) will be negative; if T′ is greater than t, C_p will be positive.

Step 4. Enter C_p (−.06°) in C_p/C_u column of the A-Sheet and calculate T_w (15.14°).

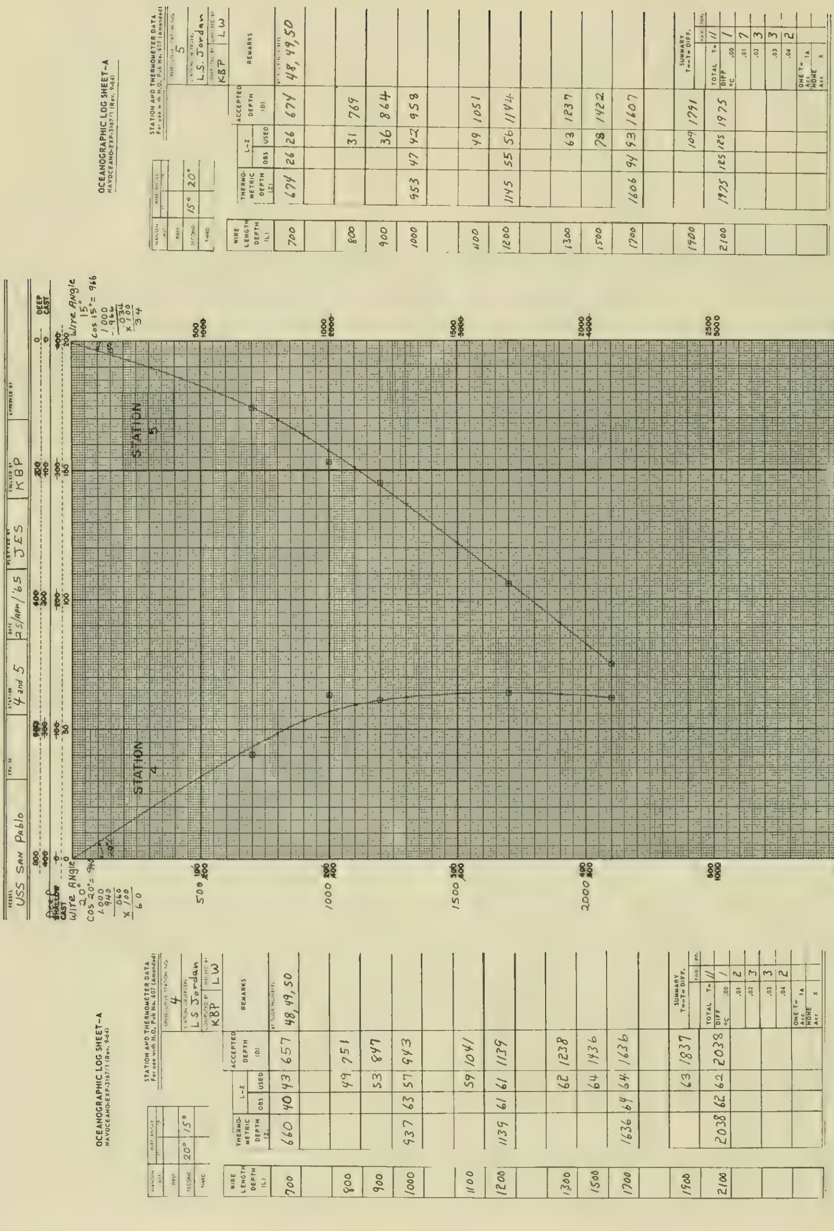


Figure F-7. **The L–Z graph with atypical curves.**

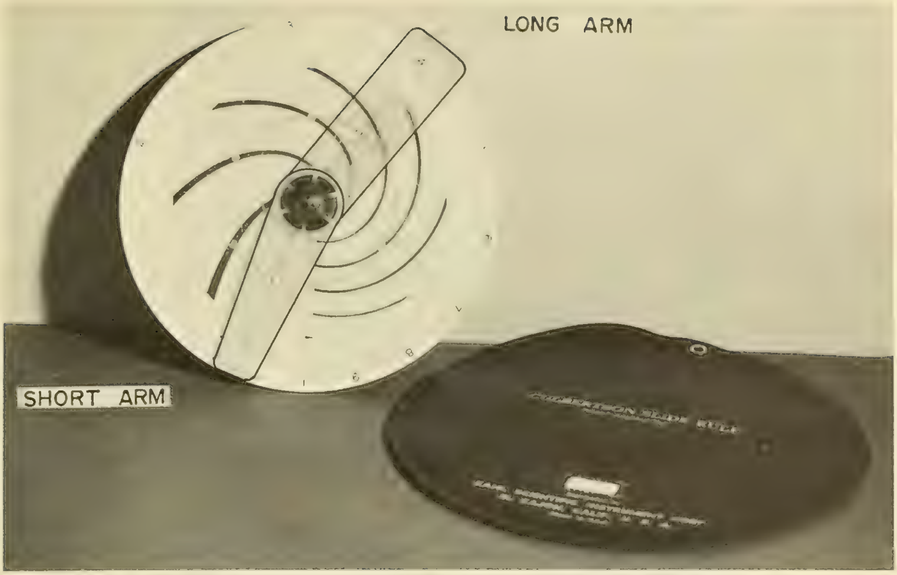


Figure F–8. **Culbertson Slide Rule.**

LEFT THERMOMETER							RIGHT THERMOMETER							ACCEPTED OR AVERAGE T_w
THERM. NO.	MAIN (T')	AUX. (t)	V_o	I	C_p/C_u	T_w	THERM. NO.	MAIN (T' OR T'_u)	AUX (t OR t_u)	V_o	I	C_p/C_u	T_w OR T_u	
327-64	(1) 15.17	18.3	94.2	+.02	−.06	15.13	701-64	15.20	18.4	105.4	−.03	−.06	15.11	15.12
	(2) 15.18	18.4		+.02	−.06	15.14		15.20	18.5		−.03	−.07	15.10	
							196-64	20.04	18.4 18.5	139.6	+.01	−.09	19.96	
								20.05	18.5 18.6		+.01	−.09	19.97	

Figure F–9. **Portion of A-Sheet taken from chapter E.**

NOTE: The average T_w always must be determined before the unprotected thermometer can be corrected.

Step 5. To calculate C_u, set the arms on the average T_w and the t_u on the linear temperature scale surrounding the striped graph. Set the long arm on the larger value and the short arm on the smaller value, e.g., average T_w (15.12°) and t_u (corrected) (18.5°) for unprotected thermometer number 196–64 (fig. F–12).

Step 6. Move the arms until the short arm is at 0° (fig. F–13).

Step 7. Under 159.65° ($V_o + T'_u$) (139.6+20.05) on the long arm, read .09° (C′) on spiral stripes. If $T'_u + V_o$ is off scale on the long arm, take half the value and double C′.

Step 8. To obtain C_u, move the long arm to the left by the amount of C′ on the linear scale (fig. F–14).

Step 9. Under 159.65° ($T'_u + V_o$) on the long arm, read the correction (C_u) .09°. If T_w is less than t_u, the correction C_u will be negative.

Step 10. Enter C_u (−.09°) in C_p/C_u column of the A-Sheet.

Footnote: When the word "set" is used, the arms are set independently, the long arm always being set first. When the word "move" is used, both arms are moved simultaneously, keeping a constant angle between them by moving the long arm.

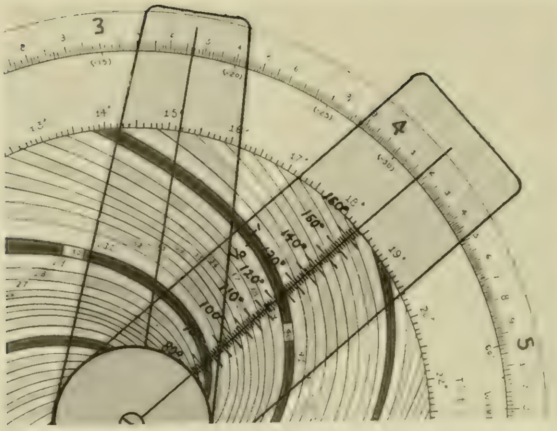


Figure F–10. Slide rule settings for correcting protected thermometer.

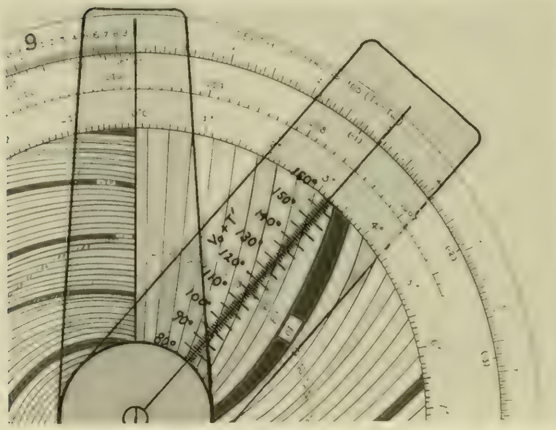


Figure F–11. Slide rule settings for obtaining C_p correction.

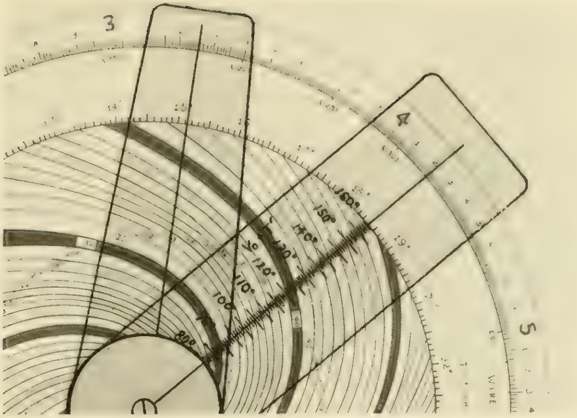


Figure F–12. Slide rule settings for correcting unprotected thermometer.

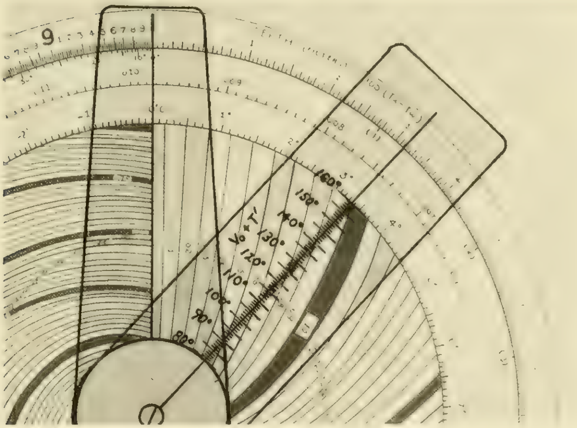


Figure F–13. Slide rule settings for obtaining C′ correction.

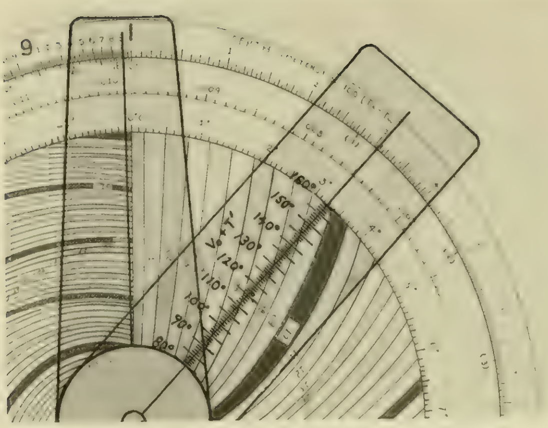


Figure F–14. Slide rule settings for obtaining C_u correction.

CHAPTER G

MANIPULATING REVERSING THERMOMETER MALFUNCTIONS

G–1 Introduction.—Reversing thermometers may become malfunctional as a result of improper handling, careless treatment, and/or aging. In the laboratories where these instruments are calibrated, malfunctions encountered during the ordinary calibration procedures generally are manipulated if the malfunction is correctable. On ocean survey operations, however, when thermometers become malfunctional, the number of instruments available for taking ocean temperature measurements is proportionately reduced, and action to relieve the condition is often desirable and necessary. Therefore, the following subjects are presented to guide field personnel who may find it necessary to manipulate malfunctional reversing thermometers:

- Types of Reversing Thermometer Malfunctions;
- Corrective and Noncorrective Malfunctions;
- Equipment and Materials for Manipulating Malfunctions;
- Detecting Malfunctions in a Reversing Thermometer;
- Manipulating the FTD Type Malfunction Aboard Ship;
- Exercising Reversing Thermometers after Manipulation.

G–2 Types of Reversing Thermometer Malfunctions.—When a reversing thermometer is reversed or righted and the mercury in the instrument does not separate or flow properly, the reversing thermometer is malfunctional. Malfunctions in reversing thermometers are classified as to type of improper mercury activity. The following is a list of malfunctions which may be encountered and the common abbreviation for the observed condition:

Fails to Break (FTB) when reversed;
Condition: Mercury does not run out of the appendix or separate.

Breaks below (BB) the appendix when reversed;
Condition: Mercury separates between the appendix and bulb.

Breaks above (BA) when reversed;
Condition: Mercury separates between the appendix and reservoir.

Does not Run (DNR) when reversed;
Condition: Mercury separates but fails to run into bulb properly.

Fails to Reproduce (FTR) when reversed;
Condition: Stem reading not the same on subsequent reversals at same temperature or the same temperature and pressure.

Fails to Drain (FTD) when righted;
Condition: Mercury does not empty out of bulb properly when the thermometer is righted.

Floods (F) when reversed;
Condition: Mercury runs out of reservoir filling the bore completely.

Mercury Sticks (HgS) in appendix when reversed;
Condition: Mercury separates at or in the appendix—all or a portion of the mercury in the appendix does not run down.

G–3 Corrective and Noncorrective Malfunctions.—Disregarding economic considerations, all malfunctions can be considered correctable. Corrective malfunctions in a practical sense, however, are those which can be manipulated without extensive laboratory equipment and the skill of an experienced glassblower. Noncorrective malfunctions are those which result from mistreatment, careless attempts to manipulate corrective malfunctions, and aging. Generally, no attempt is made to manipulate the noncorrective malfunction.

Corrective malfunctions essentially are caused by the displacement of gas from the upper end of the bulb to other locations in the thermometer system and the slight accumulation of mercurial impurities at critical points in the bore. These conditions arise as a result of improper handling such as leaving the thermometers inverted for unnecessarily long periods of time at abnormal temperatures, exposing them to shock while inverted, failing to exercise the thermometers regularly, etc.

Noncorrective malfunctions which result from aging develop slowly as a result of mercurial deterioration and glass sizing which deforms the appendix or constriction. Signs of the condition start to become evident about 1 year after the initial calibration tests have been performed and can be recognized by progressive erratic operation. Since reversing thermometers which have given satisfactory service for 1½ years or longer rarely develop this condition, the instruments which develop aging symptoms within this period of time, probably, had one or more of the following faults when they were fabricated:

- Marginal bore diameters at critical places;
- Poorly shaped appendixes;
- Glass stresses from inadequately controlled annealing processes.

G–4 Equipment and Materials for Manipulating Malfunctions.—Equipment and materials for alternately freezing and heating the mercury in the reversing thermometer are required for manipulating malfunctions. In some instances it is desirable also to cool and heat different areas of the instrument simultaneously. The following items should be available for manipulating malfunctions:

- Ice, dry ice, and/or CO_2 gas;
- Alcohol;
- A hand hot-air gun (approximately 1,000 watts);
- A small rubber headed hammer;
- Several 2,000 ml. beakers, preferably metal;
- A metal pan (approximately 15 inches long, 8 inches wide, and 6 inches deep).

G–5 Detecting the Malfunction in a Reversing Thermometer.—In the field, certain malfunctions are obvious and easily detected while others are erratic and can be discovered only by comparing a suspect thermometer with properly functioning instruments. The most common and also the most obvious malfunction is the FTD (fails to drain when righted) type. It is simple to detect and verify, and it is the only malfunction that field personnel should attempt to manipulate aboard ship. All other suspected or observed malfunctions should be verified by the following procedures since even the best reversing thermometer fails to function properly on occasion:

If the malfunctioning or suspect instrument is a protected thermometer, move it to a Nansen bottle equipped with a triple frame containing two properly functioning instruments and check its performance for several casts.

If the malfunctioning or suspect instrument is an unprotected thermometer, move it to a Nansen bottle equipped with a quadruple frame containing two protected thermometers and an unprotected thermometer which are functioning properly, and check its performance for several casts. If a quadruple frame is not available, move the unprotected thermometer to the surface Nansen bottle where its temperature should agreed with the protected thermometers. If the malfunction persists, discontinue using the thermometer on the operation, tag the instrument with a band of masking tape carrying the type malfunction abbreviation, make an entry on the Reversing Thermometer Calibration and History Record (ch. F, fig. F–1), and store the malfunctioning thermometer in the carrying case.

G–6 Manipulating the FTD Type Malfunction Aboard Ship.—In most instances when the mercury in a reversing thermometer persistently fails to drain back into the reservoir unless the instrument is tapped, the shape given the throat and bulb of the thermometer during fabrication is responsible. This is the situation in many cases of "failure to drain" and while the inaction is rightly termed, "improper mercury behavior," it is not considered a malfunction because the fault can be corrected simply by tapping the Nansen bottle gently.

On the other hand, sometimes the mercury in a thermometer deteriorates slightly and the impurities subsequently formed accumulate in the bulb end when the thermometer is left in an inverted position for an unusually long period of time. These thermometers will drain erratically at times when righted until the mercury has been thoroughly mixed as a result of the thermometer being exercised. Inexperienced attempts to manipulate this simple malfunction results in many good thermometers becoming permanently malfunctional from being pounded or jarred on the bulb end to relieve the condition. In most cases the desired manipulation is not successfully achieved and fractures are often created in other critical places of the thermometer.

When drainage cannot be stimulated by gently tapping the Nansen bottle, the thermometer should be considered malfunctional and the following steps should be performed:

Step 1. Remove the instrument from the Nansen bottle thermometer frame and try to stimulate drainage by the wrist-flip action (fig. G–1) or by a very light tapping on the bulb end of the thermometer. If this causes the bulb to drain go to step 4.

Step 2. If this does not stimulate drainage, immerse the entire thermometer in a water bath at 75° C. for about 10 minutes. This warms the mercury enough so that slight tapping will often free it in the bulb and cause it to drain into the reservoir. If it drains go to step 4. Never place thermometer in a horizontal position. Tilt slightly.

Step 3. In cases where step 2 is not successful, immerse the reservoir end of the thermometer in an ice-, or dry ice-, alcohol solution and draw most of the mercury down into the reservoir (CO_2 gas can be used). At the same time, heat the bulb end of the thermometer with a hot-air gun (fig. G–2) while the mercury in the reser-

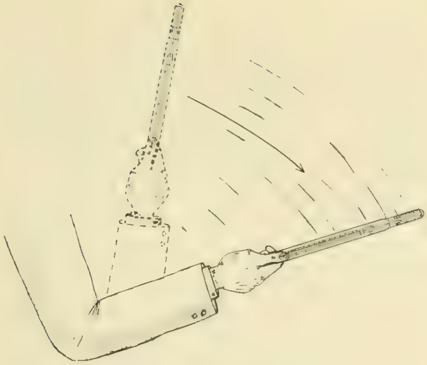


Figure G–1. Wrist-flip action.

voir is being frozen. Next, quickly remove the thermometer from the freezing solution and tap the bulb end of the thermometer while the instrument is in a righted vertical position (fig. G–3).

This procedure is usually 100 percent successful in the instances when it must be applied and even though rather vicious tapping might be necessary, the fragile area of the thermometer is not unnecessarily subjected to damaging action in this attitude. Although there may be other methods, this has been found to be the only really *safe* technique to achieve manipulation of thermometers which have not had exercise for a prolonged time and as a result fail to drain.

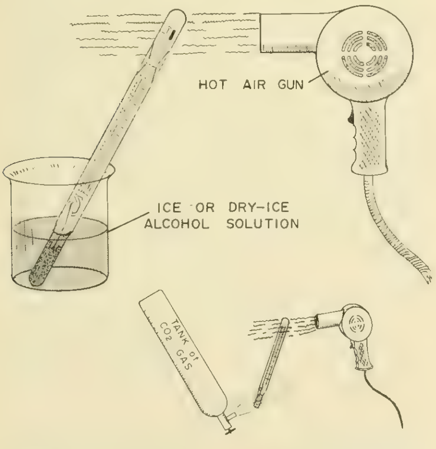


Figure G–2. Simultaneous cooling and heating action.

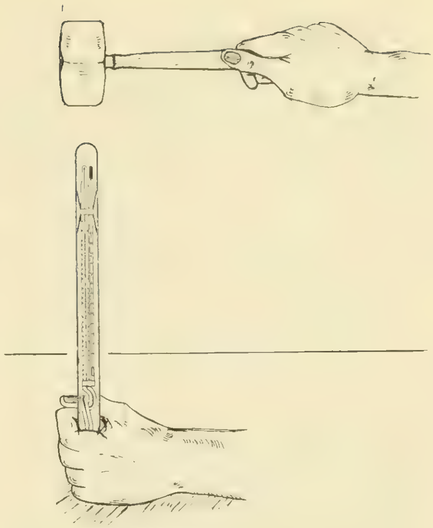


Figure G–3. Tapping action with rubber-headed hammer.

Step 4. Once the mercury is dislodged, exercise the thermometer extensively between periods of immersion in a hot water bath. Toward the end of the exercising procedures when the manipulation is almost complete, freezing all mercury in the reservoir will not do any harm and in some cases will help mix the impurities in the mercury so thoroughly that the condition will not reoccur if the thermometer is exercised regularly.

All malfunctional reversing thermometers, except the FTD type, should be returned to the U.S. Naval Oceanographic Office, Thermometer Calibration Laboratory, for manipulation and recalibration by experienced personnel.

G–7 Exercising Reversing Thermometers after Manipulation.—The importance of exercising thermometers after manipulation cannot be over emphasized since it is difficult to tell immediately whether the correction of a malfunctional reversing thermometer was entirely successful even though visual inspection leads to this conclusion. If the preexamination identification of the cause was a corrective malfunction, and the manipulation was successfully executed, the recurrence of a malfunction should not arise in a good thermometer that is properly treated thereafter. To verify the success of manipulation procedures, however, thermometers so treated should begin to be ex-

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tensively exercised directly afterward. On board ship this can be done by using the thermometer at every opportunity on a triple frame Nansen bottle until its proper functioning is verified. If during this time the malfunction is definitely recurrent, it is a good indication that progressive mercurial deterioration is taking place or glass sizing from age is deforming critical sections of the capillary or appendix. To continue trying to manipulate the mercury in such an instrument is useless since after a certain time its performance will never again be reliable. Without exercise and observation this conclusion can not be made and when a number of thermometers in this condition are counted as part of a complement selected for field survey purposes, success of the planned operation is often limited or crippled.

CHAPTER H

THE SHIPBOARD CHEMISTRY LABORATORY

H–1 General.—Shipboard chemistry employed in the analysis of sea water samples is basically the same as that carried out ashore. The seagoing chemist, however, works under certain difficulties and is subjected to some hazards that do not plague his shore based counterpart. Obviously he must be constantly alert to prevent damage to delicate equipment, resulting from ship's motion, with possible injury to himself and his shipmates. He must have sea racks to stow many types of glassware, chemicals, samples, and apparatus. His laboratory space is, of necessity, limited and must be used to the utmost. Efficient arrangement of equipment will reduce unnecessary work and is vital to the analyst and his assistants who may be working in teams to keep ahead of a backlog of samples.

H–2 Laboratory Furniture.—The properly equipped laboratory requires workbenches, storage cabinets, drawers, racks, shelves, tables, sinks, adequate lighting, and a ventilation and temperature control system. Workbenches should be of the proper height (approximately 36 inches) for laboratory work. The bench tops must be of acidproof composition. This may be commercial laboratory bench topping or heavy wood top coated with black acid-resistant paint. Storage cabinets and drawers should be compartmented to prevent excess motion of stored materials. They should be equipped with adequate retaining devices to prevent them from flying open during heavy seas. Shelves are necessary over the areas on the workbenches and tables where chemical titrations are run. These shelves should be fitted with sea racks to hold the large bottles or carboys of standard solutions to which the titration burettes are connected. A table, or a table-height (about 30 inches) portion of the workbench is necessary for titrations and other analyses that the analyst must run while seated. The laboratory must have one or more sinks. One sink must be big enough to wash large pieces of glassware and small oceanographic instruments. The sinks should be stainless steel and must have acidproof drainboards, drains, traps, pipes, seacocks, and overboard discharge outlets. They should be furnished with hot and cold fresh-water taps and a saltwater tap.

It is recommended that the laboratory deck be covered with acidproof paint or an acid resistant plastic (vinyl) tile and be provided with drainage facilities.

In addition, the laboratory should be equipped with numerous regulated voltage electrical outlets. Compressed air and vacuum lines also are desirable.

H–3 Water Purification Apparatus.—The pure water used so much in carrying out almost all shipboard analyses of sea water samples is prepared by either distillation or demineralization. Distillation changes the water into steam and thus separates it from dissolved solids. Also, gases and other transient substances escape into the atmosphere to produce a distillate with a high degree of purity. Electrical distilling apparatus will provide sufficient distilled water, using fresh water from the ship's tanks, on those ships equipped with steam evaporators. Such a still produces very pure water when properly operated in accordance with the instructions provided by the manufacturer; however, owing to the large thermal input required in distillation, the cost is considerably greater than the cost of producing distilled water by the demineralization process.

Demineralization removes cations and anions by treatment with ion exchange resins. A resin-type demineralizer, utilizing the fresh water from the ship's evaporators, will deliver water of sufficient purity for most requirements.

H–4 Miscellaneous Laboratory Equipment.—The shipboard chemistry laboratory is furnished with a large variety of miscellaneous laboratory equipment. The following list of equipment will serve as a guide for equipping a shipboard laboratory although it must be kept in mind that requirements vary considerably for different projects and surveys:

Apron, laboratory.
Barometer, Aneroid.
Beaker, Griffin low form, glass* or plastic, with pourout, capacity: 50, 100, 250, 400, 600, 800, 1,000, and 2,000 ml.
Balance, triple beam, accurate to 0.1 g.
Bottle, wash, plastic.
Brush, bottle. Assorted sizes.
Bucket, plastic, 2 to 3 gal.

- Burner, liquid petroleum, propane type, with complete set of tips.
- Carboy, plastic, 5 gal.
- Clamp, apparatus. Assorted.
- Cork borer set, brass with handles.
- Cylinder, graduated, plastic or glass*, capacity: 10, 25, 100, and 500 ml.
- File, triangular, 4-inch.
- Filter paper.
- Filter pump (aspirator), brass, with threaded filter pump coupling.
- Flask, Erlenmeyer, narrow mouth, glass*, capacity: 125, 250, 500 ml.
- Flask, volumetric, to contain, Class A, glass*, capacity: 100, 250, 500, 1,000, and 2,000 ml.
- Forceps.
- Funnel, plastic. Assorted sizes.
- Gloves, rubber or plastic.
- Hotplate.
- Lamp, titration, flourescent daylight.
- Pinchcock, screw and spring type.
- Pipe cleaners.
- Rod, stirring.
- Rod, threaded support, with connectors and feet.
- Spatula, stainless steel.
- Stirrer, magnetic.
- Stirring bar, magnetic, teflon coated.
- Stopper, rubber, regular form. Assorted sizes 00 through 13.
- Thermometer, laboratory grade.
- Tongs, beaker.
- Tongs, crucible, stainless steel.
- Towels, paper.
- Tubes, connecting, T- or Y-shape, glass* or plastic.
- Tubing, flint glass.
- Tubing, Tygon, plastic.
- Tubing, latex.
- Watch glass, glass*.
- Wiping tissues, disposable paper, absorbent, lint free.

Two things that are very important in operating a shipboard laboratory are neatness and cleanliness. A sloppy laboratory can quickly become chaos. As soon as a piece of equipment is used, it must be cleaned and returned to its proper place of stowage. Considerable time can be lost searching for a particular flask or graduate only to find it broken or too dirty to use. Chipped glassware is dangerous. Avoid using it. Clothing can be ruined and skin burned if spilled acids are not cleaned up immediately.

H–5 General Laboratory Precautions.—Although each method of analysis has detailed instructions for handling and cleaning its particular equipment, the seagoing chemist must familiarize himself with basic shipboard chemistry laboratory precautions. The chemist will at times have to handle chemicals that are corrosive and toxic. Because of the dangers involved, extreme care must be taken at all times when handling these chemicals. Most laboratory equipment is delicate and some is specially made and difficult to obtain. Costly damage and personal injury can result if such material is handled carelessly. It is obvious, therefore, that the shipboard laboratory is a space in which only qualified personnel should be authorized. The laboratory should never under any circumstances be used as a general passageway or lounge.

The shipboard laboratory must be well ventilated to remove any toxic vapors created by chemicals. As several types of equipment for sea water analysis are calibrated at 20° to 25° C. (68° to 77° F.), it is desirable that the laboratory be kept in this temperature range.

Several types of titration analyses utilize color change end points. For this reason, it is important that the lighting of the laboratory be of high quality. Fluorescent lights of the daylight type are recommended.

H–6 Handling and Storing Laboratory Glassware.—A large portion of laboratory equipment used at sea consists of delicate glassware. Although these beakers, graduates, burettes, pipettes, flasks, etc., are each designed for particular functions they unfortunately are of very awkward shapes and sizes for stowage. It is recommended that only those pieces of equipment in fairly frequent use be arranged in sea racks. The remaining spares and seldom-used pieces should be wrapped liberally with soft packing material and stowed in drawers or bins so they will be unaffected by motion of the ship in rough weather. Do not crowd glassware in drawers.

H–7 Stowage of Chemicals.—Chemicals should be stowed in bottles or jars with screw caps or stoppers and packed in cabinets or drawers with dependable latches or locks. Wrap fragile bottles with soft packing material to prevent contact with one another and to keep them from moving about with the motion of the ship. Liquids should be stowed upright in tightly capped bottles in sea racks or compartmented bins.

Strong acids and bases should be stowed in racks or bins that are well ventilated and equipped with a drain to dispose of spilled solution in the event of breakage. This drain should lead to an overboard discharge. One method is to construct a rack at the back of one of the laboratory sinks that will drain into the sink.

H–8 Handling Chemicals and First Aid Measures.—When handling chemicals, a laboratory apron or coat should be worn. When

*Heat resistant borosilicate glass is preferred.

handling strong chemicals *wear rubber gloves and safety goggles.* When mixing acid solutions, the safest method is: place container of water in a cold water bath, stir water constantly with a stirring rod, and pour acid slowly into the water. *Never pour water into acid. Keep acid away from combustible material.*

The most serious accidents that occur in a laboratory usually result from contact with strong chemicals. It is important that safety and first aid equipment be readily available. In addition to a first aid kit, an overhead quick-pull, safety shower should be provided. If a corrosive chemical is spilled on any part of the body, flush the contaminated area immediately with large quantities of water.

H–9 Cleaning General Laboratory Equipment.—Keeping laboratory glassware and other equipment clean is of extreme importance. Contamination of samples will result in invalid analyses if dirty glassware is used.

Always clean and dry the workbench tops and tables after completing analysis of samples or after making up chemical solutions.

H–10 Cleaning Burettes and Pipettes.—Before titration apparatus can be set up, the burettes and pipettes to be used must be cleaned meticulously. They must be inspected frequently during analyses and recleaned at the first signs of adherence of solutions or samples to the inner sides of the glass. The results of an analysis can be distorted greatly by the presence of a *single* droplet of solution or particle of grease adhering to the inside of the pipette or burette. For example, a one drop error in delivery of the Knudsen pipette can cause an error of 0.16 parts per thousand of salinity.

To clean this glassware, rinse the instruments inside and out with fresh water and fill them with the special acid-dichromate cleaning solution. This solution is very concentrated. *Wear safety goggles when handling.* Do not let the solution come in contact with the graduations or other markings on the burette as it will remove the color from the lines and figures. Leave the solution in the instruments for at least 12 hours.

Drain the acid-dichromate solution carefully from the instrument. The solution is returned to its container for reuse. Rinse the instrument for about 5 minutes in tap water and then make a final rinse with distilled water. If there is any sign of water adhering to the inside of the instrument, fill it again with the cleaning solution and let stand for at least 2 hours.

If the instrument is clean, remove the stopcocks and allow them to dry; lubricate, and reassemble them. The pipette or burette is now ready to be set up for titrations. When running the titrations, keep a close watch on the condition of these instruments. At the first evidence of droplets adhering to the inside, they must be cleaned again.

H–11 Preparing and Handling the Acid-Dichromate Cleaning Solution.—The acid-dichromate solution is prepared from concentrated sulfuric acid and a commercially available solution called "Chromerge." Since this acid-dichromate solution is very corrosive, safety glasses or goggles and rubber gloves must be worn during its preparation and use. To prepare the solution perform the following steps:

Step 1. Into a 9 lb bottle of concentrated sulfuric acid, slowly add the small bottle of "Chromerge" concentrate.

Step 2. Recap the 9 lb bottle tightly and mix well.

Step 3. Cool the slightly warmed mixture to room temperature before using.

A crystalline precipitate will form at the bottom of the bottle. The precipitate indicates that the solution is saturated and may be used over again as long as it remains. When the dark brown color of the solution begins to show a greenish hue, it is an indication that too many impurities are present. The solution should be disposed of and a new solution made up.

CHAPTER I

SALINITY DETERMINATION OF SEA WATER SAMPLES

I–1 General.—As explained in previous chapters, the most common method of obtaining sea water samples is by means of the Nansen bottle, and the water sample most frequently obtained is a salinity sample. For this reason, it is very important that the oceanographer develop skill in performing salinity determinations.

The salinity of a water sample can be determined by several methods, e.g., chemical titration, electrical conductivity, specific gravity, and index of refraction. At the U.S. Naval Oceanographic Office, the electrical conductivity method is used for analyzing most salinity samples; nevertheless, since the Knudsen titration method is desirable for laboratories with a sporadic incidence of salinity samples to analyze, the Knudsen method also is described. To perform analysis by the Knudsen titration and the electrical conductivity methods, a known standard water sample is required. This known sample, or standard, is "standard sea water."

I–2 Standard Sea Water.—To insure worldwide uniformity in chlorinity and salinity determinations, the International Council for the Exploration of the Sea prepared a universal reference, *Eau de Mer Normale*, under the direction of Professor Martin Knudsen in 1902. A new standard, prepared in 1937 and having a chlorinity of approximately 19.381 parts per thousand, is used to determine the chlorinites of all batches of standard sea water. Standard sea water is the basis for all chlorinity titrations and is the standard used to establish the concentration of the silver nitrate solution before and during a series of titrations. Its chlorinity has been determined with great accuracy, and it is produced only by the International Association d'Oceanographie, Physique (I.A.P.O.), Depot d'Eau Normale, Charlottenlund Slot, Denmark. Standard sea water is flame-sealed in glass vials containing about 200 ml. of water. The chlorinity, determined to three decimal places, is given on the label of each vial (fig. I–1).

The standard sea water to be used should be transferred from the vial into a sea water sample bottle. The bottle should be an old one, or one that is well leached, be absolutely clean and dry, and be provided with a good rubber gasket. To transfer the standard sea water to the bottle proceed as follows:

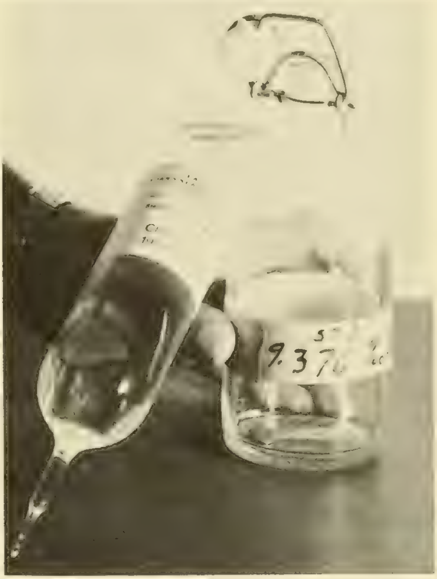

Figure I–1. A vial of standard sea water and sea water sample bottle.

Step 1. With a small file, scratch a small nick in the tapered tip of one neck of the standard sea water vial, and with a sharp rap of the file knock off the tip end of the neck.

Step 2. Shake about 20 ml. of the standard sea water into the prepared sample bottle. Stopper the bottle and shake it vigorously. Pour the rinse water out over the stopper. Repeat the rinsing operation once more.

Step 3. Next, scratch a nick on the closed end of the vial and insert the open end into the bottle. Give the scratched tip a sharp rap to break it off, and drain the standard sea water into the bottle. Stopper the sample bottle at once to prevent evaporation.

Step 4. Label the bottle, indicating the chlorinity of the vial just emptied and the date.

When a new vial of standard sea water is opened, do not pour it into a bottle already containing standard sea water. Discard the remaining standard water and rinse the bottle as described above.

I–3 Salinity Determination by the Knudsen Method.—Prof. Otto Pettersson introduced the titration of chloride method for measuring the salinity of sea water. Refinements were made by Prof. Martin Knudsen and the present method was named after him. This method is used extensively both in this country and abroad, ashore and at sea. Chlorinity is determined by titrating a sample of sea water with a solution of silver nitrate, the strength of which has been determined against a known sample—standard sea water.

A general explanation of the titration of chloride chemical reaction follows: (1) When silver nitrate is added to sea water, white flakes of silver chloride are precipitated according to the general equation:

$$AgNO_3 + NaCl \rightarrow AgCl \downarrow + NaNO_3$$

(2) One ml. of phenosafranin solution is added to the sea water as an indicator. (3) When all the chloride in the sea water sample is precipitated, a slight excess of silver nitrate gives, in the presence of the phenosafranin, a blue precipitate which indicates the titration is completed.

I–4 Chemicals Required.—The following chemicals are required for salinity titrations. The amounts in parentheses are those required to analyze 10 stations of 24 bottles each.

- Silver nitrate, crystals, C.P. (259.8 grams per jar—three jars).
- Phenosafranin, indicator (500 ml. bottle).‡
- Standard sea water, Copenhagen, *Eau de Mer Normale* (one vial per station to be analyzed).

I–5 Apparatus Required.—In addition to the apparatus previously listed in chapter H, the following apparatus is required to carry out salinity titrations by the Knudsen method:

- Bottle, dropping, capacity: 125 ml.
- Bottle or carboy (glass or polyethylene), wide-mouth, with tubulature, capacity: 2 gal.
- Bottle, glass*, narrow-mouth, S.T. ground flat glass stopper, capacity: 1 liter.
- Bulb, pressure, rubber.
- Burette, Knudsen, automatic-zeroing, range: 12–18, 16–22, and 17–23 double ml.
- Pipette, automatic-zeroing, acid, glass*, capacity: 15 ml. (or Knudsen pipette).

I–6 Tables and Log Sheet Required.—Knudsen's Hydrographical Tables of 1901 and Oceanographic Log Sheet–D, PRNC–NAVOCEANO 3167/4 (Rev. 4–63) (fig. I–2), are required for recording and computing salinity titration results. Knudsen's tables are used to convert chlorinity to salinity and to correct for variations in the preparation of the titration solution. The Log Sheet–D is used to record the titration steps and results in logical sequence.

Instructions for completing the entries on the D-Sheet will be explained as the steps are performed. Make entries in pencil. This is a permanent record. Vessel, cruise, station, and serial number are obtained from the Oceanographic Log Sheet–A.

I–7 The Automatic Pipette and Knudsen Automatic Burette.—The titrations are carried out using the automatic-zeroing pipette (fig. I–3) and the special Knudsen burette (fig. I–4). The pipette is calibrated to deliver almost exactly 15 ml. of sample water. At the top is a three-way stopcock for suction filling, off, and delivery. Although the pipette is built to deliver 15 ml., each one differs very slightly; therefore, it is important that the same pipette be used throughout a complete set of titrations.

The Knudsen burette is a very delicate piece of glassware with a two-way filling stopcock at the base, a three-way stopcock similar to that of the pipette at the top, and a two-way delivery stopcock below the graduations. It differs from the ordinary burette in that it is calibrated in double milliliters. A drainage value of 20.00 on the burette is equal to 40.00 milliliters of solution. The double milliliter graduations permit the use of a larger amount of less concentrated solution which increases the accuracy of titrations.

I–8 Setting Up the Titration Apparatus.—Before the pipette and burette are set up they must be meticulously cleaned and the stopcocks must be lubricated. Figures I–3 and I–4 show schematic diagrams for arrangement of the pipette and the Knudsen burette.

Step 1. Make the light-proof, silver nitrate solution storage bottle by painting the outside of a 2-gallon, wide-mouth bottle or carboy with several coats of black paint. Leave unpainted a half-inch vertical strip up one side of the bottle through which the solution may be seen. Graduate the strip by liters with white paint. Clean the inside thoroughly with soap and water. Rinse with tap water. Finally, rinse three times with distilled water before using.

Step 2. Clamp the pipette, burette, and flasks to support bars which are attached rigidly to the titration table. Attach a filter pump, or aspirator, to the salt water tap and connect it with tygon tubing through the trap flask to the pipette. Connect a piece of tygon tubing to the overflow valve of the burette and terminate

‡Phenosafranin indicator usually is prepared in the laboratory ashore. See paragraph I–9.
*Heat resistant borosilicate glass is preferred.

OCEANOGRAPHIC LOG SHEET-D
PRNC-NAVOCEANO-3167/4 (Rev. 4-63)

U.S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON 25, D. C.

CHLORINITY & SALINITY DETERMINATION
For use with Pub. No. 607

VESSEL	CRUISE	STATION	CHEMIST	DATE ANALYZED	CHECKED BY
USS Rehoboth	RE-3	8	L. Wilson	29 Aug. 1965	J. W. Brown

SERIAL NUMBER	SAMPLE BOTTLE NUMBER	1st. BURETTE READING	2nd. BURETTE READING	3rd. BURETTE READING	AVERAGE BURETTE READING	k	CHLORINITY o/oo	SALINITY o/oo	TIME	STANDARDIZATION (N)−(A)=a: Cl o/oo of STANDARD (N)	amt. of A_gNO_3 (A)	a	REMARKS
151	151	19.81	19.81		19.81	+0.01	19.82	35.81	1950	*19.395	19.375	+.020	Titrate standard
152	152	19.79	19.80		19.795	0.01	19.805	35.78		19.395	19.365	+.030	sea water three
153	153	19.79	19.79		19.79	0.01	19.80	35.77		19.395	19.370	+.025	times.
154	154	19.78	19.78		19.78	0.01	19.79	35.75			+	.025	
155	155	19.79	19.79		19.79	0.01	19.80	35.77					
156	156	19.79	19.79		19.79	0.01	19.80	35.77					
157	157	19.79	19.79		19.79	0.01	19.80	35.77					
158	158	19.75	19.76		19.755	+0.02	19.775	35.72					
159	159	19.72	19.71		19.715	+0.02	19.735	35.65					
160	160	19.69	19.70		19.695	0.02	19.715	35.62					
161	161	19.64	19.67	19.64	19.64	0.02	19.66	35.52					Third titration
162	162	19.58	19.57		19.575	0.02	19.595	35.40					necessary.
163	163	19.51	19.52		19.515	0.02	19.535	35.29					
164	164	19.48	19.49		19.485	0.02	19.505	35.24					
165	165	19.44	19.44		19.44	0.02	19.46	35.16					Third titration
166	166	19.32	19.37	19.36	19.365	0.02	19.385	35.02					necessary.
167	167	19.34	19.34		19.34	0.02	19.36	34.97					
168	168	19.33	19.32		19.325	+0.03	19.355	34.97					
169	169	19.31	19.31		19.31	0.03	19.34	34.94		*19.395	19.365	+.030	
170	170	19.31	19.31		19.31	0.03	19.34	34.94	2155	19.395	19.375	+.020	
										19.395	19.370	+.025	
											+	.025	

* RUN STANDARD

Figure I–2. Oceanographic Log Sheet–D.

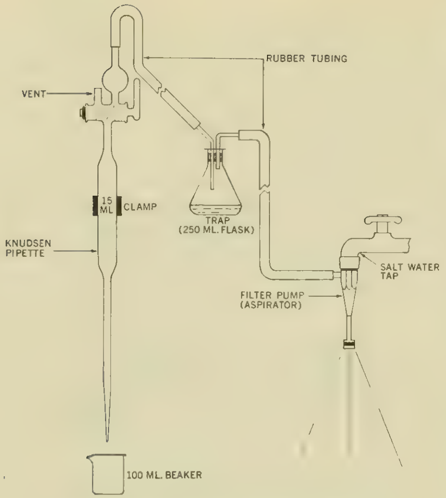

Figure I–3. Automatic-zeroing pipette.

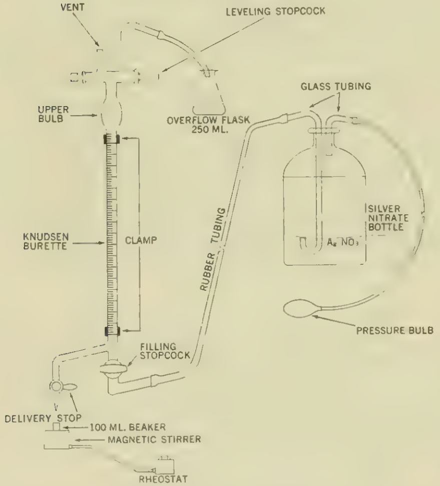

Figure I–4. Knudsen burette.

it in the overflow flask. Attach the magnetic stirrer to the support rod below the burette so it will be centered under the delivery tip. Place the silver nitrate solution bottle in a sea rack or on a shelf that is high enough to permit gravity flow to fill the burette, if possible; otherwise, connect the pressure bulb.

It is recommended that (1) a doughnut-shaped piece of half-inch-thick foam rubber be cemented to the top of the stirrer to prevent the 100–ml. beaker, used for titration, from sliding, (2) the table be provided with a sea rack to hold the bottle of standard sea water, the dropping bottle of indicator solution, and two or three 100–ml. beakers, (3) the background behind the burette be painted flat white to aid in reading the burette and in interpreting the color of the titration end point, (4) a fluorescent titration lamp be rigged behind the magnetic stirrer at a height to provide proper light to the sample.

I–9 Preparing the Indicator Solution.—Phenosafranin is used as the indicator in determining the end point of the titration. The solution is prepared in the following manner:

Step 1. Place 700 ml. of distilled water in a 1-liter beaker and add 1 g. of sodium benzoate U.S.P. powder; bring solution to a vigorous boil.

Step 2. In a separate beaker, make a starch suspension by mixing 40 g. of a soluble starch in 75 ml. of distilled water.

Step 3. While stirring, slowly add the cold starch suspension to the boiling sodium benzoate solution, and continue to boil for 2 to 5 minutes after addition of starch suspension; then, remove from heat and filter while hot through borosilicate glass wool.

Step 4. To 50 ml. of cold distilled water, add 2.5 g. of phenosafranin dye concentrate. Stir thoroughly then slowly add the dye suspension to the hot starch solution. Mix well, and when cooled to room temperature dilute to 1,000 ml. volume with distilled water. (1 ml. is required per determination.)

I–10 Preparing the Silver Nitrate Solution.—The silver nitrate solution is prepared by dissolving 37.11 grams of silver nitrate in 1 liter of distilled water. The best results, however, are obtained by making up solutions in 7 liter amounts because the smaller the amount prepared the greater the chance of error.

Step 1. To mix 7 liters, first open a silver nitrate jar of 259.8 g. and carefully pour all the crystals into a clean 1,000-ml. beaker. Place a teflon coated magnetic stirring bar in the beaker. Fill a 2-liter volumetric flask to the mark with distilled water. Pour off a small amount of the water into the jar; empty the jar into the beaker; repeat three or four times. This will insure that all silver nitrate is removed from the jar. Next, pour enough water from the flask into the beaker to fill it three-fourths full. Set the beaker on a magnetic stirrer and stir until the silver nitrate crystals are dissolved. *Silver nitrate is a corrosive chemical and should be handled with care.*

Step 2. Check the solution. If it is cloudy or if it turns whitish, it is contaminated and must be discarded; then, the silver nitrate storage bottle, the beaker, the flask and the stirring bar must be cleaned thoroughly before repeating step 1.

Step 3. After the silver nitrate is in solution, pour the contents of the beaker into the silver nitrate storage bottle. To insure that all silver nitrate is removed from the beaker, rinse it several times with water from the flask, and pour the rinse water into the silver nitrate bottle. Then, pour the remaining water from the flask into the bottle. Next, fill the volumetric flask with distilled water, empty it into the silver nitrate bottle; refill and empty a second time; finally fill a 1-liter volumetric flask with distilled water, and empty it into the silver nitrate bottle to make 7 liters of solution. Shake the silver nitrate bottle vigorously for at least 5 minutes and return it to its place in the apparatus. After handling the equipment and chemical, wash hands thoroughly with salt water and rinse with fresh water.

I–11 Standardization of Silver Nitrate Solution.—After the silver nitrate solution is prepared, it must be standardized to determine its exact concentration in parts per thousand (‰). Standardization is the process of determining the difference between the concentration of the silver nitrate solution (A) and the chlorinity of the standard sea water (N). The difference is called alpha (α). To standardize a silver nitrate solution, titrate a standard sea water sample three times at the beginning of the analysis. Standardization also is performed following the duplicate titration of approximately 24 water samples or at the end of each station.

I–12 Titration of a Sea Water Sample.—Titration of a sea water sample (either standard sea water or an unknown sea water sample) involves the following operations:

(1) Drawing the Sample with the Automatic Pipette.—Drawing the sample for analysis, whether it is standard sea water or an unknown sea water sample, is carried out in precisely the same manner. Before titration commences, all solutions, samples, and apparatus must have remained in the laboratory long enough to have come to the same temperature. This usually requires 6 to 12 hours.

Step 1. Record the sample bottle serial number and sample bottle number on the D-Sheet in the appropriate columns. If the sample is standard sea water, enter the chlorinity of the standard (N) in the *Standardization* column.

Step 2. Turn on the salt water tap to which the aspirator is attached, wipe the pipette delivery tube with a clean paper tissue, insert the tip of the pipette into the sample bottle, and turn the stopcock to the fill position (fig. I–5). Partially fill the pipette and remove the sample bottle to allow thorough rinsing by the suction applied. Turn the stopcock to the vent position, and drain the sample water into a beaker. Discard this water.

Figure I–5. Drawing the sample with the automatic pipette.

Step 3. Repeat Step 2.

Step 4. Turn the stopcock to the fill position, draw 15-ml. from the sample bottle, turn stopcock to off position and wipe the pipette delivery tube with a paper tissue after withdrawing the bottle.

Step 5. Drain the water sample in the pipette into a clean 100-ml. beaker, containing a teflon covered magnetic stirring bar. When the pipette is drained, water will remain in the tip of the pipette. After the last drop has fallen, bring the beaker up to the pipette tip and barely touch the tip to a wet portion of the beaker near the surface of the liquid.

Follow the same technique each and every time so the results will be consistent.

It is important when drawing samples to remember to always follow the same routine of "always rinse twice—draw—wipe—drain."

(2) Titrating with the Knudsen Automatic Burette.—Titrating the sample, whether it is standard sea water or an unknown sea water sample, is carried out in precisely the same manner. Once the chemist has established his routine, every analysis should be carried out in exactly the same way. The titration time for each of the samples should be approximately the same.

Step 1. Fill the burette with silver nitrate solution. To do this, close the delivery stopcock, turn the leveling stopcock to the overflow position, and open the filling stopcock at the bottom of the burette. If the solution does not fill the burette until it overflows, press the rubber pressure bulb connected to the silver nitrate bottle.

Step 2. After the burette has filled and some silver nitrate has entered the overflow flask, close the filling stopcock; turn the leveling stopcock to the vent position. The burette is now automatically zeroed and is ready for titration. Inspect the burette carefully for the presence of air bubbles. If air bubbles are present, drain the burette by opening the delivery stopcock and refill. Before the first titrations are run each day or after the solution has been in the burette for an hour or more, always drain completely and refill the burette at least twice. Shake the silver nitrate bottle occasionally to assure a uniform mixture.

Step 3. Add 1 ml. of the phenosafranin indicator solution to the sample in the beaker.

Step 4. Place the sample beaker on the magnetic stirrer beneath the delivery tip of the burette. Turn the magnetic stirrer to a low speed that will not cause splattering.

Step 5. Open the delivery stopcock wide until the silver nitrate solution drains to the base of the burette bulb (fig. I–6); then, reduce flow and proceed with caution. Increase the speed of the magnetic stirrer to maintain uniform stirring as the volume of solution increases in the beaker. The stirring speed should be as fast as possible without causing splattering of the sample up the sides of the beaker. A speed that is just short of that which will cause splattering is considered best.

Step 6. Once the silver nitrate solution leaves the bulb and starts down the graduated bore of the burette, concentrate on the color of the sample and the rate of delivery. Watching the burette scale during the period of titration is considered poor practice. As the silver nitrate solution is added, the liquid in the beaker will change in color from red to pink to lavender.

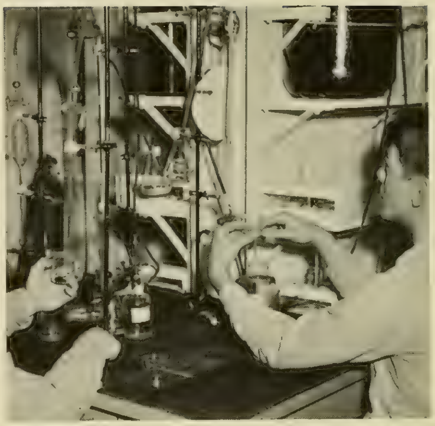

Figure I–6. **Titrating a salinity sample.**

Step 7. As the lavender tint increases, reduce the speed of delivery to a drop at a time, then a half drop at a time, until there is no trace of lavender remaining and the solution is a solid blue.

Step 8. At this point, close the delivery stopcock (the stirrer continuously running), and observe the color for 20 seconds. If a lavender color should return, add another half drop of silver nitrate. This is the final color change or end point.

Step 9. Immediately read the burette scale. If a standard is being run, read the value to the nearest (.005) five-thousandth, and enter the result in the *Standardization* column (A) of the D–Sheet. If a sea water sample is being run, read the burette to the nearest (.01) hundredth and enter in *Burette Reading* column. Shut off the stirrer. While reading the burette, it is convenient to hold a piece of stiff white cardboard directly behind the burette. As a result, the meniscus can be seen easily and read quickly. The true meniscus is the bottom line of the concave surface of the solution when the observer's eye is level with the surface of the solution (fig. I–7).

Step 10. Remove the magnet from the beaker with a magnetized pickup rod and discard the titrated sample. Once the titrations are started, it is not necessary to reclean the beaker after each titration unless the titration has run over the end point.

Step 11. Repeat the process beginning with drawing the sample with the automatic pipette. When running unknown sea water sample titrations, a minimum of two titrations of each sample must be made, and two burette readings must be within 0.01 to be acceptable. Whenever the readings have a difference greater than 0.01, a third or fourth titration, if necessary, must be run until two readings are obtained within the prescribed limits. When making the standardization titrations of standard sea water, a minimum of three titrations must be made.

I–13 Standardizing and Adjusting the Silver Nitrate Solution.—As the titrations are performed to standardize the silver nitrate solution, record the burette readings (A) in the *Standardization* column of the D-Sheet and compute the difference alpha (α) between the chlorinity of the standard water sample (N) and the burette reading (A) for each titration. For example:

An average alpha is obtained from the three best titrations of the standard sea water. This average alpha is the value used to obtain the correction k from Knudsen's tables, which in turn is applied to the burette readings of the sea water samples to obtain chlorinity. For example:

(N) −	(A) =	(α)	
19.395	19.375	+0.020	
19.395	19.365	.030	
19.395	19.370	.025	
		+ .025	(average)

Or where alpha comes out negative:

(N) −	(A) =	(α)	
19.395	19.420	−0.025	
19.395	19.420	− .025	
19.395	19.470	− .075	(poor run—discard)
19.395	19.420	− .025	
		− .025	(average)

In the event the standardization reveals that alpha is not within −0.150 to +0.145, the solution must be adjusted. This adjustment is made by adding more silver nitrate crystals if the solution is too weak, i.e., shows a negative alpha lower than −0.150 or by adding distilled water if too strong, i.e., shows a positive alpha of more than 0.145.

To assist in making these adjustments, two linear graphs are shown in figures I–8 and I–9. The first graph shows the number of grams of silver nitrate to be added to each liter of solution when the titration reveals a negative alpha value. The second graph shows the number of milliliters of distilled water to be added to each liter of solution when titration reveals a positive alpha.

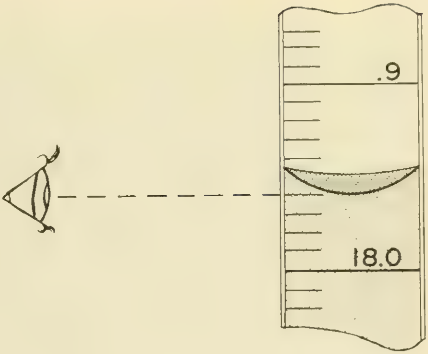

Figure I–7. The true meniscus and the observer's eye.

After the silver nitrate solution is adjusted, repeat the titration process with a standard sea water sample.

I–14 Computing the D-Sheet.—After the standardizations and titrations have been made, compute the salinity of each sample.

Step. 1. Compute the average burette reading for each sample, and enter in *Average Burette Reading* column.

Step. 2. Average the beginning and the ending alpha (α), and turn to the appropriate alpha (α) column of table I–1, Table of the correction k.

Step. 3. Read down the column until the average burette reading (a) is less than the upper number and greater than the lower number, and read the value of k in the right hand column of table. Enter this value in the *k* column of the D-Sheet.

Step 4. Algebraically add k to the average burette reading and enter the value in the *Chlorinity* ‰ column.

Step. 5. Compute salinity with Knudsen's tables or by the following formula: S‰ = 0.03 +

Table I–1. Table of the correction k (taken from Hydrographical tables, edited by Martin Knudsen)

$\alpha = 0.025$

a=	k=
20.15	
	+0.01
19.76	
	+0.02
19.34	
	+0.03
18.93	

a is average burette reading

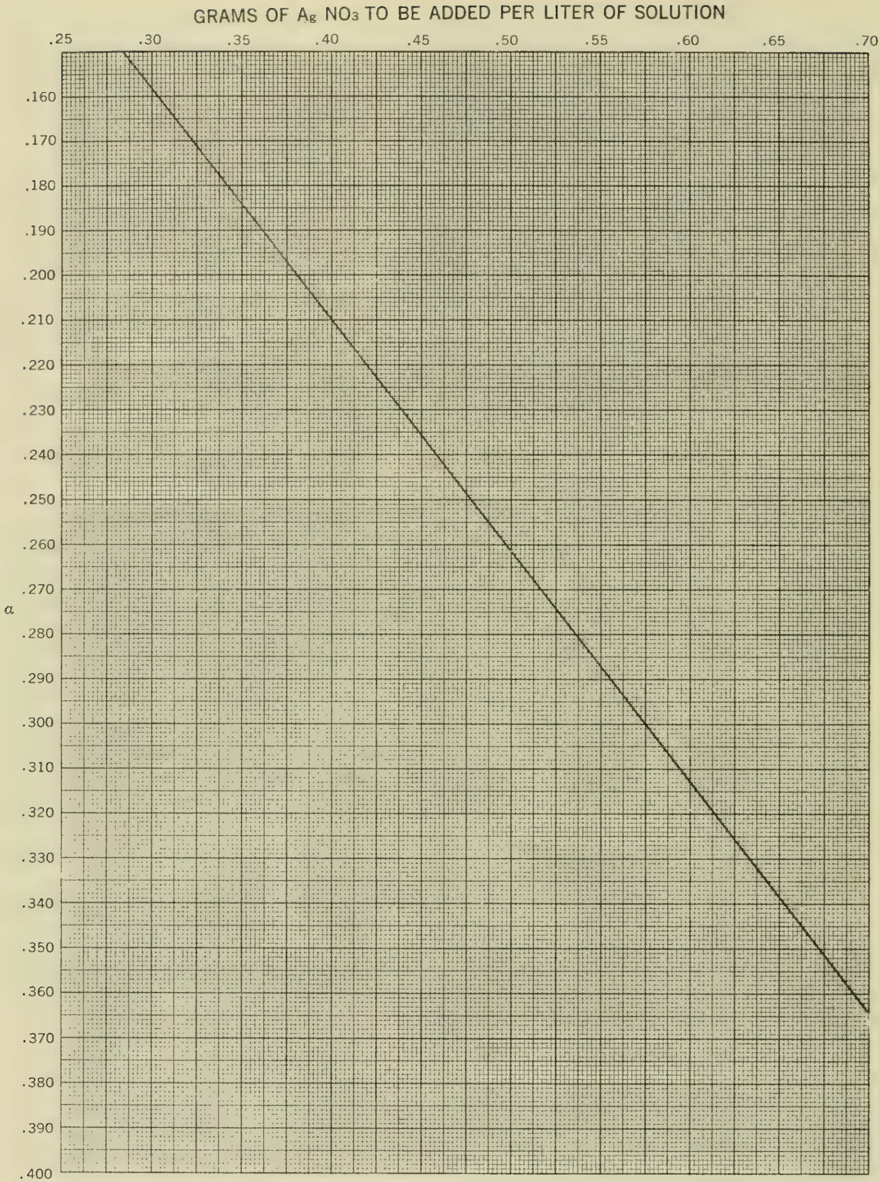

Figure I–8. Grams of $AgNO_3$ to be added to the solution when alpha is negative.

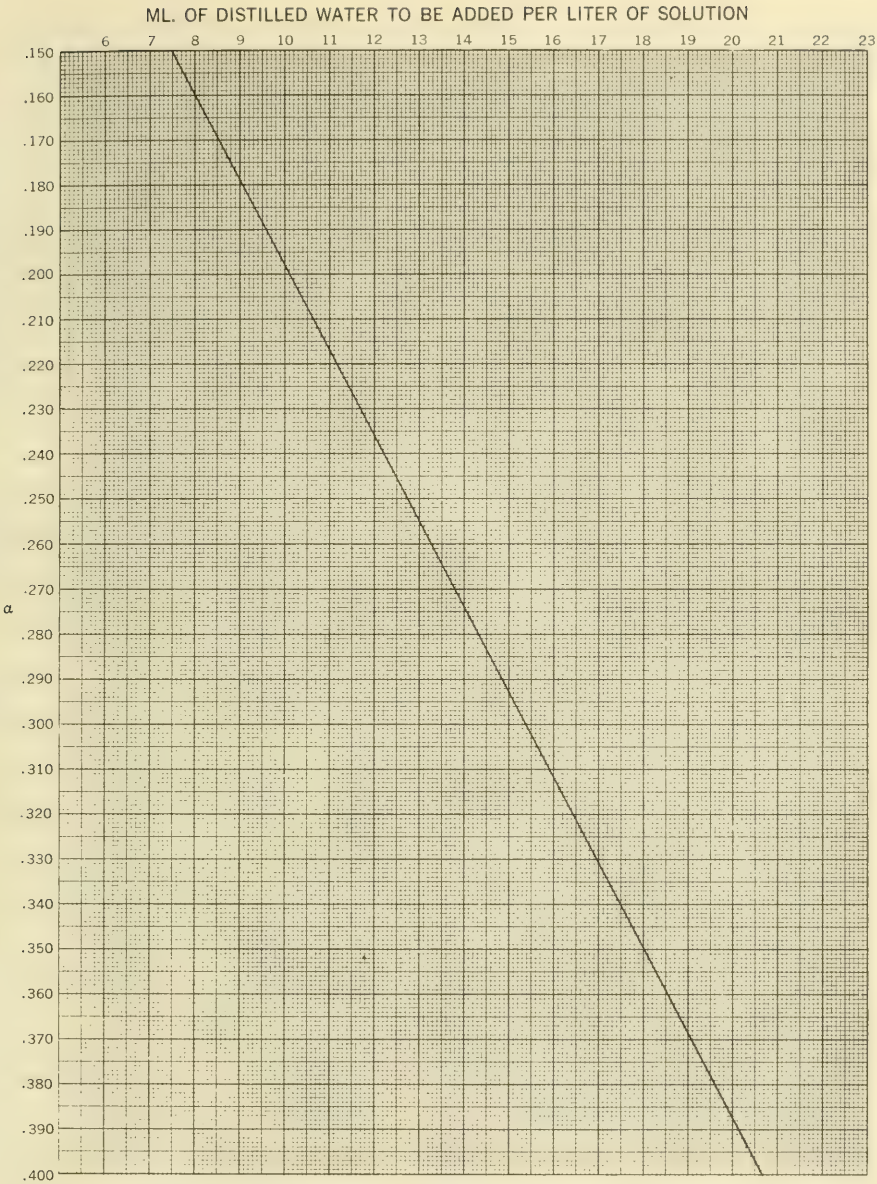

Figure I–9. Ml. of distilled water to add to the solution when alpha is positive.

1.805 (chlorinity ‰). Some other person should check all computations on the D-Sheet and sign off in the *checked by* block. The D-Sheet is filed in the Oceanographic Station Folder with the A-Sheet and other oceanographic station data.

I–15 Securing the Apparatus After Completing the Titration.—After the analyses of a station have been completed, or a day's work has been finished, the apparatus must be secured. The pipette and burette will last longer between cleanings if, whenever they are not in use, they are kept filled. Fill the pipette with sea water and the burette with silver nitrate, and check to see there are no air bubbles. Set the upper leveling stopcock of the burette to the overflow position. This will allow expansion of solution in the burette in the event of temperature change. Apply a pinchclamp to the tubing from the silver nitrate botttle. Place an empty beaker below the delivery stopcock of the burette to catch any leakage. Clean the table with sea water, and wash and dry all beakers, magnetic stirring bars, pickup, and stirring rods. Do not leave unwashed any apparatus that has been used.

I–16 Maintenance and Repair of Apparatus.—The Knudsen titration apparatus requires little maintenance except routine cleaning. It is almost impossible to repair broken burettes or pipettes. Even when done by experienced glassblowers, they must be recalibrated. It is better to use a new piece of apparatus.

I–17 Salinity Determination by Electrical Conductivity Method.—Salinity determination of sea water samples by electrical conductivity was demonstrated as early as 1922 by Dr. Frank Wenner, who developed a shipboard instrument capable of measuring the salinity of sea water to as high a degree of accuracy (1 part in 4,000 of electrical conductivity) as was possible by means of the more tedious method of titration. Extensive tests and refinements conducted by E. H. Smith and F. M. Soule led to this instrument being known as the Wenner, Smith, Soule salinity bridge. The theory involved was that of the instrument comparing the electrolytic conductivity of a sea water sample with the electrolytic conductivity of standard sea water. Though the principle has remained basically the same, instruments have been refined, and at the present time several excellent salinometers (instruments for measuring the salinity of a sea water sample) are available to the oceanographer.

I–18 Equipment Used.—One type of portable induction salinometer now being used by the U.S. Naval Oceanographic Office for salinity determinations of sea water is shown in figure I–10. The salinometer weighs 48 pounds and is housed in a fiberglass carrying case. The instrument is simple to operate and maintain. Results obtained have proved to be accurate, precise, and reproducible within satisfactory limits. A block diagram of the instrument is shown in figure I–11. A sample of sea water is drawn into the cell for the analysis. This liquid acts as a single turn loop to provide a link coupling between the transmitter toroid and the receiver toroid for a 10 kc. oscillator signal. The degree of coupling is directly porportional to the conductance of the sea water loop. The coupling between the two toroids is alternated by operator-controlled transformers until two currents of equal magnitude (I_t and I_r), but of opposite phase, are indicated on a nullmeter. The control settings then are translated to salinity values with tables.

Another model induction salinometer that will be in use at the U.S. Naval Oceanographic Office in the near future is described in paragraph I–25.

I–19 Setting Up the Salinometer.—The salinometer should be set up on a work table with adequate room for sample bottles, log sheet, and drain bottle, and the following preliminary adjustments should be made to the instrument (fig. I–12):

Step 1. Attach a 10– or 12–inch piece of 7/16-inch outside and 5/16-inch inside diameter natural latex tubing (A) to the sample cell.

Step 2. Attach a 4-foot piece of the latex tubing (B) to the drain tube of the sample cell. Run the tube into a large waste bottle.

Step 3. For model RS–7A, attach an air relief tube (C), a 4-inch piece of latex tubing, to the air relief inlet (D) of the sample cell, and place a screw clamp (E) across the tube. For some models that are equipped with the fill knob (F), which performs the same function as the screw clamp and the air relief tube, this step is not necessary.

I–20 Preliminary Checkout.—Before the analysis is commenced, the instrument should be checked as follows:

Step 1. Check to be sure that the null indicator (G) needle reads zero (with power off). If needle is off zero, breathe on meter to eliminate any static charge. If needle is still off zero, correct by adjusting small screw below needle.

Step 2. Connect power cable (H) to 110 v. a.c. outlet, turn on power switch (I), and allow 1 minute warm up. Set Conductivity Ratio dials (J) to zero, set Function Selector dial (K) to Salinity, and set Standardization dials (L) to zero. Again check null indicator. If it does not read zero, remove panel screws, slide chassis out of the case, and adjust Zero Adjustment with screwdriver (fig. I–13).

Step 3. Set Standardization dials to 5000. Change Conductivity Ratio dials by 0.00001, 0.00002, etc., to observe meter sensitivity. Meter deflections should be perceptible for the smallest change and should be reasonably linear for the first few steps.

Step 4. Set the Function Selector to Temperature and adjust Temperature °C. controls (M) until null indicator meter reads zero. This temperature should be approximately room temperature.

Step 5. Set the Stir Fill switch (N) to Fill, and listen for sound of the pump to make sure the pump motor is functioning.

Step 6. Screw the overflow jar (O) into place, and turn the three-way valve (P) to Fill position. Place fill tube in a bottle of water, adjust air relief tube clamp (or fill knob) to observe that pump is drawing water into sample cell.

I–21 Filling, Rinsing, and Draining the Sample Cell.—Proper filling of the sample cell is probably the most important technique in the operation of the salinometer. Proper rinsing between samples ranks next in importance. The water must be drawn into the sample cell in such a way that bubbles do not form on the inner surface of the cell. The sample cell should be rinsed carefully with a cell full of the new sample each time a different sample is to be analyzed. When the sample cell is drained care must be taken to avoid contaminating the sample. The steps listed below should be performed

223-812 O - 68 - 7

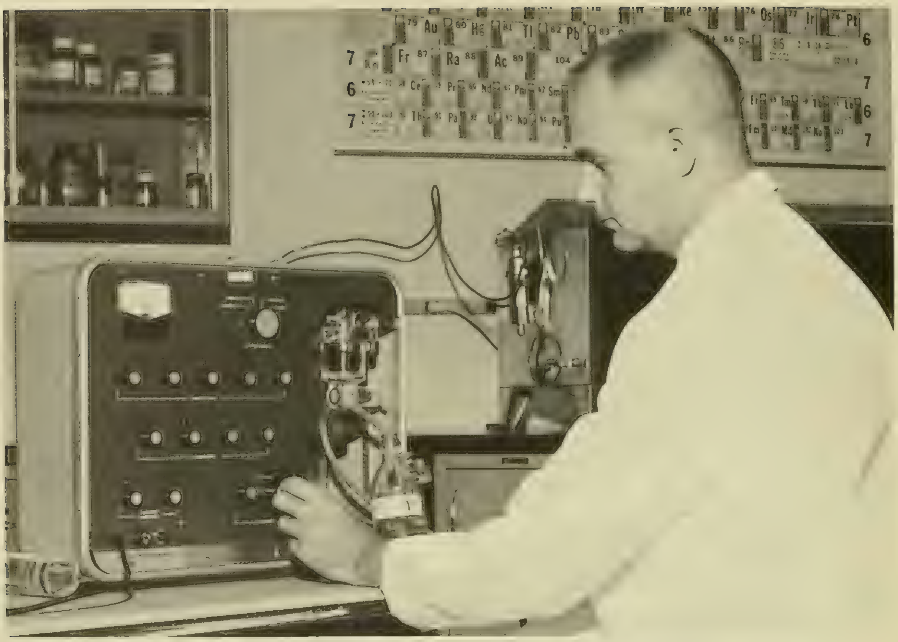

Figure I–10. Industrial Instruments Inc. Model RS–7A Portable Induction Salinometer.

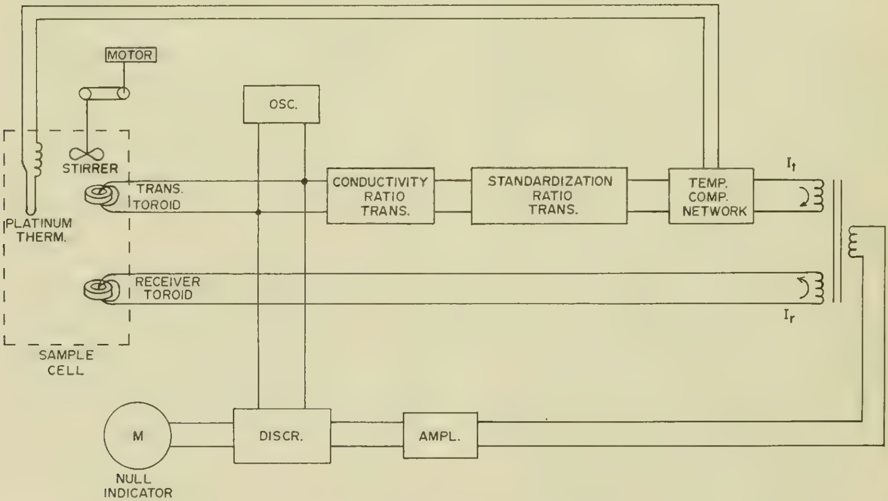

Figure I–11. Block diagram of salinometer.

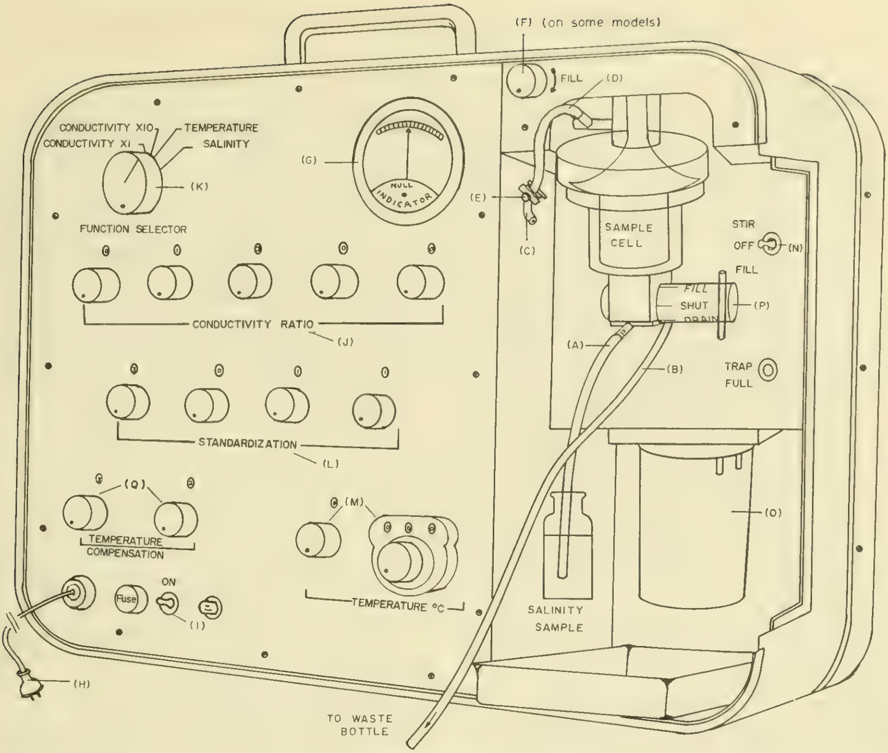

Figure I–12. Salinometer set up for operation.

carefully when filling, rinsing, and draining the salinometer sample cell during salinity analysis:

Step 1. Set the Stir Fill switch to Fill. Wipe the latex fill tube with a cleansing tissue, and insert the tube into the liquid or sample to be drawn into the cell.

Step 2. Turn the three-way valve to Fill position, and adjust the screw clamp on the air relief tube (or turn the fill knob) until the cell fills at a speed that does not produce bubbles on the inner surfaces of the cell.

Step 3. Allow the cell to fill until the liquid starts to enter the overflow tube at the top of the cell. Turn the three-way valve to Shut position, and set the Stir Fill switch to Stir. This will rinse the inner surfaces of the cell.

Step 4. To drain the contents of the cell into the waste bottle, turn the Stir Fill switch to Off position and set the three-way valve to Drain position. **NOTE:** If the three-way valve is

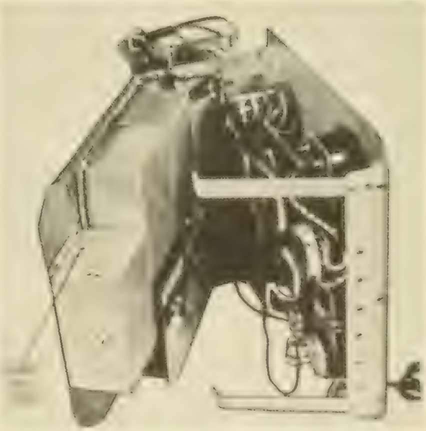

Figure I–13. Internal zero adjustment.

Table I-2. Abstract of Conversion of Conductivity Ratio to Salinity Table.
Table for 0.0000 to 1.3999 conductivity ratios (equivalent to 0.000 to 50.00 ‰ salinity) is furnished with each salinometer

CONDUCTIVITY RATIO	SALINITY (parts per thousand)									
	0	1	2	3	4	5	6	7	8	9
0.990	.608	.611	.615	.619	.623	.627	.631	.635	.639	.643
1	.647	.651	.655	.659	.662	.666	.670	.674	.678	.682
2	.686	.690	.694	.698	.702	.706	.710	.714	.717	.721
3	.725	.729	.733	.737	.741	.745	.749	.753	.757	.761
4	.765	.768	.772	.776	.780	.784	.788	.792	.796	.800
5	.804	.808	.812	.816	.820	.823	.827	.831	.835	.839
6	.843	.847	.851	.855	.859	.863	.867	.871	.874	.878
7	.882	.886	.890	.894	.898	.902	.906	.910	.914	.918
8	.922	.926	.929	.933	.937	.941	.945	.949	.953	.957
9	.961	.965	.969	.973	.977	.980	.984	.988	.992	.996
1.000	35.000	.004	.008	.012	.016	.020	.024	.028	.031	.035
1	.039	.043	.047	.051	.055	.059	.063	.067	.071	.075
2	.079	.083	.087	.091	.094	.098	.102	.106	.110	.114
3	.118	.122	.126	.130	.134	.138	.142	.146	.150	.154
4	.157	.161	.165	.169	.173	.177	.181	.185	.189	.193
5	.197	.201	.205	.209	.213	.217	.220	.224	.228	.232
6	.236	.240	.244	.248	.252	.256	.260	.264	.268	.272
7	.276	.279	.283	.287	.291	.295	.299	.303	.307	.311
8	.315	.319	.323	.327	.331	.335	.339	.342	.346	.350
9	.354	.358	.362	.366	.370	.374	.378	.382	.386	.390
1.010	.394	.398	.402	.405	.409	.413	.417	.421	.425	.429

turned to the Fill position, the contents of the cell will drain out through the fill tube and can contaminate the balance of the sample.

I-22 Analysis of Salinity Samples.—The analysis of salinity samples should be recorded on Log Sheet–DDD (fig. I-14) and should include the following processes:

1. Standardization.—Standardization is performed before and after the analysis of a series of salinity samples. Its purpose is to provide a direct reading of a conductivity ratio corresponding to the exact salinity of a standard sea water sample. Because the conductivity ratio usually drifts during the analysis of a series of salinity samples, the standardization and the salinity sample run operations should be performed without interruption. Standardization procedures include the following steps:

Step 1. Enter ship, cruise number, station number, and bridge number (Salinometer Serial Number) in the appropriate blocks of the DDD–Sheet.

Step 2. Transcribe the *Serial No. Salinity Bottle No.* column number from the Log Sheet–A to the *Serial Number* column of the DDD–Sheet, and enter salinity sample bottle number (number on sample bottle) in the *Bottle Number* column next to the appropriate serial number. Arrange the series of samples to be run in order of increasing depth.

Step 3. Open a vial of standard sea water (see par. I-2), and compute the salinity by the formula

$$\text{Salinity ‰} = 0.030 + 1.805\ (\text{Cl ‰})$$

Step 4. Enter the letters Std and the number 1 in *Bottle Number* column, and on the same line, enter the salinity of the standard sea water in the *Nominal Salinity ‰* column.

Step 5. From Conversion of Conductivity Ratio to Salinity table (see table I-2), determine the conductivity ratio for the Std 1 salinity, and enter this value in the *Conductivity Ratio Average* column; then, set the salinometer Conductivity Ratio dials to this value.

Step 6. Fill the sample cell with the standard sea water, and set the Function Selector knob to Temperature.

Step 7. Set the Stir Fill switch on Stir, and adjust the two Temperature °C controls to obtain a zero reading on the null indicator. Enter the resulting temperature reading in the *Sample Temp.* block. Left dial digits are tens; right dial digits are units, tenths, and hundredths. Drain the sample cell.

Step 8. From Temperature Compensation Dial Settings table (see table I-3), determine temperature compensation dial settings for sample temperature, enter this value in the *Temp. Comp. Dial Setting* block, and set Temperature Compensation knobs (Q) to the number.

OCEANOGRAPHIC LOG SHEET – DDD
PRNC-NAVOCEANO-3167/4 B (10-64)

U. S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

SALINITY DETERMINATION BY INDUCTIVELY COUPLED SALINOMETER

from table I-3

SHIP	CRUISE NUMBER	STATION NUMBER	BRIDGE NUMBER	CHEMIST	SAMPLE TEMP.	TEMP. COMP. DIAL SETTING	STD. DIAL SETTING	DATE ANALYZED	CHECKED BY
EDISTO	E.ARCTIC-65	31	90421	J.J.C.	23.80	79	4715	10/7/'65	KAC

SERIAL NUMBER	BOTTLE NUMBER	CONDUCTIVITY RATIO 1ST DETERM.	CONDUCTIVITY RATIO 2ND DETERM.	CONDUCTIVITY RATIO AVERAGE	NOMINAL SALINITY ‰	CORRECTIONS ‰ DRIFT	CORRECTIONS ‰ TEMP.	CORRECTIONS ‰ DILTN.	CORRECTIONS ‰ TOTAL	CORRECTED SALINITY ‰	REMARKS
	Std 1			.99995	34.998					34.998	
568	568	.99770	.99766	.99768	34.909	0	0		0	34.909	
569	569	.99796	.99794	.99795	34.920	.001	0		+.001	34.921	
570	570	.99800	.99800	.99800	34.922	.001	0		+.001	34.923	
571	571	.99780	.99780	.99780	34.914	.001	0		+.001	34.915	
572	572	.99789	.99789	.99789	34.918	.001	0		+.001	34.919	
573	573	.99824	.99824	.99824	34.931	002	0		+.002	34.933	
	Std 2	.99990	.99990	.99990	34.996	+.002			+.002	34.998	
		Drift:			From Table I-2		From Table I-4				
	std 1	34.998									
	std 2	34.996									
		−.002									
		std.1 > std 2									

Figure I-14. **Oceanographic Log Sheet DDD.**

Table I-3. Abstract of Temperature Compensation Dial Settings table

For temperature °C. reading	Set temperature compensation	
	Left dial	*Right dial*
16.00	4	6
18.00	5	4
20.00	6	3
22.00	7	2
24.00	8	0
26.00	8	7

Table with Temperature Compensation Dial Settings for temperatures from 6° to 40° C. is furnished with each salinometer

Step 9. Set the Function Selector knob to Salinity, refill the sample cell, set the Stir Fill switch to Stir, and adjust the Standardization dials until the null indicator needle is on scale. Then turn the Stir Fill switch to Off, drain the cell, refill again, stir the sample, and finally zero the null indicator needle with the Standardization dials. Turn the Stir Fill switch to Off, the three-way valve to Fill, and let the sample drain back into the bottle of standard sea water. Refill the sample cell once again and make sure the Standardization dial settings zero the null indicator meter.

Step 10. Record the Standardization dial settings in the *Std. Dial Setting* block.

2. Salinity Sample Runs.—Salinity samples should be within one or two degrees centigrade of the sample temperature obtained during standardization (Step 7 above) when they are analyzed, and the steps listed below should be followed carefully as the salinity samples are run:

Step 1. Open the first sample bottle, turn all Conductivity Ratio dials to zero, fill the sample cell full, and set the Stir Fill switch to Stir to rinse the cell with the sample. While rinsing, adjust the Conductivity Ratio dials to obtain an on scale reading on the null indicator meter. *DO NOT CHANGE THE STANDARDIZATION DIALS.*

Step 2. Drain the cell into the waste bottle, refill the cell, set the Stir Fill switch to Stir, and adjust the Conductivity Ratio dials to obtain a zero reading on the null indicator meter; then, stop the stirrer and record the Conductivity Ratio dial settings in the *Conductivity Ratio 1st Determ.* column.

Step. 3. Immediately drain the cell either into the waste bottle or back into the sample bottle, depending on the amount of sample available. Refill the cell, stir, and adjust the Conductivity Ratio dials to obtain a zero reading on the null indicator meter. Stop the stirrer, record the dial settings in the *Conductivity Ratio 2nd Determ.* column.

Step 4. If the 1st and 2nd Determ. conductivity ratios are within ±.00010, go on to step 5. If they do not agree within the above limits, rerun a third or fourth sample until acceptable values are obtained.

Step 5. Recap the sample bottle, and return it to the salinity sample case. Samples are not discarded until salinity analysis data are computed and verified.

Step 6. Repeat steps 2 through 7 for other salinity samples (the maximum number of samples run at one time usually is 24).

Step 7. After the salinity samples have been run, analyze a sample from the standard sea water used for the standardization; this time, however, adjust the Conductivity Ratio dials to obtain a zero reading on the null indicator. Enter the dial settings in *Conductivity Ratio* column(s), and write Std and the number 2 in *Bottle Number* column. The second standardization run is most important because the salinometer usually has a tendency to drift.

3. Conversion of Conductivity Ratio to Salinity.—Average conductivity ratios are computed and entered in the *Conductivity Ratio Average* column, and then converted to nominal salinity ‰ by means of the Conversion of Conductivity Ratio to Salinity table (see table I-2). Determine salinity ‰ to the nearest thousandth by interpolation, and enter in the *Nominal Salinity* ‰ column.

4. Computation of Drift Corrections.—After the conductivity ratio is obtained by rerunning the standard (Std2), the drift that occurred in the salinometer can be determined.

Step 1. Determine the difference between the nominal salinity ‰ of Std1 and Std2 and enter this value in the *Drift* column of Std2 line. If Std1>Std2 the drift correction is plus; if Std1<Std2 the drift correction is minus.

Step 2. Distribute the drift corrections proportionally between the salinity samples run, beginning with zero (or minimum) drift correction for the first sample run after standardization (Std1) and increasing to maximum drift correction at the last sample run before rerunning the standard Std2. Enter in *Drift* column.

An excessive drift may require a standardization following the running of 12 salinity samples. Drift can be reduced by maintaining a constant temperature in the laboratory and by analyzing the series of salinity samples in the minimum time consistent with good techniques.

5. Computation of Temperature Corrections.—Sample temperatures have an effect on salinity values. This temperature correction is determined by using the Temperature Corrections to Salinity table (see table I-4). Using sample temperature (*Sample Temp.* block) and the nominal salinity ‰ for each sample, determine the temperature correction and enter the value in the *Temp.* column. It is most important that temperatures of the samples vary no more than one or two degrees celsius.

Table I-4. Abstract of Temperature Corrections to Salinity table

Salinity ‰	16	18	20	22	24	26
	Sample Temperature °C.					
34	+.003	+.002	+.001	.000	−.001	−.002
35	.000	.000	.000	.000	.000	.000
36	−.003	−.002	−.001	.000	+.001	+.001

Table with additional Temperature Corrections to Salinity from 12° to 32° C. and 32‰ to 39‰ salinity is furnished with each salinometer

6. Computation of Total Corrections ‰.—*Diltn.* column is not used when the above rinse procedures are employed. The total corrections ‰ are computed by algebraically combining the drift and temperature corrections. Enter in the *Total Corrections* ‰ column.

7. Computation of Corrected Salinity ‰.—The corrected salinity for each sample is computed by algebraically combining the nominal salinity ‰ and the total corrections ‰. The resulting salinity value is entered in the *Corrected Salinity* ‰ column.

The *Remarks* column should be used to record notations such as loose sample bottle cap, dirt in bottle, etc. The chemist should enter his initials and the date of analysis in the appropriate blocks, and all calculations and conversions on the DDD-Sheet should be checked by another person. The DDD-Sheet is filed in the Oceanographic Station Folder with the Log Sheet-A.

I–23 Maintenance of Induction Salinometer.—The induction salinometer is relatively simple to maintain, and the only tools and materials necessary are a screwdriver, a small adjustable wrench, spare parts, lab tissues, silicone lubricants and oils. After a series of salinity samples have been run, rinse the sample cell with fresh water; empty, rinse, and dry the overflow jar; rinse and dry the latex tubing; replace the carrying case cover, and secure the instrument in an upright position. Maintenance, inspections, and repairs should be performed as follows:

(1) Routine Checking. Check to assure that power cable is not frayed or broken, that all components are securely mounted, that all water connections are secure, and that pump and stirrer drive belts are not worn.

(2) Cleaning. When the cell is obviously dirty, or when large droplets of water cling to cell surfaces, cleaning is required. Refer to paragraph I–24.

I–24 Trouble Shooting.—The procedures described deal with problems experienced by operating personnel and are confined to those repairs which can be made in the field. Refer to figures I–15 and I–16.

1. Air Bubbles.—Air bubbles in the sample cell are caused by one of three conditions: (a) air leak from the outside, (b) bubble (air) entrapment from the inside, (c) or a dirty cell. To determine the cause of air bubbles,

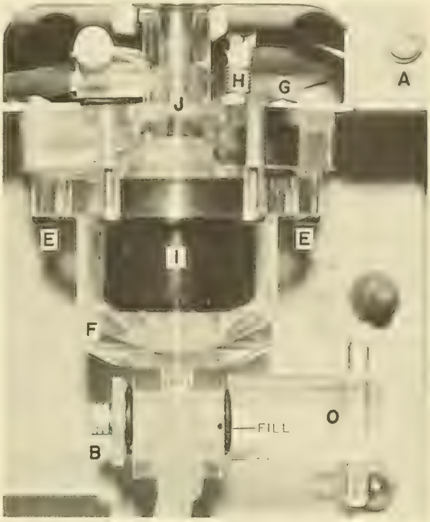

Figure I–15. Sample cell assembly.

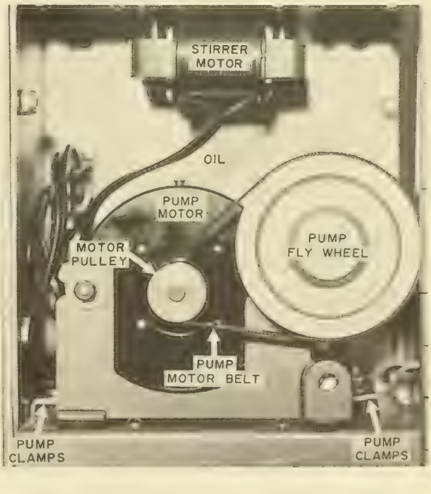

Figure I–16. Pump motor and stirrer motor.

Step 1. Fill cell in accordance with paragraph I–21.

Step 2. Close off air relief inlet or fill knob and let pump run.

Step 3. While continuing to pump, visually examine the entire cell. Any air leak will be located and pinpointed quickly. If a leak is not visible, the bubbles are caused by condition b or c which will be discussed below.

a. If an air leak is visible proceed as follows:

(1) Stopcock area air leak. Remove panel screws (A) to allow access to cell, then remove the retaining plate (B), and pull stopcock (O) out of housing. Clean stopcock with lab tissue, and clean out housing in the same manner. Recoat stopcock with a thin coating of Dow-Corning high vacuum grease, Fisher high vacuum Cello-Grease or equivalent. Replace stopcock and retaining plate. Should the stopcock still leak air, apply a heavier coat of grease. If this does not correct the situation, the stopcock is probably scored and should be replaced.

(2) Toroid mounting stud area air leak.

(a) Remove the six screws (E) and remove cell bowl (F). CAUTION: *Use extreme care during disassembly to avoid damage to the platinum thermometer assembly (the dark probe behind the toroid). Its replacement cost is approximately $400.00.*

(b) Observe the above caution and back off the toroid mounting nut (G) all the way up to the top of the toroid mounting stud (H). This will allow the toroid assembly (I) to be lowered about ¾ to 1 inch. Lower the toroid and apply a heavy coating of vacuum grease on the small black sleeve of the toroid mounting stud. Push the toroid back to its secured position, tighten down the nut on the mounting stud making sure that the toroid is about ⅛ inch away from the platinum thermometer. Clean off the excess grease that shows on the toroid or the underside of the lucite toroid mounting. Clean and lightly recoat the joint between cell bowl with vacuum grease, taking care not to get any grease on the inside of the cell. Reassemble the cell with the six mounting screws previously removed during disassembly, making sure the stopcock handle is to the right. CAUTION: *Use care when handling platinum thermometer.*

(3) Air leak between cell bowl and cell top. Disassemble the cell bowl by removing the six mounting screws. Carefully remove the cell bowl. Wipe off all old grease around the joint with lab tissue and lightly grease the joint with vacuum grease. Wipe off excess grease on the inside of the cell bowl or bowl top. Reassemble the cell with the six mounting screws.

(4) Air leak around stirrer and stirrer bearing housing. The plexiglass housing (J) which contains the stirrer bearing has been known to come apart, causing an air leak. If this occurs, remove the cell bowl. Remove the stirrer-motor belt and stirrer pulley by loosening the set screws on the pulley. Lower the toroid assembly and swing it forward about 90°. Pull the stirrer shaft through the bearing from the bottom. Reglue the stirrer housing with Dupont Duco or similar cement. *Do not use Epoxy cement.* Apply a thin coat of Dow-Corning No. 44 ball-bearing grease to the stirrer shaft and reinsert into the stirrer bearing from the bottom. Reinstall the pulley, secure the set screws, and reattach the drive belt from the stirrer-motor to the stirrer. Make sure the pulley exerts a small amount of pressure on the bearing top to prevent any vertical movement of the stirrer. Realine and secure the toroid assembly and reattach the cell bowl with the six mounting screws. Allow the glue to set for at least 12 hours before pumping any water into the cell bowl.

(5) Air leak around the platinum thermometer assembly. Since the platinum thermometer is so delicate, it is advisable not to disassemble in the field. Should an air leak develop where the thermometer is joined to the cell top, apply a heavy coat of vacuum grease around the four mounting screws, the edge of the light green mounting plate, and the top of the shaft of the thermometer itself. Return to Oceanographic Office for final repair.

(6) Air leaks caused by hairline cracks in the cell bowl or cell top. Temporarily fill cracks in the cell bowl with vacuum grease from the outside. Return to the Oceanographic Office for final repair. *Do not use beeswax, core wax, pipe dope, or similar expedients for this type repair.*

b. Air Entrapment.

(1) Toroid assembly inside sample cell is too close to platinum thermometer. The space between the toroid assembly and the platinum thermometer should be ⅛ of an inch. To obtain this spacing, back off the toroid mounting nut about one turn or until the threaded toroid mounting stud swings free with a slight pressure from the fingers. Facing the right side of the sample cell, space the toroid approximately ⅛ inch from the platinum thermometer, and tighten the mounting nut, while holding the toroid mounting stud tightly with the fingers at the same time.

(2) Air is being entrapped around stopcock assembly.

(a) Make sure stopcock holes are alined properly with the stopcock housing holes when drawing sample into the cell..

(b) Remove any excess grease visibly showing in the stopcock holes or stopcock housing holes.

(3) Air is being entrapped between the front of the toroid and inside the front of the cell bowl. Realine the toroid as described in b(1) above.

(4) Air is being entrapped at the bottom or

top of the toroid. This condition usually is caused by the pumping rate being too fast or the sample cell not being "wetted" (see par. c). When filling cell to assure proper pump rate, adjust Fill knob until the proper pump rate is obtained. Or, if the latex rubber tube is on the air relief inlet (Step 3, par. I–19), adjust the screw clamp until proper pump rate is attained.

c. Air is being entrapped because of a dirty sample cell or toroid, or the inside of the sample cell is not "wetted." If the inside of the cell is visibly dirty or if excess grease can be seen on the inside of the cell, disassemble the cell as described above in 1a(2)(a). *Observe the caution about damaging the platinum resistance thermometer.* Carefully wipe off the inside of the cell bowl, the inside top of the sample cell, and the toroid with a lab tissue. Make sure that any visible vacuum or stopcock grease is removed. Check the alinement of the toroid assembly with the platinum therometer as described in b(1) above. Reassemble the sample cell as described in 1a(2)(b), again observing *caution about possible damage to the platinum thermometer.* Fill the cell with a wetting agent solution such as Tergitol or Cutscum, prepared by taking 1 part wetting agent to 20 parts of lukewarm water. Shake to hasten solution. Turn on the stirrer and allow wetting agent to remain in the cell for 5 minutes. Drain the cell and rinse with fresh water several times. Allow the sample cell to come to room temperature, especially if lukewarm solution was used (this may take several hours) before running any salinity determinations. This treatment usually is very effective and should be done about once a week if the salinometer is in constant use. The solution of wetting agent can be used over and over again.

2. Sample cell cannot be filled. Failure of the pumping assembly can be traced to one or more of the following causes:

a. Overflow jar is not tight. Grease overflow jar threads with stopcock grease. Make sure jar is properly placed and tightened to the overflow jar lid.

b. One or more of the hose connections are not tight. Remove the RS–7A salinometer chassis from the case by taking off the seven retaining screws along the top and bottom of the front panel. On newer models, remove the rear cover. Loosen the pump clamps. Pull out the pump. Check all of the hose connections to make sure they are tight.

c. Rubber hose is pinched somewhere in the system. Check all rubber hoses to make sure that they are not pinched or bent sharply, closing off a part of the pumping system. This could mean shortening or lengthening one or more of the hoses.

d. Ball check valve is not operating or temporarily stuck or direction was erroneously reversed during installation. The ball check valve of the pumping system is located in line of the hose that connects the pump cylinder to the overflow jar. Disconnect this hose from the pump cyclinder and the overflow jar. Remove the check valve by pulling the hose apart. This valve should be constructed of a stainless steel sleeve and a Teflon ball. If not, replace with this type. Make sure the ball is loose in the sleeve. Should it be frozen, clean with fresh water and dry. If still frozen, replace. Reinstall the check valve in the black rubber tubing, connect to the pump cylinder and overflow jar. *Make sure the ball end of the stainless steel sleeve is toward the pump cylinder;* otherwise, the system will not operate.

e. Leather cup washer on the bottom of pump piston is worn out or has pulled away from the inside of the cylinder wall. Loosen the screw near the slot atop the piston. Loosen the screw that holds the pump cylinder to the pump motor frame. Remove the cylinder and the piston assembly. Pull out the piston. Remove the screw that holds the leather cup washer to the piston shaft. Replace the cup washer with a new one, but first massage the new washer with motor oil. Reassemble and aline the pump cylinder properly, making sure the piston shaft does not touch the cylinder when the pump flywheel is turned (by hand) a complete revolution. Do not tighten the screw near the piston slot too much or the bearing will freeze; too loose an adjustment will cause a knocking noise.

f. Pump motor belt is loose, worn and slipping, or is too tight. If the pump belt looks worn, replace it. If the pump belt is too tight the motor will not start the pump. If it is too loose, the pulley or flywheel will slide under the belt. For proper tension, loosen the two motor mount nuts on the pump motor frame and move the motor to the right or left to obtain proper spacing. Retighten the mounting nuts. Several trials may be necessary to insure proper belt tension.

g. Pump bearings or motor needs lubrication. Lubricate each of the oil points with two drops of about #SAE 30W motor oil. Wipe off any excess or spilled oil.

h. Large air leak from outside the sample cell. Follow procedures outlined in 1a (1) through (6).

3. Stirrer does not operate.

a. Belt from motor stirrer pulley is loose or worn. Replace belt.

b. Stirrer sticks or stirrer speed is erratic and/or not consistent.

(1) Make sure stirrer pulley set screws are tight. These screws may be slotted or Allen-type. If stirrer still sticks or is erratic, proceed as follows:

(a) Remove the six screws and remove the cell bowl.

(b) Loosen the brass hex nut on the toroid mounting stud to permit the toroid assembly to be lowered and rotated clear of the stirrer.

(c) Remove the stirrer belt and stirrer pulley.

(d) Push the stirrer shaft down into the bearing and remove the stirrer from the bottom.

(e) Clean out the bearing with lab tissue or cotton swab.

(f) Clean the stirrer shaft and on model RS–7A remove small O-ring, pack the groove with Dow-Corning No. 44 bearing grease, install a new O-ring in the groove, and coat the stirrer shaft with the bearing grease.

(g) On newer models, equipped with ball bearing assembly, pack with Dow-Corning No. 44 bearing grease.

(h) Reinstall the stirrer and be sure it turns freely before replacing the pulley.

(i) Install the pulley so that it exerts gentle pressure on the bearing top to prevent any vertical motion of the stirrer.

(j) Replace the belt. Reposition the toroid assembly.

4. Electrical problems.

a. Instrument pilot light will not light when main power switch is turned on.

(1) Plug in instrument line cord or check power source.

(2) Check main fuse to the left of pilot light. Replace if necessary. If fuse blows again, do not replace. Investigate circuitry for cause. Look for loose wire connections or broken wires. Refer to wiring diagram in instruction manual. *Do not attempt any repair on printed circuit boards or modular components without the help of a competent electronics technician.* If repairs are made by an electronics technician, log all changes made. Return instrument to U.S. Naval Oceanographic Office for further repair.

b. Nulling meter will not respond to any change of the Conductivity Ratio dials when the instrument is turned on and the cell is filled with sea water. Remove the chassis from the case or remove back cover. Check and/or replace the fuses in the oscillator power supply and the amplifier power supply.

c. Stirrer motor does not operate. Check stirrer motor wiring and stirrer switch.

d. Pump motor is not operating. Check all wiring to motor. Check pump switch. Check fuse on lower left front panel. Replace one, or all as necessary.

e. Other electronic maintenance. For other electronic trouble shooting and maintenance, refer to the instruction manual. *Do not attempt any repair of electronic printed circuit boards or modular components without the assistance of a competent electronics technician.*

I–25 Model 6220 Laboratory Salinometer.— The Model 6220 laboratory salinometer is shown in figure I–17. Generally, the preceding operating instructions apply to this instrument with the following exceptions:

Figure I–17. **Laboratory salinometer, Model 6220, Bissett-Berman Corp.**

1. The power switch (I) is on the upper right of the panel.
2. The Function Selector switch (K) is on salinity at all times except when depressed for a temperature reading.
3. The meter (G) on the model 6220 indicates temperature °C. when the function switch is depressed, eliminating the need for the Temperature °C. knobs (M). Temperature compensation is automatic, thus, eliminating the need for Temperature Compensation dials (Q).
4. The switch (N) is labeled Pump-Off-Stir instead of Stir-Off-Fill.
5. The Vacuum Control (F) and the Fill Control (E) on the 6220 serve the same functions as the Fill knob (F) and the Fill Control (E) on the instrument in figure I–12. The finger is placed over the Fill Control (E) on the 6220 to pump a sample.
6. The Stopcock (P) is glass instead of plastic.
7. The Overflow jar (O) is plastic rather than glass, and it can be emptied without removing it by opening a pinch clamp on the rubber drain tube.
8. The Standardizing Ratio Table (S) on the panel lists the conductivity ratios for the usual standards employed.

The instruction manual furnished by the manufacturer should be referred to if the instrument malfunctions.

CHAPTER J

DISSOLVED OXYGEN CONTENT DETERMINATION OF SEA WATER SAMPLES

J-1 General.—The concentration of dissolved oxygen in sea water may vary from supersaturation near the surface, where photosynthetic activity by the phytoplankton is very high, to no oxygen in stagnant basins or deep fjords. The values, therefore, may be anything from 0 to 10 milliliters or more per liter of sea water.

The analysis for dissolved oxygen in sea water is important for numerous reasons: It aids in the interpretation of biological processes taking place in the ocean. It is finding increased use in studies of oceanic currents and mixing processes. And it is sometimes used as an index for detecting malfunctional sampling equipment and erroneous values.

Oxygen samples are drawn for a specific analysis method: (1) The (Modified) Winkler (Macro) Method, (2) the Chesapeake Bay Institute technique for the Winkler Method, or (3) the Gas Chromatography Method.

J-2 Modified Winkler (Macro) Method.—The chemical reactions involved in the modified Winkler (Macro) Method are rather complex, and the complete reactions unknown; however, the analysis itself is not difficult to perform if the necessary precautions are taken in preparing the reagents, in cleaning the glassware, and in carrying out the treatment of the samples and the titrations.

The method requires that the sample be treated with an alkaline manganous solution while it is protected from oxygenation by air. A white precipitate of manganous hydroxide forms first.

$$Mn^{++} + 2OH^{-} \rightarrow Mn(OH)_2$$

This precipitate rapidly turns brown in the presence of dissolved oxygen as it reacts with the manganous hydroxide to form a tetravalent manganese compound.

$$2Mn(OH)_2 + O_2 \rightarrow 2MnO(OH)_2$$

When this solution is acidified to excess in the presence of an iodide, iodine is released quantitatively; i.e., free iodine (more correctly, triiodide ion) is liberated from the iodide which is equivalent to the amount of dissolved oxygen present in the sample:

$$MnO(OH)_2 + 4H^{+} + 3I^{-} \rightarrow Mn^{++} + I_3^{-} + 3H_2O$$

This free iodine (or triiodide ion) is titrated with a standardized solution of sodium thiosulfate:

$$I_3^{-} + 2S_2O_3^{--} \rightarrow 3I^{-} + S_4O_6^{--}$$

J-3 Chemicals Required.—The following chemicals are required for the (Macro) Winkler method:

- Manganous Chloride ($MnCl_2 \cdot 4H_2O$) (C.P., A.R.)
- Sodium Hydroxide ($NaOH$) (C.P., A.R.)
- Sodium Iodide (NaI) (C.P., A.R.)
- Sulfuric Acid (H_2SO_4) (C.P., A.R.)
- Starch soluble (purified)
- Sodium Thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) (C.P., A.R.)
- Potassium Biiodate ($KH(IO_3)_2$) or Potassium Iodate (KIO_3) (C.P., A.R.)
- Sodium Carbonate (Anhydrous) (Na_2CO_3) (C.P., A.R.)
- Chromerge cleaning solution

The various compounds required in this method must be free of oxidizing agents, and every effort must be taken to prevent contamination. All containers must be clean, rinsed in distilled water, and dried in an oven before use. Amber glass jars with a vinyl plastic cap are strongly recommended for the dry chemicals. Extreme care must be taken when handling chemicals, especially concentrated sulfuric acid and strong sodium hydroxide solution. These materials will cause severe burns and must be removed immediately from the skin and clothes with large quantities of water. Safety glasses or goggles must be worn during the preparation of the alkaline-iodide solution and chromic acid cleaning solution and also when cleaning glassware with cleaning solution.

J-4 Apparatus Required.—In addition to the apparatus previously listed in Chapter H, the following apparatus is required to carry out oxygen titrations by the Modified Winkler (Macro) Method:

- Bottle, amber glass*, S.T. stopper, capacity: 1,000 ml.
- Bottle, dropping, capacity: 125 ml.
- Bottle, polyethylene, screw cap, capacity: 500 and 1,000 ml.

*Heat resistant borosilicate glass is preferred.

Bottle, polyethylene, with tubulature.
Bottle, reagent storage, amber glass or black painted, capacity: 500 and 8,000 ml.
Burette, auto-zero, three-way stopcock, graduated in 0.05 ml. increments, capacity: 0–10 ml.
Pipette, automatic, A.B.A. type, capacity: up to 2 ml.
Pipette, automatic zero, acid type, capacity: 50 ml.
Pipette, volumetric, transfer type Class "A", capacity: 5 and 10 ml.

J–5 Setting up the Apparatus.—Figures J–1 and J–2 show schematic arrangements for the automatic 50-ml. pipette and the burette.

Step 1. Clamp the glassware to the support rods that are rigidly attached to the titration bench.

Step 2. Attach the filter pump, or aspirator, to the salt water tap and connect it to the pipette with rubber tubing. If a salt water tap is not available, a small electric vacuum pump of the portable laboratory type may be used in place of the aspirator.

Step 3. Attach the magnetic stirrer below the burette.

Step 4. Secure sea racks to the top of the table to hold three 500-ml. reagent bottles, the starch solution dropping bottle, the sample bottle, and several Erlenmeyer flasks.

Step 5. Above the sea racks, secure a rack to hold the various small pipettes.

Step 6. Rig a fluorescent titration lamp behind the burette.

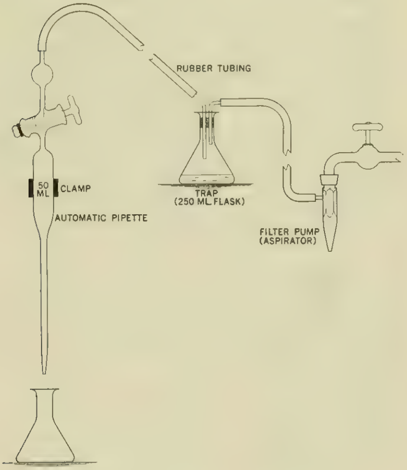

Figure J–1. Automatic pipette assembly.

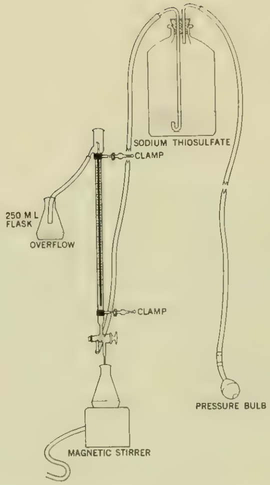

Figure J–2. Automatic self zeroing (0–10 ml.) burette assembly.

J–6 Preparing the Reagents.—Several days before oxygen samples are to be analyzed, the following reagents must be prepared for the (Macro) Winkler titration process: (1) Manganous reagent (2) Sodium Iodide-Sodium Hydroxide solution (3) Starch solution (4) Potassium Iodate (or Biiodate) solution (5) Sodium Thiosulfate solution and (6) 10N Sulfuric acid.

1. Manganous reagent.

Step 1. Dissolve 600 grams of $MnCl_2 \cdot 4H_2O$ in about 500 ml. of distilled water. An electric magnetic stirrer and heat will hasten solution of the salt.

Step 2. Dilute to one liter, and for convenience, split solution into two 500-ml. polyethylene bottles.

2. Sodium Iodide-Sodium Hydroxide solution.

Step 1. Pour 600 ml. of cold distilled water into a 1,000 ml. beaker, and place the beaker in a pan or sink of cold water.

Step 2. Put on safety goggles while preparing the solution.

Step 3. Slowly add 320 grams of NaOH pellets, stirring all the while until all pellets are dissolved. Cool to room temperature. This technique prevents overheating and boiling of the solution.

Step 4. Add 600 grams of NaI to the above beaker and stir until dissolved.

Step 5. Pour into a graduated cylinder, and dilute to 1 liter.

Step 6. Transfer the liter of NaOH–NaI solution to a beaker. Stir until well mixed.

Step 7. Split into two 500-ml. polyethylene bottles.

3. Starch solution.

Step 1. Make a suspension of 3 grams of soluble starch in a small amount of cold distilled water and stir into 300 ml. of boiling distilled water. Cover and boil vigorously for a few minutes.

Step 2. Allow the solution to cool. Pour off a portion of the supernatant liquid into a 125-ml. dropping bottle, and decant the remainder of the supernatant liquid into another dropping bottle and store in a refrigerator. Discard the residual portion.

4. Potassium Iodate or Potassium Biiodate Solution.—The solution can be prepared from 0.3567 grams of powdered KIO_3 (preweighed in laboratory ashore) or from Hellige concentrated $KH(IO_3)_2$ reagent. Since the validity of the titration results depends primarily on the accuracy of the preparation of the KIO_3 or $KH(IO_3)_2$ solution, two batches of the standard should be made, and one should be used as a check on the other. If powdered potassium salt is used, perform step 1; otherwise, proceed to step 2.

Step 1. Tap the vial lightly to shake the salt to the bottom of the vial, and remove the screwcap while holding the vial over a funnel which has been placed in a 1,000-ml., Class "A", volumetric flask; then, holding the cap over the funnel, wash the inside of the cap several times with distilled water. Next, pour the salt from the vial into the funnel, and wash down the inside of the vial and the screwcap threads on the outside of the vial at least five times to insure the quantitative transfer of all the salt. Finally, wash the funnel with distilled water at least five times, draining each washing into the flask; go to step 3.

Step 2. Dilute the Hellige concentrated $KH(IO_3)_2$ reagent solution, following the instructions supplied with the boxed ampoule. Care should be taken to quantitatively transfer all the solution into a 1,000-ml., Class "A", volumetric flask.

Step 3. Dilute the $KH(IO_3)_2$, or KIO_3, solution with distilled water to the 1,000-ml. mark on the volumetric flask. Seal the flask with a rubber stopper that has been cleaned with distilled water, and mix well by inverting and shaking several times.

Step 4. Pour the solution into a clean dry 1,000-ml. amber glass stoppered bottle.

5. Sodium Thiosulfate Solution.

Step 1. Boil 6 or 7 liters of distilled water for about 10 minutes to expel carbon dioxide.

Step 2. Dissolve 15.0 grams of $Na_2S_2O_3 \cdot 5H_2O$ in 6 liters of the boiled water.

Step 3. Add 6 grams of Na_2CO_3 to stabilize the solution.

Step 4. Store the solution in an amber glass bottle or black bottle out of contact with air or direct sunlight. Allow the solution to age for several days before using.

6. 10N Sulfuric Acid.—Safety goggles must be worn when diluting H_2SO_4.

Step 1. Pour 600 ml. of cold distilled water into a 1-liter glass beaker, which has been placed in a pan of cold water.

Step 2. While stirring the distilled water, *slowly* add 280 ml. of concentrated H_2SO_4.

Step 3. Allow solution to cool to room temperature.

Step 4. Pour into a 1,000-ml. graduated cylinder, and dilute to 1 liter with distilled water.

Step 5. Transfer the liter of H_2SO_4 solution into a beaker. Stir until well mixed.

Step 6. Split the solution into two 500-ml. polyethylene bottles.

The above quantities of the reagents are enough for titrating approximately 240 samples by the (Macro) Winkler method.

J–7 Treating (Macro) Winkler Oxygen Samples.—As soon as the oxygen samples are drawn (instructions for drawing oxygen samples are given in ch. E, Taking an Oceanographic Station), they should be taken to the ship's chemical laboratory and treated immediately.

Step 1. Remove the glass stopper from the amber sample bottle, and add 2 ml. of $MnCl_2$ reagent and 2 ml. of NaOH-NaI solution. Introduce the solutions ¼ inch below the surface of the liquid. A precipitate will form and sink rapidly to the bottom of the bottle.

Step 2. Stopper the bottle in such a manner that no air bubbles are trapped in the bottle; then, shake bottle thoroughly to mix the precipitate.

Step 3. Repeat steps 1 and 2 with other oxygen samples. After approximately 5 minutes, reshake the sample to mix the precipitate thoroughly.

Step 4. Allow the precipitate to settle about halfway down the bottle; then, remove glass stopper from bottle, add 2 ml. of 10N H_2SO_4, restopper bottle, and shake thoroughly until all precipitate is dissolved. The introduction of the acid may cause bubble formation from the liberation of CO_2 and N_2; this is of no concern, however, as an aliquot of 100 or 50 ml. of the sample is analyzed.

The sample is now ready for titration.

J–8 Analysis of Oxygen Samples by (Macro) Winkler Technique.—Analysis of oxygen samples includes the following processes: (1) Blank Run, (2) Standardization, (3) Titration of the Oxygen Sample, (4) Calculation of dissolved oxygen. These processes are recorded on Oceanographic Log Sheet-C (fig. J–3). The vessel, cruise, consec. station number, and serial number are obtained from the A–Sheet.

OCEANOGRAPHIC LOG SHEET - C
NAVOCEANO-EXP-3167/3 (REV. 6-67)

U.S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D.C. 20390

(MACRO) WINKLER DISSOLVED OXYGEN DETERMINATION
For use with Pub. No. 607

VESSEL	CRUISE	CONSEC. STATION NO.	CHEMIST	DATE ANALYZED	CHECKED BY
USS Edisto	Arctic '65	48	HAWES	17 Sept. '65	J.A.S.

SERIAL NUMBER	SAMPLE BOTTLE NUMBER	1ST BURETTE READING ml.	2ND BURETTE READING ml.	3RD BURETTE READING ml.	AVERAGE BURETTE READING ml.	V_b	CORRECTED BURETTE READING V	DISSOLVED OXYGEN O_2 ml./L	REMARKS
818	1	6.99	6.97		6.98	0	6.98	8.22	
819	2	7.06	7.06		7.06		7.06	8.31	
820	3	6.90	6.92		6.91		6.91	8.14	
821	4	~~6.87~~	6.91	6.91	6.91		6.91	8.14	
822	5	6.82	6.84		6.83		6.83	8.05	
823	6	6.70	6.71		6.70		6.70	7.89	
824	7	6.27	6.27		6.27		6.27	7.39	
825	8	6.06	6.04		6.05		6.05	7.13	
826	9	5.87	5.87		5.87		5.87	6.91	
827	10	5.84	5.84		5.84		5.84	6.88	
828	11	5.54	5.52		5.53		5.53	6.51	

NORMALITY DETERMINATION

BLANK RUN

V_b (1st Run) = –0–
$-V_b$ (2nd Run) = –0–
V_b = –0–

STANDARDIZATION OF $Na_2S_2O_3$

V_2 (1st Run) = 9.65
V_2 (2nd Run) = 9.66
V_2 (3rd Run) = 9.66
TOTAL = 28.97

V_2 (Average) = 9.66

50 ml. SAMPLE

$$K = \frac{11.380}{V_2 - V_b} = 1.178$$

CHECK VOLUME OF SAMPLES TITRATED

☐ 100 ml. ☒ 50 ml.

100 ml. SAMPLE

$$K = \frac{5.690}{V_2 - V_b} =$$

$O_2 = KV$

Figure J–3. Oceanographic Log Sheet–C.

1. Blank Run.—The blank run is made to determine the correction to apply for the amount of I_2-liberating oxidizing substances or reductants present as impurities in the reagents. A blank run should be made after the reagents are prepared to determine that they are satisfactory, and that the titration equipment is functioning properly. In addition, blank runs are made before each series (maximum of 24) of oxygen samples is analyzed. To make the blank run perform the following steps:

Step 1. With the automatic burette assembled and supplied with sodium thiosulfate solution (See fig. J–2), place a clean, 1-inch, teflon-covered magnetic bar in a clean 125-ml. Erlenmeyer flask.

Step 2. Pipette 5.0 ml. of potassium iodate (or biiodate) solution into the flask; then, add 90.0 ml. of distilled water.

Step 3. Add 2.0 ml. of 10N H_2SO_4 and 2.0 ml. of NaOH–NaI solution.

Step 4. Mix solution with the magnetic stirrer for 1 minute; then add 2.0 ml. of $MnCl_2$ reagent and 1.0 ml. of starch solution. This will cause the solution to turn blue.

Step 5. Zero the burette by turning the three-way stopcock and filling until burette overflows; then, place flask under the delivery tip, open three-way stopcock and titrate until the instant the solution becomes colorless. As the endpoint is approached, reduce delivery to drop by drop, then half drops until colorless end point is reached.

Step 6. Read the burette to a hundredth of a ml., and record the value in V_b (*1st Run*) space on the log sheet. Refer to chapter I, paragraph I–12, for burette reading instruction.

Step 7. Pipette 5.0 ml. of the potassium solution into the same flask. Repeat steps 5 and 6. Record burette reading in V_b (*2d Run*) space. V_b's must agree within ±.10 ml.

If impurities are present in excess of the above limits, new reagents must be prepared.

Step 8. Calculate V_b by subtracting V_b (2d Run) from V_b (1st Run). If V_b is positive, the blank is oxidizing; if negative, reducing.

2. Standardization.—Standardization is the process of determining the slight changes that occur in the $Na_2S_2O_3$ solution. Standardization should be performed before each series (maximum of 24) of samples is analyzed. After the blank run, standardize according to the following directions:

Step 1. Place a clean, 1-inch teflon-covered magnetic stirring bar in a clean 125-ml. Erlenmeyer flask.

Step 2. Pipette 10.0 ml. of the potassium solution into the flask, and add 90.0 ml. of distilled water.

Step 3. Add 2.0 ml. of 10N H_2SO_4 and 2.0 ml. of the NaOH−NaI reagent, and mix.

Step 4. Place the flask under the delivery tip of the burette, and titrate solution with $Na_2S_2O_3$ until the (liberated I_2) deep yellow color turns to a pale straw yellow.

Step 5. Add 1.0 ml. of starch solution. This will cause the solution to turn blue. Continue to add $Na_2S_2O_3$ until the blue color disappears and the solution is just colorless.

Step 6. Read the burette and record the value in V_2 (*1st Run*) space on the log sheet.

Step 7. Repeat steps 1 through 6 two times, and record burette readings in V_2 (*2d Run*) and V_2 (*3d Run*) spaces on the log sheet. Acceptable values must agree with ±0.03 ml. Calculate average V_2.

3. Titration of the Oxygen Sample.—Oxygen samples should be titrated within 4 hours of the time they are treated. Always follow the same techniques for every sample.

Step 1. Fill the self-zeroing burette by turning the three-way stopcock of the burette to open until the sodium thiosulfate solution flows out the small spout into the overflow flask. Turn the stopcock to off. Arrange samples to be analyzed in order of descending depth.

Step 2. Record the sample bottle numbers in the *Sample Bottle Number* column of the log sheet. Check the A-Sheet to match serial number and sample bottle number.

Step 3. Place a 1-inch, teflon-covered, magnetic stirring bar in a 125-ml. Erlenmeyer flask. The bar and flask should be rinsed one time with distilled water between samples.

Step 4. Turn on salt water tap to activate filter pump aspirator. Adjust the vacuum to get gentle aspiration (fig. J–1).

Step 5. Shake the sample bottle vigorously. Remove the glass stopper from the bottle. Place the tip of the automatic pipette near the bottom of the bottle. Turn the pipette stopcock to the fill position, and slowly draw 15 to 25 ml. of sample. Withdraw the sample bottle; rinse the pipette and drain. Rinse the pipette once or twice, depending on the volume of sample to be analyzed. Since the sample bottle for the (Macro) Winkler method contains 250 ml. of sample, it is recommended that a 50 ml. volume sample be analyzed; however, in some areas where the dissolved oxygen content of sea water is extremely low, it may be necessary to analyze a 100-ml. volume sample.

Step 6. Again place the tip of the pipette near the bottom of the sample bottle. Turn the stopcock to the fill position, and slowly fill the pipette, turn the stopcock to off position, remove the sample bottle, and replace the stopper; then, wipe the pipette tip with a lab tissue.

Step 7. Hold the flask (from step 3) beneath the pipette tip and with a minimum of splashing, drain the contents of the pipette into the flask. After the pipette is drained, slowly withdraw the pipette stem from the water to obtain the last drop of sample from the pipette. Follow the same technique for each sample.

Step 8. Place the flask under the delivery tip of the burette. Start the magnetic stirrer and stir constantly without splashing. Open the burette stopcock and add sodium thiosulfate solution until the dark yellow color of the sample becomes a pale straw yellow.

Step 9. Add 1 ml. of starch solution. This will produce a deep blue color. Continue to add the sodium thiosulfate drop by drop until the solution becomes colorless.

Step 10. The instant the sample becomes colorless, close the stopcock, and immediately read the burette to the nearest hundredth of a ml. Record this value in *1st Burette Reading ml.* column.

Step 11. Drain the flask well, and rinse with distilled water. Repeat steps 6 through 10. Record the burette reading in *2nd Burette Reading ml.* column. The first and second burette readings must be within $\pm$ 0.03 ml.; otherwise, run a third sample.

4. Calculation of Dissolved Oxygen.—After the samples are titrated, calculations for dissolved oxygen are performed as follows:

Step 1. Compute the average burette reading for each sample and algebraically add the V_b (average) to compute the corrected burette reading.

Step 2. Compute the dissolved oxygen O_2 ml/L for each sample by the formula:

$$O_2 \text{ ml/L} = K \cdot V$$

where V = Corrected burette reading and $K = 11.380/(V_2 - V_b)$ for a 50 ml. sample or $K = 5.690/(V_2 - V_b)$ for a 100-ml. sample. This formula is derived from the equation:

$$O_2 \text{ in ml/L} = V \times \frac{B}{B-4} \times 5.598 \times \frac{1000}{V_s} \times \frac{.01}{V_2 - V_b}$$

where B = volume of water in oxygen sample bottle in ml., i.e., 250 ml., B – 4 = volume of water in sample bottle after treating sample with 2 ml. of $MnCl_2$ and 2 ml. of NaOH-NaI, 5.598 = a constant representing the ml. of oxygen equivalent to 1.0 ml. of normal sodium thiosulfate solution, and V_s = volume of pipetted sample.

Step 3. After the chemist has entered his name in the appropriate block of the log sheet, another member of the survey party should check each computation. File the C–Sheet in the oceanographic station folder with the A–Sheet.

J–9 Securing the Apparatus After Completing the Titrations.—After the samples of a station have been titrated, or a day's work has been finished, the apparatus must be secured. The pipette and the burette will stay clean longer if they are kept filled when not in use.

Rinse and fill the pipette with distilled water. Fill the burette with sodium thiosulfate solution and check to see that there are no air bubbles. Apply a pinch clamp to the tubing from the sodium thiosulfate solution bottle.

Clean the table, and wash and dry all beakers, flasks, magnetic stirring bars, and other glassware.

J–10 The Chesapeake Bay Institute Technique for the Winkler Method.—A modified technique for the Winkler determination of dissolved O_2 has been developed by Dr. James H. Carpenter of the Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Md. This technique is described in the January 1965 issue of Limnology and Oceanography, vol. 10. no. 1.

This (Micro) Winkler technique, as it will be referred to in the remainder of this chapter, has been adopted by the U.S. Naval Oceanographic Office because it is a fast, precise, accurate, and convenient method of determining dissolved oxygen content of sea water samples. The chemical reactions involved are the same as those described in paragraph J-2, Modified Winkler (Macro) Method.

Replicate samples are collected from each Nansen bottle in 125-ml. glass stoppered Erlenmeyer flasks that have been calibrated "to contain" by weighing. (These flasks vary in volume from 130 to 145 ml., enough to cause considerable error if volume is not calculated; therefore, sample flasks to be used are calibrated by the weighing of distilled water content of each and multiplying the weight of H_2O by the specific volume of distilled H_2O at weighing temperature.)

The entire sample is titrated, and the amount of $Na_2S_2O_3 \cdot 5H_2O$ required is indicated on a burette digital readout to the nearest 0.0001 ml. By titrating the entire sample, the transfer of I_2 solution by either pouring or pipetting is avoided; thus, no loss of I_2 occurs.

A higher normality $Na_2S_2O_3 \cdot 5H_2O$ is used, and less than 1 ml. of solution is required for each titration; therefore, 0.2 liters of solution will titrate 240 samples while approximately 3 liters of $Na_2S_2O_3 \cdot 5H_2O$ are required for the (Macro) Winkler method.

J–11 Chemicals Required.—The chemicals required for the (Micro) Winkler method are the same as those required for the (Macro) method (see para. J–3).

J–12 Apparatus Required.—In addition to the apparatus previously listed in chapter H, the following apparatus is required to carry out titration by the (Micro) Winkler method:

- Bottle, amber glass*, S.T. stopper, capacity: 1,000 ml.
- Bottle, dropping, capacity: 125 ml.
- Bottle, polyethylene, screw cap, capacity: 500 and 1,000 ml.
- Flask, Erlenmeyer, glass*, S.T. 19/38 solid glass stoppered, capacity: 125 ml. (calibrated to contain)
- Micro Burette with glassware.
- Pipette, automatic, A.B.A.-type, capacity: up to 2 ml.
- Pipette, volumetric, transfer type Class "A", capacity: 1 and 10 ml.

*Heat resistant borosilicate glass is preferred.

J–13 Setting up the Apparatus.—Figure J–4 shows the (Micro) Winkler apparatus set up in the laboratory. Shown are the reagents, the rapid delivery pipettes, a magnetic stirrer, a fluorescent light case, and the microburette with the burette digital readout counter.

The details of the microburette and the digital counter are shown in figure J–5. To zero the counter and operate the microburette, perform the following steps:

Step 1. With the three-way stopcock in the FILL position (Arm B toward the reservoir; arm A toward the digital counter) and with glass stopper in the reservoir turned to open the vent, carefully rotate the delivery crank in a counterclockwise direction until the piston is flush with the glass-metal point between the burette and the counter. Do not draw the piston inside the digital counter assembly. Always make certain the three-way stopcock is in the fill position when the delivery gear is being turned in a counterclockwise direction; otherwise, bubbles will form in the burette.

Step 2. Press the ZERO SET button on the digital counter assembly to clear the counter and set it at zero.

Step 3. To deliver the solution from the microburette, which is titrating, place the delivery tip ¼ inch below the surface of the solution receiving delivery, turn the three-way stopcock to delivery position (B toward counter; A toward delivery tip) and rotate the delivery gear in a clockwise direction. This will move the piston to the left and the digital counter will record the amount of solution forced from the burette to the nearest 0.0001 ml. In order to avoid damaging the microburette, do not deliver more than 0.8 ml. Do not turn the delivery gear in a counterclockwise direction while delivery tube is in a solution and three-way stopcock is in DELIVERY position, as this will contaminate the solution in the burette.

While the apparatus arrangement shown in figure J–4 is usable in the laboratory, the titration box designed by Dr. J. H. Carpenter (fig. J–6) is highly recommended for shipboard oxygen analysis.

The titration box is approximately 12 inches wide, 24 inches high and 14 inches deep, and the interior is painted with a high quality white paint. The shielded eight-watt fluorescent lamps attached to the inside of the box provide the brilliant lighting required for best end point titration results. The counter assembly extends through an opening in the right side of the box, and the microburette glass components are connected to the counter assembly by a standard

223-812 O - 68 - 8

Figure J–4. (Micro) Winkler apparatus.

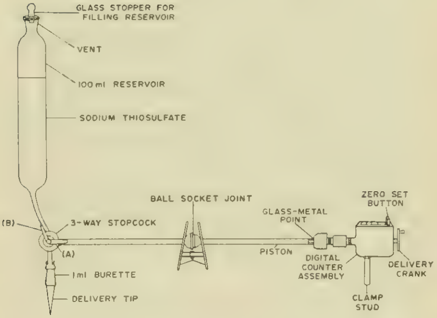

Figure J–5. Details of the microburette and the digital counter.

tapered ground glass ball and socket joint. The microburette is held in the proper position inside the box by clamps, and the magnetic stirrer is installed to swing out so the sample flask can be positioned beneath the delivery tube of the microburette.

All equipment should be clamped or attached rigidly to the titration bench, and sea racks should be secured to the top of the table to hold reagent bottles and sample flasks.

J–14 Preparing the Reagents.—Reagents required for the (Micro) Winkler titration process are the same as those required for the (Macro) Winkler titration method with the exception of the sodium thiosulfate solution. Prepare the Manganous reagent, the Sodium Iodide-Sodium Hydroxide solution, the Starch solution, the Potassium Iodate (or biiodate) solution, and the 10N Sulfuric acid by instructions listed in paragraph J–6, Preparing the Reagents. The Sodium Thiosulfate solution for the (Micro) Winkler titration method usually will be prepared in 70 grams per liter concentration; however, in areas where the dissolved oxygen content of the sample is more than 10 ml./L, a stronger concentration should be used. To prepare the solution proceed as follows:

Step 1. Boil 1½ liters of distilled water for about 10 minutes to expel carbon dioxide.

Step 2. Dissolve the $Na_2S_2O_3 \cdot 5H_2O$ in about

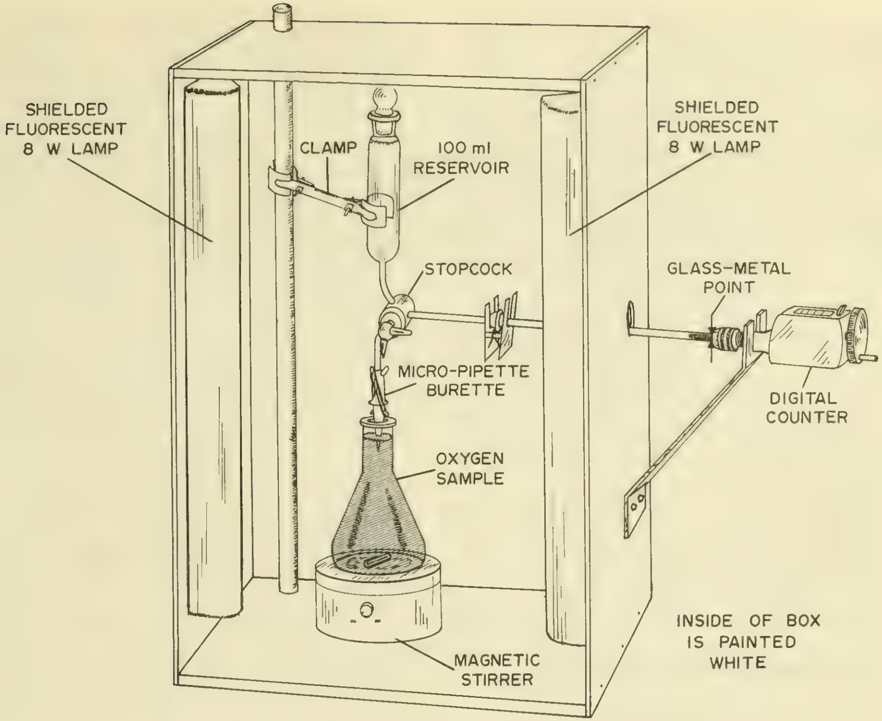

Figure J–6. Titration box (Micro) Winkler method (after J. H. Carpenter).

900 ml. of the boiled water, contained in a 1,000 ml. volumetric flask.

Step 3. Add 1 gram of sodium carbonate, and dilute to 1.000 ml. with the boiled water.

Step 4. Store the solution in a 1,000 ml. polyethylene bottle. Label bottle, indicating concentration.

J–15 Treating Oxygen Samples.—As soon as the O_2 samples are drawn (instructions for drawing O_2 samples are given in chapter F, Taking an Oceanographic Station), they should be taken to the ship's laboratory and treated immediately. *NOTE:* Two separate O_2 samples should be drawn from each Nansen bottle for the (Micro) Winkler titration method, and the sample flask numbers etched on the flask should be used as the sample bottle numbers on the A sheet. To treat the sample, perform the following steps:

Step 1. Remove the glass stopper from the sample flask, and with a rapid delivery pipette ¼ inch below the surface of the liquid, add 1 ml. of manganous solution.

Step 2. Add 1 ml. of NaOH–NaI solution in the same manner as step 1.

Step 3. Seat the stopper securely without trapping bubbles, and shake thoroughly to mix the precipitate.

Step 4. Repeat steps 1, 2, and 3 with other oxygen samples; then, after approximately 5 minutes, reshake each sample again to mix the precipitate thoroughly.

Step 5. When the precipitate has settled approximately two-thirds of the way to the bottom of the sample flask, add 1.0 ml. of ioN H_2SO_4, restopper the flask, and shake thoroughly until all precipitate is dissolved. The introduction of the acid may cause the liberation of CO_2 and N_2; however, this does not affect the titration results.

Samples are now ready to be titrated, and they should be titrated within a 4-hour period.

J-16 Analysis of Oxygen Samples.—Analysis of O_2 samples includes the following processes: (1) Blank Run, (2) Standardization, (3) Titration of the O_2 samples, and (4) Calculation of dissolved oxygen. These processes are recorded on Oceanographic Log Sheet–CCC (fig. J–7). The vessel, cruise, consec. station number, and serial number are obtained from the A–Sheet.

(1) Blank Run.—The blank run is made to determine the correction to apply for the amount of I_2-liberating oxidizing substances or reductants present as impurities in the reagents. A blank run should be made after the reagents are prepared to determine that they are satisfactory, and that the titration equipment is functioning properly. In addition, blank runs are made before each series (maximum of 24) of O_2 samples is analyzed. To make the blank run, perform the following steps:

Step 1. Place a 1-inch, teflon-covered magnetic stirring bar in a clean 125-ml. glass stoppered Erlenmeyer flask that has been calibrated "to contain" by weighing.

Step. 2. Pipette 1 ml. or KIO_3 or $KH(IO_3)_2$ into the flask; then, fill the flask with distilled water to the ground glass neck.

Step 3. Add 1.0 ml. of 10N H_2SO_4 and 1.0 ml. of NaOH–NaI.

Step 4. Mix with the magnetic stirrer for 1 minute, and then add 1.0 ml. of manganous reagent and 1.0 ml. of starch solution. Blue color will appear. Zero the digital counter.

Step 5. Place the flask under the delivery tip of the burette (¼ inch below surface of solution), and titrate until the instant the solution becomes colorless. As the end point is approached, turn the delivery crank very slowly, but never reverse the direction of rotation while the stopcock is in DELIVERY position as this will contaminate the reagent in the burette.

Step 6. Read the digital counter, and record the value in V_b (*1st Run*) space on the log sheet.

Step 7. Pipette 1.0 ml. of KIO_3 or $KH(IO_3)_2$ into the same sample flask; rezero the digital counter; wait 1 minute and then repeat steps 5 and 6. Record the digital counter reading in V_b (*2d Run*) space. V_b's must agree within ± .0010 ml.

Step 8. Calculate V_b by subtracting V_b (2d Run) from V_b (1st Run). If V_b is positive, the blank is oxidizing; if negative, reducing.

(2) Standardization.—Standardization is the process of determining the slight changes that occur in the $Na_2S_2O_3$ solution during O_2 analysis. Standardization should be performed before each series (maximum of 24 samples) is analyzed.

Step 1. Place a 1-inch, teflon-covered magnetic stirring bar in a clean 125-ml. glass stoppered Erlenmeyer flask that has been calibrated "to contain" by weighing.

Step 2. Pipette 10 ml. of KIO_3 or $KH(IO_3)_2$ into the flask, and fill the flask with distilled water to the ground glass neck.

Step 3. Add 1.0 ml. of the H_2SO_4 and 1.0 ml. of the NaOH–NaI reagent, and mix for 1 minute.

Step 4. Titrate the liberated I_2 in the same way as for the sample. Place the flask under the delivery tip of the burette (¼ inch below surface of solution), and titrate solution with $Na_2S_2O_3$ until the deep yellow color turns to pale straw yellow.

Step 5. Add 1 ml. of starch solution. This will cause the solution to turn blue. Add $Na_2S_2O_3$ until the blue color disappears and the solution is just colorless.

Step 6. Read the digital counter and record the value in V_2 (*1st Run*) space on the log sheet.

Step 7. Repeat steps 1 through 6 two times, and record the digital counter reading in V_2 (*2d run*) and V_2 (*3d Run*) spaces on the log sheet. Acceptable values must agree within ± .0005.

Step 8. Calculate average V_2. In *Sodium Thiosulfate Concentration* block, indicate concentration of solution used.

(3) Titration of the Oxygen Samples.—O_2 samples should be titrated within 4 hours of the time they are treated. Always follow the same techniques for every sample.

Step 1. Fill burette, return piston to glass metal point, and zero the counter.

Step 2. Record the sample flask number in the appropriate space on the log sheet. The sample number is etched on the flask and stopper. Enter the volume of the flask in the *V (ml.) Flask Weighed "To contain"* column. Flasks are weighed at a shore facility before the survey operation.

Step 3. Shake the sample flask vigorously.

Step 4. Remove the glass stopper from the sample flask and place a 1–inch, teflon-covered, magnetic stirring bar in flask.

Step 5. Place the sample flask under the burette with the delivery tip ¼ inch below the surface of the sample solution, and turn on the magnetic stirrer.

Step 6. Add $Na_2S_2O_3$ to the sample by rotating the delivery crank in a clockwise direction until the dark yellow color of the sample becomes a pale straw yellow.

Step 7. Add 1 ml. of starch solution. This will produce a deep blue color. Continue to add $Na_2S_2O_3$ slowly until the instant the solution becomes colorless. As the end point is approached, turn the delivery gear very slowly, but never reverse the direction of rotation of the gear while the stopcock is in DELIVERY position as this will contaminate the reagent in the burette.

Step 8. The instant the sample becomes colorless, stop the delivery crank and read the digital

OCEANOGRAPHIC LOG SHEET – CCC
NAVOCEANO-EXP-3167/86 (2-67)

U.S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

(MICRO) WINKLER DISSOLVED OXYGEN DETERMINATION
For use with Pub. No. 607

VESSEL: BURTON ISLAND | CRUISE: ARCTIC '66 | CONSEC. STATION NO.: 1 | CHEMIST: m. T. B. | DATE ANALYZED: 20 Aug. 66 | CHECKED BY: CAR

SERIAL NUMBER	SAMPLE BOTTLE NUMBER	V_s (ml) FLASK WEIGHED "To contain"	V (ml) DIGITAL COUNTER READING	$V - V_b$	$V_2 - V_b$	$\frac{V - V_b}{V_2 - V_b}$	K FACTOR	$K \times \frac{V - V_b}{V_2 - V_b}$	O_x	DISSOLVED OXYGEN O_2 ml/L	AVERAGE DISSOLVED OXYGEN O_2 ml/L
1	5	142.21	.8994	.8996	.3681	2.444	3.993	9.759	−.018	9.741	9.744
	13	142.07	.8992	.8994		2.443	3.997	9.765		9.747	
2	8	141.54	.9028	.9030		2.453	4.012	9.841		9.823	9.834
	9	141.47	.9044	.9046		2.457	4.014	9.862		9.844	
3	3	141.17	.9100	.9102		2.473	4.022	9.946		9.928	9.924
	4	141.19	.9092	.9094		2.471	4.022	9.938		9.920	
4	2	136.65	.8918	.8920		2.423	4.158	10.075		10.057	10.06
	32	136.42	.8825	.8827		2.398	4.165	9.988		9.970	X
5	28	135.77	.9482	.9484		2.576	4.185	10.781		10.763	10.768
	37	135.45	.9465	.9467		2.572	4.195	10.790		10.772	
6	23	135.45	.9056	.9058		2.461	4.195	10.324		10.306	10.310
	20	135.29	.9052	.9054		2.460	4.200	10.332		10.314	
7	24	134.97	.7772	.7774		2.112	4.210	8.892		8.874	X
	21	134.78	.7850	.7852		2.133	4.216	8.993		8.975	8.98
8	42	134.53	.6019	.6021		1.636	4.224	6.910		6.892	6.880
	33	134.44	.5994	.5996		1.629	4.227	6.886		6.868	
9	25	134.31	.5975	.5977		1.624	4.231	6.871		6.853	6.842
	39	134.18	.5951	.5953	↓	1.617	4.235	6.848	↓	6.830	

SODIUM THIOSULFATE CONCENTRATION 70 g/L

BLANK RUN
V_b (1st RUN) = .0368
$-V_b$ (2nd RUN) = .0370

V_b = −.0002

STANDARDIZATION OF $Na_2S_2O_3$
V_2 (1st RUN) = .3680
V_2 (2nd RUN) = .3680
V_2 (3rd RUN) = .3678
TOTAL = 1.1038

V_2 (AVERAGE) = .3679

$$O_2 = \frac{(V-V_b)\ V_3 \cdot N \cdot E}{(V_2-V_b)\ (V_s-2)} - OX$$

V_3 = VOLUME OF KIO_3 STANDARD ml

N = NORMALITY OF KIO_3 STANDARD EQUIV/L

E = 5,598 ml O_2/EQUIV

2 = VOLUME OF SAMPLE DISPLACED BY REAGENT (ml)

$O_x = O_2$ ADDED WITH REAGENTS = .018

$$K = \frac{V_3 \cdot N \cdot E}{(V_s - 2)}$$

$$O_2 = \frac{(V - V_b)\ 559.8}{(V_2 \cdot V_b)\ (V_s - 2)} - 0.018$$

Figure J–7. Oceanographic Log Sheet–CCC.

counter and record the reading in the V (ml.) *Digital Counter Reading* column of the CCC-Sheet.

The proper technique for the analyst to follow is to keep the eyes on the sample and not on the digital counter because the end point (colorless solution) is the important step in the determination. Never reverse the rotation direction of the delivery crank while the stopcock is in DELIVERY position. Always wipe the delivery tip with a laboratory tissue between titrations.

(4) Calculations of Dissolved Oxygen.—After the samples are titrated, calculations for dissolved O_2 are performed as follows:

Step 1. Compute $V-V_b$, V_2-V_b, and $V-V_b/V_2-V_b$; enter these values in the appropriate columns of the log sheet.

Table J-1. K Factor for (Micro) Winkler dissolved oxygen calculations

V_s (ml.) flask weighed "to contain"	K Factor $K=\frac{V_3 \cdot N \cdot E}{(V_s-2)}$
131.00	4.340
132.00	4.306
133.00	4.273
134.00	4.241
135.00	4.209
136.00	4.178
137.00	4.147
138.00	4.116
139.00	4.086
140.00	4.057
141.00	4.027
142.00	3.999
143.00	3.970
144.00	3.942
145.00	3.915

V_3=Volume of KIO_3 or $KH(IO_3)_2$ standard in ml. (10 ml.)

N=Normality of KIO_3 or $KH(IO_3)_2$ standard (equivalent/liter) (.01N).

E =5,598 ml. $O_2/Na_2S_2O_3 \cdot 5H_2O$ equivalent.

2 =Volume of sample displaced by reagents when sample was treated (ml.)

Step 2. From table J-1, K Factor for (Micro) Winkler dissolved O_2 oxygen calculations, determine the K Factor for the V_s, Flask Weighed "to contain," and enter the value in the K Factor column of the log sheet.

Step 3. Calculate the dissolved O_2 for each sample, using the following formula:

$$O_2=\frac{(V-V_b)}{(V_2-V_b)}K-O_x$$

Where O_x=0.018 ml. of O_2 added to the sample with reagents when sample was treated.

Step 4. Enter the calculated dissolved O_2 in the *Dissolved Oxygen O_2 ml/L* column of the log sheet.

Step 5. Calculate the average dissolved oxygen of the two samples for each serial number, and enter the value in the *Average Dissolved Oxygen O_2 ml/L* column. If the analysis results for the replicate samples differ by more than ±.01 ml./L, place a question mark in the average column and determine the accepted value after comparing all sample results. After the oxygen calculations are performed, they should be checked by another person. File the CCC-Sheet in the Oceanographic Station Folder along with the A-Sheet and other data sheets for the oceanographic station.

J-17 Securing the Apparatus After Completing a Series of Titrations.—After a series of samples have been titrated, or a day's work has been finished, the apparatus must be secured. Turn the stopcock to the fill position, and turn the glass stopper in the reservoir to close the vent. The microburette will remain clean longer if it is kept filled when not in use.

After the survey is completed, drain the solution from the burette and flush with distilled water. *Never use the cleaning solution to clean the burette.* Disassemble the burette at the ball socket joint to remove it from the titration box. Store the digital counter assembly in its case, and pack the reservoir, stopcock, microburette glass component in a well-padded storage case.

If it is necessary to disassemble the digital counter assembly, remove the coupling nut at the glass-metal point. When assembling lubricate the piston, gasket, and "O" rings with a thin coat of silicone grease.

J–18 Gas Chromatography Oxygen Analysis.—Gas chromatography has been used as a means of analyzing gas mixtures for several years; however, application of the technique to dissolved gases in sea water evolved from procedures developed by Swinnerton, Linnenbom, and Cheek of the U.S. Naval Research Laboratory, while studing gases formed in irradiated solutions.

The application of gas chromatography to determining the O_2 (and N_2) content of a sea water sample, in effect, is a measurement of the difference between the thermal conductivity of pure He gas and the gas mixture obtained by bubbling He gas through a sea water sample.

Gas chromatography sea water sample analysis has several advantages. It is less time consuming than titration methods, and the instrumentation is relatively simple to operate and maintain, yet no loss is experienced in either precision or accuracy. In addition, the dissolved N_2 content of the sample is obtained at the same time.

J–19 Theory of Gas Chromatography.—In carrying out the quantitative analysis of a sea water sample for dissolved O_2 (and N_2) by gas chromatography, an inert gas, He, is used to carry the gas mixture through a chromatographic column. This column is filled with finely divided powder of a proper type having relatively large surface areas. Molecules of different gases travel through the column at different speeds. Therefore, since each component of a gas mixture remains in the column for a different period of time, it is possible, by a suitable choice of column dimension and type, to separate these components for measurement.

The gas partitioner is used to measure the amount of each gas component of the gas mixture. It contains temperature sensitive devices that detect slight changes in the thermal conductivity and thermal capacity of the gas stream; these changes result in an imbalance of an electrical bridge circuit, and this voltage change is recorded on a strip chart recorder with an integrator.

J–20 Setting Up the Gas Chromatographic Equipment.—The gas chromatographic sea water analysis equipment used by the U.S. Naval Oceanographic Office includes three major components: An all glass sample chamber with automatic sampling valves, a gas partitioner (either a modified Fisher Gas Partitioner Model 25 or a Fisher-Hamilton Gas Partitioner Model 29), and a Texas Instrument, Model PWSN, one millivolt Strip Chart Recorder with an integrator. In addition, a tank of technical Grade A helium, a tank of air, a flow meter, and spare drying tubes and gas partitioner columns are required for gas chromatographic sea water sample analysis. Figure J–8 shows the modified Fisher Gas Partitioner, and figure J–9 shows the Fisher-Hamilton Gas Partitioner. The main difference between the two systems is the arrangement of the four-way valve and the automatic sampling valve. The Fisher Gas Partitioner has been modified with the four-way valve and the automatic sampling valve installed on the partitioner. The Fisher-Hamilton equipment has these valves mounted on a separate cabinet.

The equipment should be set up and checked out prior to taking an oceanographic station in order for O_2 samples to be analyzed immediately after they are drawn. O_2 samples for gas chromatography analysis must be drawn in special sample bottles (see chs. D and F for a description of the sample bottle and drawing the O_2 sample).

Two 6-inch adjustable wrenches and a medium-size screwdriver are the only tools required. All tube fittings are brass Swagelok connections except where other fittings are indicated. Procedures for setting up the instrumentation follow:

1. Gas chromatographic equipment with Fisher Gas Partitioner (Modified) (fig. J–10).

Step 1. Remove the cover from the partitioner, and disconnect the Drierite tube (A) from the left connection (facing panel) of the four-way valve. Bring the free end of the Drierite tube (A) out through the slot in the left side of the partitioner cabinet.

Step 2. Connect a 2-foot long x ¼-inch O.D. polypropylene tube (B) to the left connection of the four-way valve. Bring the free end of tube (B) out through the hole in the front panel.

Step 3. Replace the partitioner cover, and mount the automatic sampling valve assembly on the partitioner cover with ¾-inch brass round head wood screws.

Step 4. Connect tube (B) to the automatic sampling valve.

Step 5. Extend tube (A) with 2-foot long x ¼-inch O.D. polypropylene drying tube (C) and connect the end to the top side arm of the sample chamber, using a nylon fitting.

Step 6. Connect the bottom of the glass chamber to the sampling valve (this fitting must be nylon at the glass chamber, and a Perkin-Elmer fitting at the valve).

2. Gas chromatographic equipment with Fisher-Hamilton Gas Partitioner (fig. J–11).

Step 1. Connect a 2-foot long x ¼-inch Drierite filled drying tube (A) to the rear connection on the left side (facing panel) of the valve cabinet. The valve cabinet contains the four-way valve, the automatic sampling valve, and a support for the glass sample chamber.

Step 2. Connect 2-foot long x ¼-inch O.D. drying tube (C) to tube (A). Connect the other end of tube (C) to the upper side arm of the glass sampling chamber with a nylon fitting.

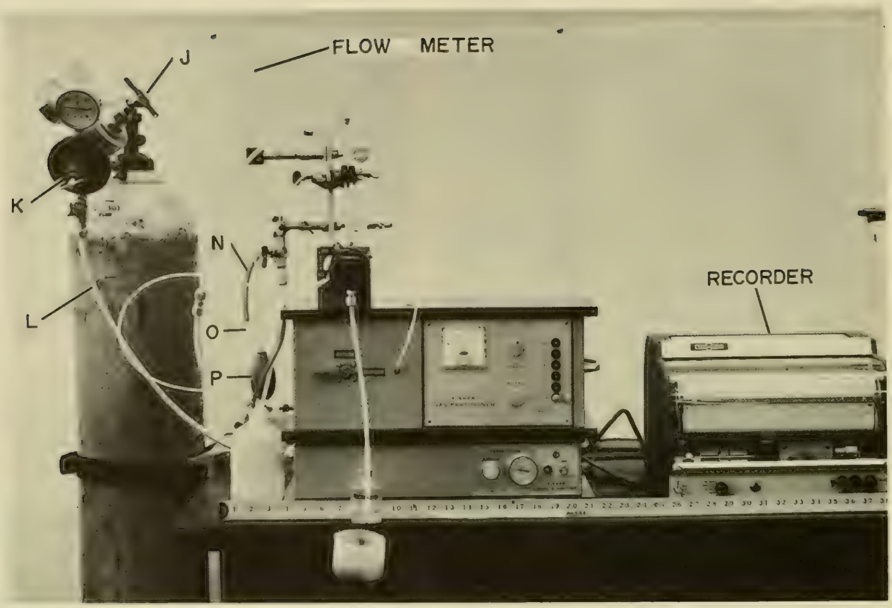

Figure J–8. Fisher Gas Partitioner modified, helium tank and recorder.

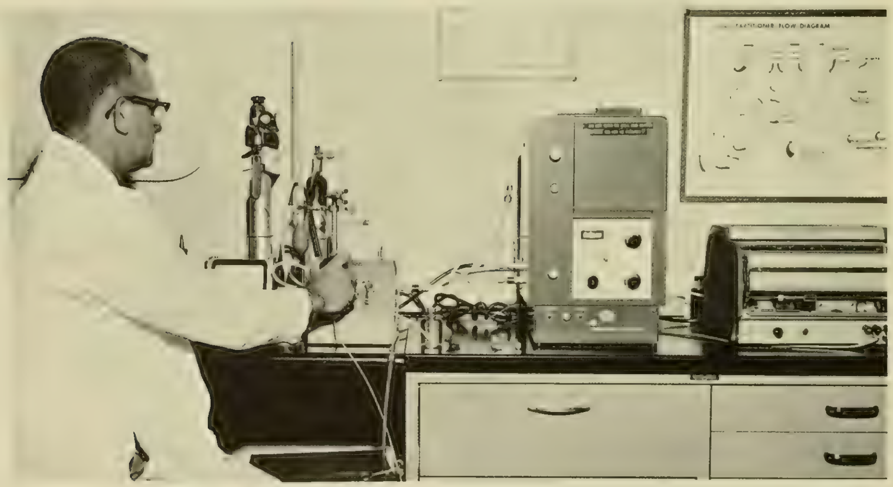
Figure J–9. Fisher-Hamilton Gas Partitioner and recorder.

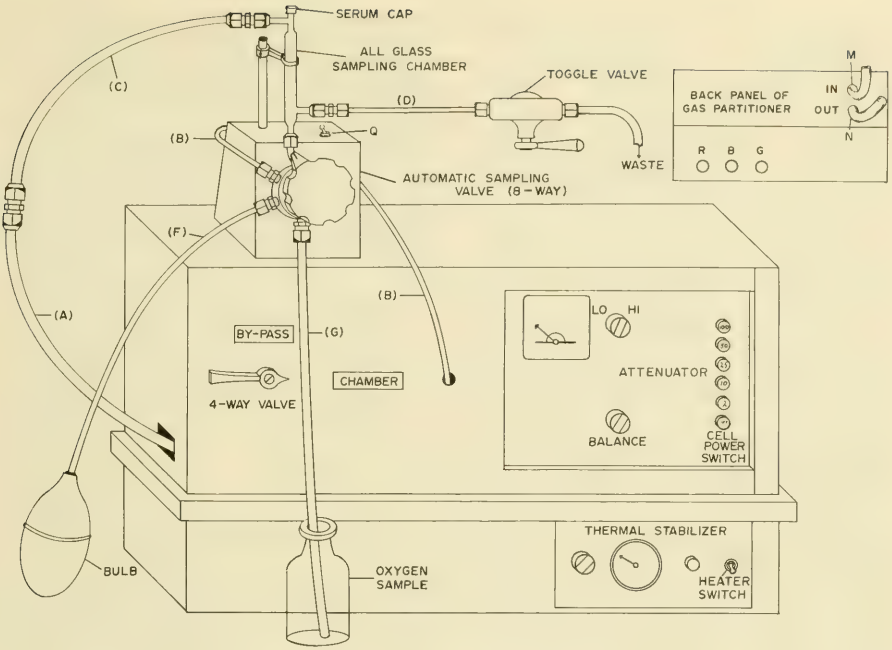

Figure J–10. **Fisher Gas Partitioner, modified.**

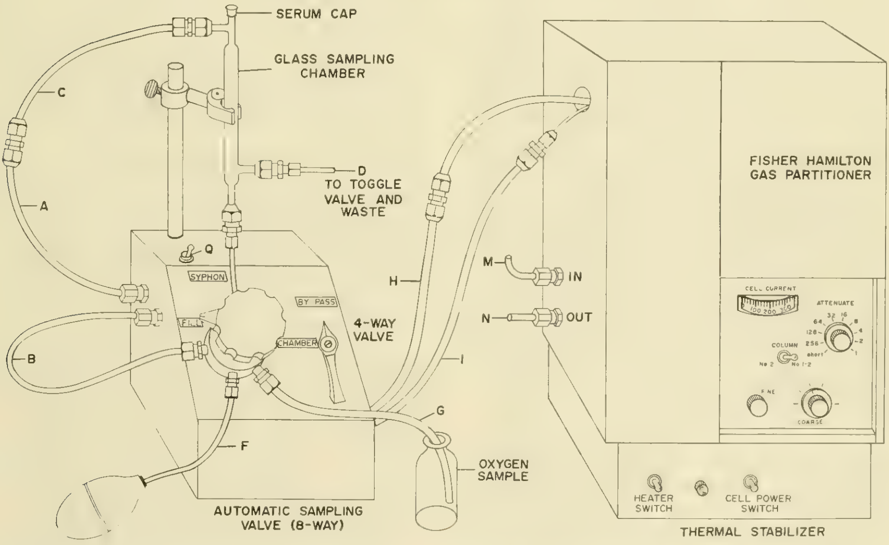

Figure J–11. **Fisher-Hamilton Gas Partitioner, the glass sample chamber, and the valve cabinet.**

Step 3. Connect a 2-foot long x 1/4-inch O.D. polypropylene tube (B) between the front left connection of the valve cabinet and the automatic sampling valve, using a Perkin-Elmer fitting at the valve.

Step 4. Connect the automatic sampling valve and the bottom of the glass sampling chamber with a 6-inch long x 1/8-inch O.D. nylon tube using a nylon fitting on the glass sampling chamber and a Perkin-Elmer fitting on the valve.

Step 5. Connect a 2-foot long x 1/4-inch O.D. tube (H) between the 1/4-inch O.D. tube from the partitioner and the rear right connection of the valve cabinet.

Step 6. Connect a 2-foot long x 1/4-inch O.D Ascarite Drying tube (I) between the 1/8-inch O.D. tube from the partitioner and the front right connection of the valve cabinet.

3. The following instructions apply to both systems:

Step 1. Insert a silicone rubber serum cap in the top of the glass sampling chamber.

Step 2. Connect one end of a 1-foot long x 1/8-inch O.D. nylon tube (D) to the bottom side arm of the sampling chamber. Use a nylon fitting. Connect the other end of tube (D) to a toggle valve, and run a tube from the toggle valve to a liquid waste container.

Step 3. Connect a 2-foot long x 1/8-inch O.D. nylon tube (F) from the automatic sampling valve. Connect a metal fitting on this tube and connect a rubber bulb to the fitting.

Step 4. Connect a 2-foot long x 1/4-inch O.D. nylon tube (G) to the automatic sampling valve. This tube goes to the sea water sample.

Step 5. Connect the two-stage regulator (J) and the line regulator (K) to the 200-cubic foot helium cylinder, lashing the helium cylinder (fig. J–8) securely to the bulkhead to prevent its toppling over in rough seas.

Step 6. Connect a 2-foot long x 1/4-inch O.D. Drierite filled drying tube (L) to the line regulator, and connect a 6-foot long x 1/4-inch O.D. polypropylene tube (M) between tube (L) and the "in" connection on the gas partitioner.

Step 7. Connect one end of a 2-foot long x 3/8-inch O.D. tygon tube (N) (figs. J–10 and J–11) to the "out" fitting of the gas partitioner. Connect the other end of tube (N) to the side arm (O) of the bubble counter 25 ml. burette. Place a rubber bulb (P) filled with a detergent solution on the bottom of the burette. Mount this flow meter near the sampling valve with a burette clamp (fig. J–8).

Step 8. Connect the shielded cable to the output terminals of the partitioner and the input terminals of the strip-chart recorder (fig. J–12). Connect the three black binding posts on the recorder with a strip of solder or a wire.

Step 9. Connect power cables of the partitioner and the recorder to a 110-volt outlet, and turn on the partitioner thermal stabilizer heater toggle switch. It will require about 8 hours to stabilize the temperature of the partitioner above laboratory temperature. *Caution:* Do not turn on the cell power switch until helium is flowing.

Step 10. Open the two stage regulator on the helium cylinder until the gage reads 30 psi, and adjust the line regulator valve until the gage reads 12 psi. Set the four-way valve to By Pass position, and check all connections with a leak detector. A detergent can be used to improvise a leak detector.

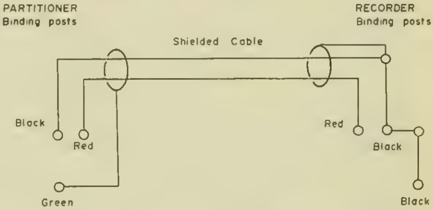

Figure J–12. Two-conductor cable connections between gas partitioner and recorder.

J–21 How the System Works.—The flow path of the carrier gas through the gas chromatographic system is controlled by the four-way valve and the automatic sampling valve. Figure J–13 shows the flow path of the carrier gas through the system.

1. With the four-way valve in chamber position, the gas flow is measured and adjusted, and the partitioner and recorder are calibrated.

2. With the automatic sampling (eight-way) valve in the Syphon (clockwise) position, a precise amount of water sample is syphoned into the system.

3. When the gas flow, partitioner, and recorder are adjusted and the sample has been syphoned into the system, the eight-way valve is turned counterclockwise to position Fill Chamber and the four-way valve is turned to the Chamber position. This forces the water sample into the sample chamber where the helium bubbles through the sample and strips it of its dissolved gases.

4. The He gas and the stripped dissolved gases flow through the partitioner drying column and then through the Ascarite which absorbs the CO_2. The 1st detector then measures the thermal conductivity of the remaining composite (He, N_2, O_2, and A) gas.

5. The composite gas then flows through the gas partitioner molecular sieve column which separates the N_2 gas from the O_2-A gas.

6. Thus, the strip-chart recorder, which is adjusted to zero for pure He, records three peaks: Peak 1, the composite gas; Peak 2, the O_2-A

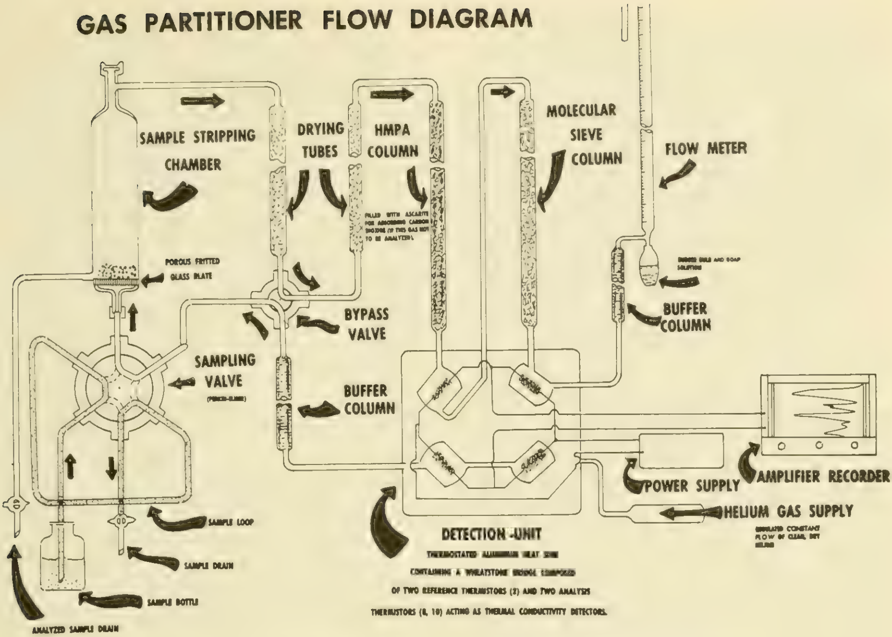

Figure J–13. Flow path of the carrier gas through the gas partitioner system.

gas; and Peak 3, the N_2 gas. The area under each peak represents the quantity of gas in the sample.

7. The integrator pen on the recorder graphically integrates the area under each peak as the recorder pen traces the curve.

J–22 Analyzing Oxygen Samples.—After the thermal stabilizer in the partitioner has been turned on for about 8 hours, O_2 sample analysis can be performed. Oceanographic Log Sheet–CC NAVOCEANO–EXP–3167/3A (9–63) is used for recording the results of the analysis of O_2 samples by gas chromatography (fig. J–14). Ship's name, cruise number, station number, serial number, and sample bottle number are taken from Oceanographic Log Sheet-A.

Step 1. About 30 minutes prior to sample analysis, the He gas flow should be turned on and adjusted to 12 psi.

Step 2. Turn the four-way valve to Chamber position, and the automatic sampling valve to Syphon position.

Step 3. Place the end of tube (G) well down in a bottle of sea water from a discarded salinity sample, and start syphoning by depressing the rubber bulb.

Step 4. Turn the automatic sampling valve to Fill position when the syphoned water begins to flow into tube (F). This will cause the water in the sample loop to be moved into the glass sampling chamber, where the helium gas will strip it of any gases. It is important to have several centimeters of stripped water in the sampling chamber before a sample is injected into the system for analysis.

Step 5. Set the sensitivity attenuator knob and the cell current on the gas partitioner as follows: On the Fisher Gas Partitioner, set sensitivity at 2 percent and cell current at 7 ma (Hi); on the Fisher-Hamilton Gas Partitioner, set sensitivity at 8 (12½ percent) and cell current at 250 ma.

It is important to operate the gas partitioner at a sensitivity that will cause the recorder to utilize the maximum width of the chart paper since this will give a clearer record and more accurate calculations. The rule is: Set the sensitivity as high as possible and still keep the recording pen on scale.

To determine the sensitivity for operation of the partitioner, analyze a surface sea water sample with the sensitivity set at 50 percent, and observe the recorded peaks on the Chromatogram. If the composite and N_2 peaks are on scale and the O_2 peak is between one-half and full scale, the 50 percent sensitivity is satisfactory. If, however, the dissolved gas content of

OCEANOGRAPHIC LOG SHEET–CC
NAVOCEANO-EXP-3167/3A (9-63)

U. S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D.C. 20390

OXYGEN DETERMINATION BY GAS CHROMATOGRAPHY

SHIP	CRUISE NO.	STATION NO.	SYSTEM NO.	CHEMIST	COMPUTED BY	CHECKED BY	THERM. STAB. SET	O_2 ML/L/COUNT	N_2 ML/L/COUNT	DATE ANALYZED
USS EDISTO	E.ARCTIC-65	39	4	J.A.S.	J.B.C.	T. McK.	35°C	4.129×10^{-4}	3.954×10^{-4}	7 Sep 65

SERIAL NUMBER	BOTTLE NUMBER	SENSITIVITY	N_2 COUNTS READ	N_2 COUNTS AT 100 %	N_2 ML/LITER	T° C INSITU	ARGON FACTOR	A FACTOR TIMES N_2 COUNTS AT 100 %	$A+O_2$ COUNTS READ	$A+O_2$ COUNTS AT 100 %	O_2 COUNTS*	O_2 ML/LITER
654	1	25%	10,429	41,716	16.495	-2	3.05×10^{-2}	1272	5560	22.240	20968	8.66
655	2		11,250	45000	17.793	-2		5832	5832	23.328	21955	9.07
656	3		11,428	45712	18.075	-1	3.06×10^{-2}	6085	6085	24.340	22941	9.47
657	4		11,340	45360	17.935	-2	3.05×10^{-2}	5850	5850	23.400	22017	9.09
658	5		11,680	46720	18.473	-2		5932	5932	23.728	22303	9.21
659	6		11,455	45820	18.117	-2		5645	5645	22.580	21182	8.75
660	7		11,420	45680	18.062	-2		5823	5823	23.292	21899	9.04
661	8		11,990	47960	18.963	-2		5835	5835	23.340	21877	9.03
662	9		11,534	46136	18.242	-2		5805	5805	23.220	21813	9.01

* $A+O_2$ COUNTS AT 100% MINUS A FACTOR TIMES N_2 COUNTS AT 100%

Figure J–14. Oceanographic Log Sheet–CC.

a sample is so low that the peaks are below the center of the chart, the sensitivity should be increased. Also, in areas where dissolved gas content of sea water is extremely low, a larger sample loop can be installed in the automatic sampling valve to increase the quantity of gas available in a sample. The Fisher-Hamilton Gas Partitioner usually can be operated with the sensitivity set at 8 (12½ percent) except where dissolved O_2 content of sea water is low.

Step 6. Set the recorder switch on Standby and the chart-speed gearshift on 1½ or 2.

Step 7. Adjust the line regulator valve (K) until the He flow is 50 ml. per minute ± 0.5 of a second, by depressing the detergent filled bulb on the bubble counter burette (O) and by measuring, with a stopwatch, the time it takes a bubble to move 25 ml. in the burette.

Step 8. Remove serum cap from the oxygen sample bottle, and place tube (G) deep in the sample bottle. Turn automatic sampling valve to Syphon position.

Step 9. Start syphoning by depressing rubber bulb (P). Turn on switch (Q) for 5 seconds to activate vibrator, which insures complete filling of the sample loop. Turn the automatic sampling valve to Fill position when sample loop is rinsed and filled; then after 10 seconds, turn the automatic sampling valve back to Syphon position, and remove tube (G) from sample bottle and wipe excess water from tube with lab tissue.

Step 10. Start chart paper by turning recorder On switch to "Inches per minute," and set gas partitioner sensitivity to 50 percent, or 8.

Step 11. Annotate the strip chart with ship's name, sample bottle number, and sensitivity setting.

Step 12. Adjust partitioner Balance (or Coarse and Fine) until (green) pen is on 0 line of the chart paper (fig. J–15), and observe the pens to determine when sample results are recorded. Analysis of a sample usually requires 4 to 5 minutes.

J–23 Calculating the Oxygen and Nitrogen Counts.—As the sample is analyzed, three signal peaks will be traced on the chart paper by the signal (green) pen. The first is the composite peak, the second is the O_2–A peak, and the third is the N_2 peak. While the signal pen traces a peak, the integrator (red) pen produces a separate but mathematically related curve. It moves back and forth across the chart at a speed proportional to the position of the signal pen, i.e., as the signal pen moves away from the 0 line, the integrator pen moves faster. Therefore, the integral curve developed is the total movement of the integrator pen across the chart during the time the signal peak is being recorded.

To arrive at the number defining the integral of the recorded signal, read the displacement of the integrator (red) pen directly in chart units or counts as follows (fig. J–15):

Step 1. With the signal (green) pen on 0 and the integrator (red) pen at its steady position (anywhere between 0 and 1.0 on the chromatogram) e.g., .580, watch for the sample results to be recorded.

Step 2. When the green pen starts to trace a peak, the red pen moves across the chart paper. Count the number of complete spans, or traverses, the red pen makes across the chart, e.g., 3.0.

Step 3. When the green pen returns to the zero line and the red pen is steady, read the end position of the red pen, and compute the total distance traversed on the chart paper, e.g.,

$$.580+3.0+(1.0-.641)=3.939$$

Step 4. Calculate total counts, e.g., $3.939\times 1000=3939$ counts, and annotate the counts on the strip chart (chromatogram), indicating composite peak (COMP), Oxygen and Argon peak (O_2+A), or nitrogen peak (N_2), e.g., 3939 O_2+A. Enter the O_2+A peak and N_2 peak counts in the appropriate column of Log Sheet-CC.

Step 5. When the sample has been analyzed, open the toggle valve on tube (D), and drain off as liquid waste about 3 centimeters of the stripped sea water to allow space for the next sample.

Step 6. Repeat the above procedures for other samples, and when all samples for the cast have been analyzed, set the recorder in Stand-by position, drain the sample chamber, and set the four-way valve to By-pass, but do not change the gas pressure.

J–24 Determining the Gas Chromatography Calibration Factor.—Before the O_2 and N_2 counts obtained during O_2 sample analysis can be converted to milliliters per liter, the gas chromatography calibration factor must be determined for O_2 and N_2. Calibration usually is performed at the beginning, the middle, and the end of a cruise to assure quality control of data analysis. Figure J–16 presents a format for setting up the calibration sheet.

Step 1. Fill a 500-ml. capacity separatory funnel with distilled water.

Step 2. Purge the water with air from the tank of air until it is saturated (about 15 minutes). Use a glass purging tube.

Step 3. Measure the temperature of the water sample (T_1 of H_2O) to the nearest tenth C°.

Step 4. Record the barometric pressure in mm. of mercury.

Step 5. Analyze several samples from the purged solution to obtain an average. Record sensitivity and average counts, and revert counts to 100 percent.

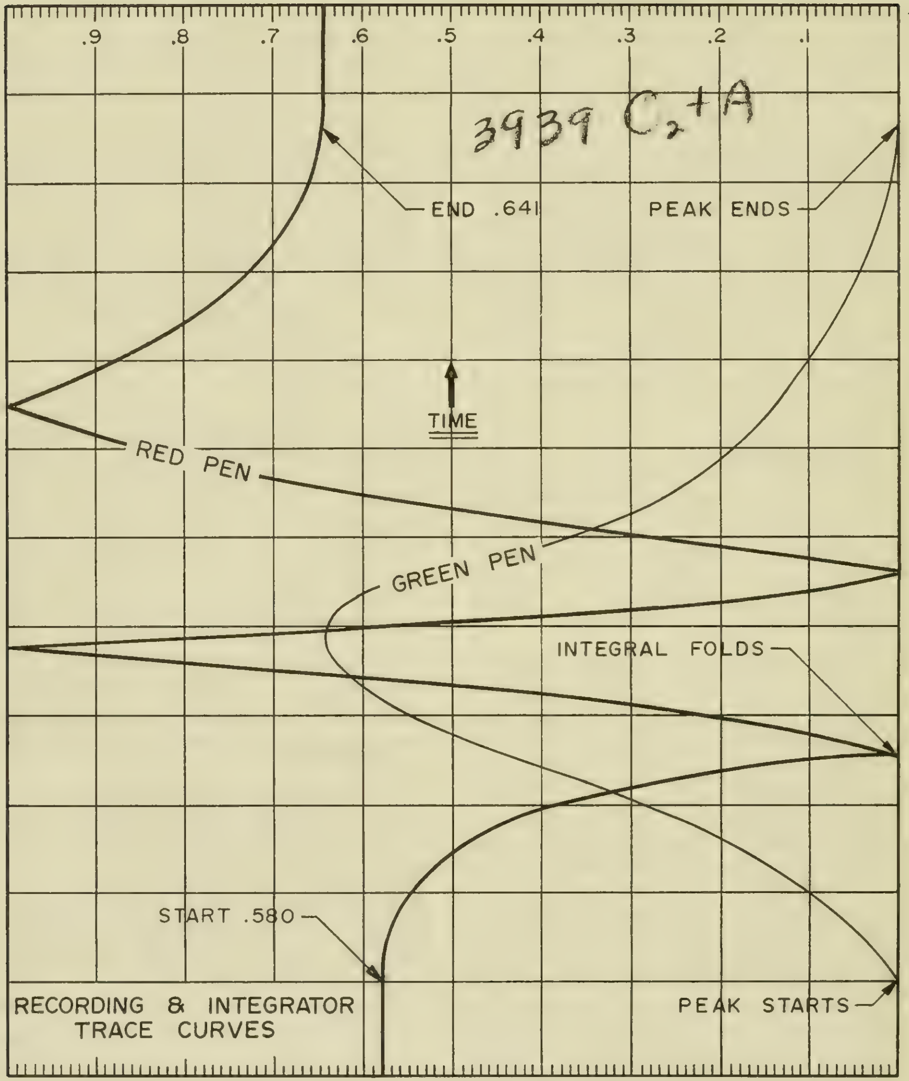

Figure J–15. Chromatogram showing red and green pen traces.

Step 6. Determine pressure correction by dividing barometric pressure by standard pressure.

Step 7. Determine saturation value of gas from figures J–17 or J–18 using (T_1 of H_2O).

Step 8. Compute solubility corrected for pressure. Saturation value for (T_1 of H_2O) times pressure correction.

Step 9. Compute calibration factor. Solubility corrected for pressure divided by counts reverted to 100 percent.

DATA FOR DETERMINATION OF GAS CHROMATOGRAPHY CALIBRATION FACTOR

SHIP EDISTO CRUISE ARCTIC 65 CHEMIST SAS DATE 25 AUG 65

GAS (O_2 or N_2 from AIR) STANDARD PRESSURE 760 mm

T_1 of H_2O 24.0 °C. SENSITIVITY 25 %

BAROMETRIC PRESSURE 755 mm COUNTS (Average) 7087

REVERTED TO 100% 28,348

PRESSURE CORRECTION = B.P/S.P = 755/760 0.99342

SATURATION OF GAS (From graph) 11.28

SATURATION VALUE TIMES PRESSURE CORRECTION = 11.21
(Solubility Corrected for Pressure)

$$\frac{\text{SOLUBILITY CORRECTED FOR PRESSURE}}{\text{COUNTS REVERTED TO 100\%}} = \frac{11.21}{28{,}348} = 3.954 \times 10^{-4}$$

ML/L/COUNT

Figure J–16. Format for setting up calibration sheet.

J–25 Calculations of Oxygen and Nitrogen.—To calculate the O_2 and N_2 content from the counts obtained during analysis, perform the following steps using the Log Sheet-CC (fig. J–14):

Step 1. From the Oceanographic Log Sheet-A for the station involved, determine the *in situ* temperature (to the nearest degree) for each sample and enter in T °C *In Situ* column, e.g. $-1°$ (Serial Number 656; Bottle Number 3).

Step 2. From the calibration sheets, enter the O_2 and N_2 calibration factors in the blocks at top of log sheet, e.g., O_2ml./L count$=4.129 \times 10^{-4}$, N_2ml./L count$=3.954\times 10^{-4}$.

Step 3. Convert A+O_2 Counts Read to 100 percent by dividing by sensitivity, e.g., $6085 \div .25 = 24340$. Convert N_2 Counts Read to 100 percent, e.g., $11428 \div .25 = 45712$. Enter results in columns A+O_2 Counts at 100 percent and N_2 Counts at 100 percent.

Step 4. Compute the A correction factor with the following formula and enter results in A Factor column, e.g., 3.06×10^{-2}:

A Correction Factor$= (8.0\times 10^{-5})(T) + (3.07 \times 10^{-2})$ where T=*in situ* temperature of sample. In the chromatographic analysis of air saturated liquids, O_2 and A have equal retention times at room temperature, i.e., they appear as one peak on the chromatogram.

Step 5. Multiply the N_2 Counts at 100 percent column by the A Factor column, and enter the result in A Factor Times N_2 Counts at 100 percent column, e.g., 1399.

Step 6. Subtract A Factor Times N_2 Counts at 100 percent column from A+O_2 Counts at 100 percent column to determine O_2 count. Enter in O_2 Counts column, e.g., $24340-1399=22941$.

Step 7. Multiply O_2 Counts column by the O_2 calibration factor, e.g., $22941\times 4129\times 10^{-4} = 9.47$. Enter result in O_2ml./Liter column.

Step 8. Multiply N_2 Counts at 100 percent by the N_2 calibration factor, e.g., $45712\times 3.954 \times 10^{-4}=18.075$. Enter results in N_2ml./Liter column.

Step 9. After the chromatogram has been removed from the recorder, check all computations carefully.

J–26 Maintenance of Gas Chromatography Equipment.—In general the gas chromatographic equipment requires very little maintenance. If O_2 samples are collected at each oceanographic station, the equipment usually is not secured until the cruise has ended.

A tank of He usually will last for 4 to 6 weeks at the regulated flow rate of 50 ml./min.

A roll of chart paper usually will be ample for 100 samples.

The Ascarite drying tubes should be changed when their blue color fades to pink.

The columns in the gas partitioner should be changed if the signal pen fails to return to 1.0 margin on chromatogram between the N_2 and O_2 peaks.

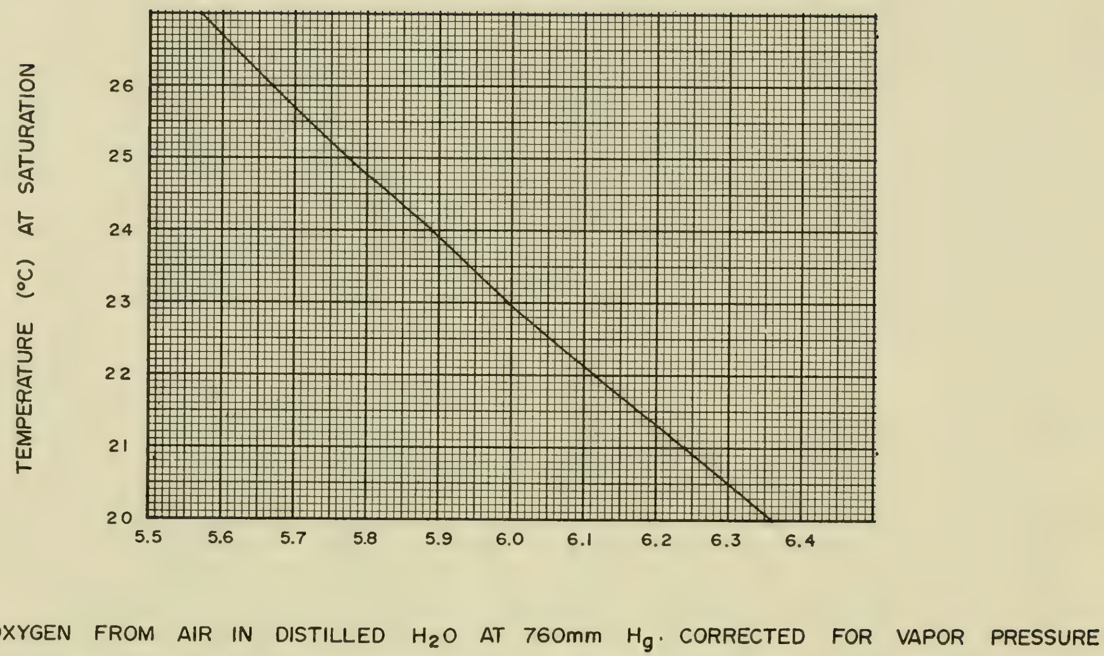

Figure J–17. Oxygen saturation graph (do not extrapolate beyond 20° or 26° C.). From Klots and Benson, Journal of Physical Chemistry, Volume 68, No. 1, January 1964, page 169–174.

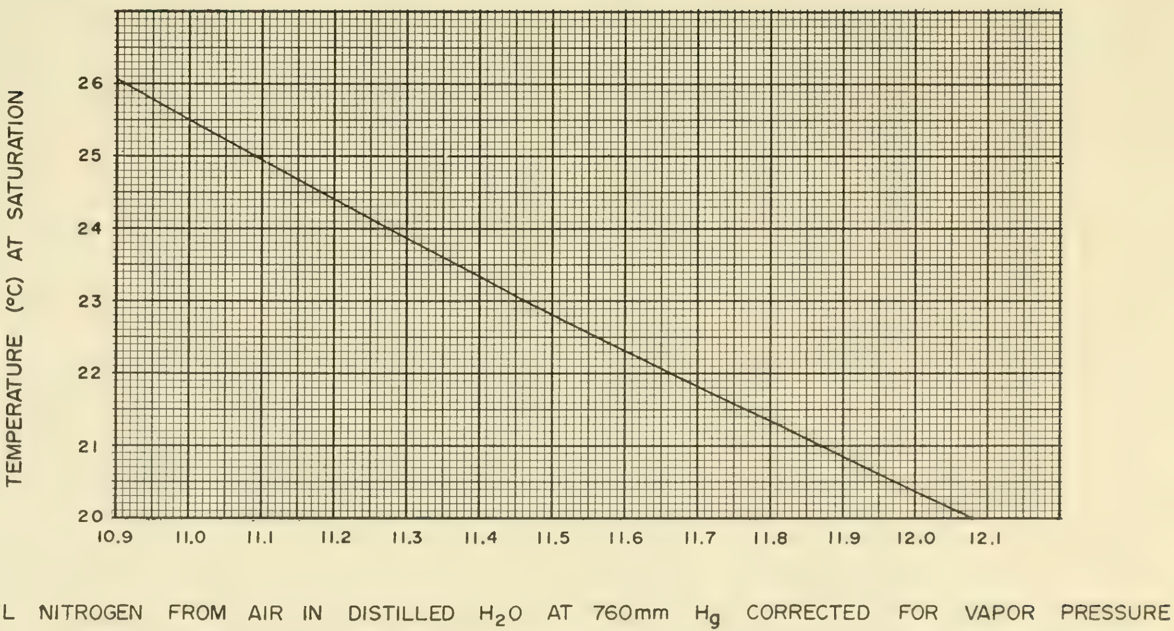

Figure J–18. Nitrogen saturation graph (do not extrapolate beyond 20° or 26° C). From Klots and Benson, Journal of Physical Chemistry, Volume 68, No. 1, January 1964, pages 169–174.

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CHAPTER L

BOTTOM SEDIMENT SAMPLING

L–1 General.—Marine sedimentation embraces that phase of oceanography which is related to the deposition, composition, classification, and structure of organic and inorganic material of the ocean floor. Various sampling devices are utilized to obtain bottom sediments from a particular locality under investigation. Once obtained, samples are packed and shipped to a sedimentation laboratory to be analyzed and classified.

Analysis of marine sediments generally includes the determination of size, shape, and percentage of component particles; identification of minerals and ratio of light to heavy minerals; wet density; pH; and calcium carbonate content. Biological and ecological studies emphasize the animal population as well as the environmental factors determined by temperature, depth, type of sediment, and geographic location.

Classification of bottom sediments is based on a combination of grain size and genesis (origin). Hence, one may have samples composed of terrigenous material, subaerial or submarine volcanic material, organic matter, inorganic material, and extraterrestrial matter. Size of the component materials may range in extremes and is used as a further, more detailed classification criteria. Bottom samples composed of volcanic materials for example, may range in size from very fine ash to pebbles and cobbles. Very often bottom samples contain an aggregation of sizes so that a combination of volcanic ash and other material of pebble size is possible.

Bottom sediment charts are prepared from thousands of reported classifications and collected samples. These charts illustrate the nature of the sea bottom in coastal and oceanic areas.

L–2 Collecting Samples.—Collecting marine sediments involves the use of a variety of samplers which fall into three basic categories: Corers, snappers or grabs, and dredges. Selection and use of the proper device will depend on the nature of the investigation, the character of the bottom, the depth of water, and the shipboard equipment available for lowering and retrieving the samplers. For example, if the investigation has to do with the strength of the sediment or its ability to support equipment, the sample should be obtained with one of the larger corers so that engineering properties as well as size and composition analyses can be made. On the other hand if previous reconnaissance indicated the character of the bottom to be hard and rocky, perhaps a dredge or grab sample will verify this condition. Where the depth of water is great and the sediments are unconsolidated, excessive washout may eliminate the use of certain devices.

L–3 General Procedures for Coring Operations.—Coring operations aboard an oceanographic survey ship are guided by procedures established to facilitate the collection of useful samples, insure a maximum degree of efficiency, and provide for safety of personnel in handling of coring equipment.

The typical coring device consists of interchangeable core tubes and an upper assembly. The upper assembly provides support for the drive weights and the core tubes. These corers essentially are driven into the ocean floor by gravity, and the bottom sample is retained in the core tube. The time involved in a coring operation is dependent on water depth and the speed at which the wire is payed out and retrieved. The length of core collected will be governed by the penetrability of the bottom, the length of the corer, the amount of weight on the device, and the design of the corer. In areas of predominantly rocky or coral bottoms, it may be impossible to obtain a core.

L–4 Gravity- and Piston-Type Corers.—Aboard the survey ships of the U.S. Naval Oceanographic Office, two types of coring devices are used: Gravity-type and piston-type corers. Both types of corers achieve their penetration of the ocean floor by gravity, i.e., when the release mechanism is tripped, the specific gravity of the device is great enough to cause the corer to free fall rapidly through the water and strike the bottom with enough force to penetrate the ocean floor (fig. L–1). Interest in obtaining undisturbed core samples has resulted in the development of several piston-type bottom coring samplers. These piston-type corers are designed to offset the downward force of the coring device on the sediment. The piston inside the coring tube reduces distortion to the upper layers of the core sample, promotes greater penetration of the ocean floor, and, according to some authorities, provides a more representative sample of the bottom sediment column *in situ* (fig. L–2). Piston-type corers rigged without the piston mechanism are gravity corers. Sometimes in an emergency when a release mechanism is not available, gravity corers are rigged without the device, but the speed at which the corer sinks through the water is limited by the payout speed of the winch, and true free-fall speed is not achieved.

L–5 The Phleger Corer.—The Phleger corer, a gravity type, is designed to obtain cores up to 4 feet in length. It is widely used for collecting marine sediments because of its small size and weight. The corer has an overall length of 3 or 5 feet—3 feet if the 12–inch coring tube is used, and 5 feet if the 3–foot is used. The corer, usually, is operated from the oceanographic winch using $\frac{5}{32}$– or $\frac{3}{16}$–inch oceanographic wire.

The Phleger corer assembly consists of the following components (fig. L–3):

The main weight (80 lbs.) comprised of the upper tube, the main body weight, check valve, tail fin assembly, and bail;

Coring tube, 12 and 36 inches;

A core catcher;

A cutting edge;

A release mechanism with a 20–foot chain;

A trigger line and weight;

Plastic (cellulose acetate butyrate (CAB) or one of the new type, high density, low permeability plastics) liner, 1½ inches outside diameter and end caps;

Spare parts and 2 shipping cases.

L–6 Instructions for Assembling and Operating the Phleger Corer.—The Phleger corer is simple to assemble and operate. The following tools are required:

Pliers, 8-inch combination;

Pipe wrench;

Small hacksaw.

Step 1. Screw the threaded end of the coring tube into the main weight.

Step 2. Examine the check valve and make sure it is operating properly.

Step 3. Insert a length of plastic liner into the corer as far as it will go, and score a mark on the plastic liner flush with the end of the coring tube.

Step 4. Cut the plastic liner, with knife or saw, approximately ½ inch shorter than marked in step 3.

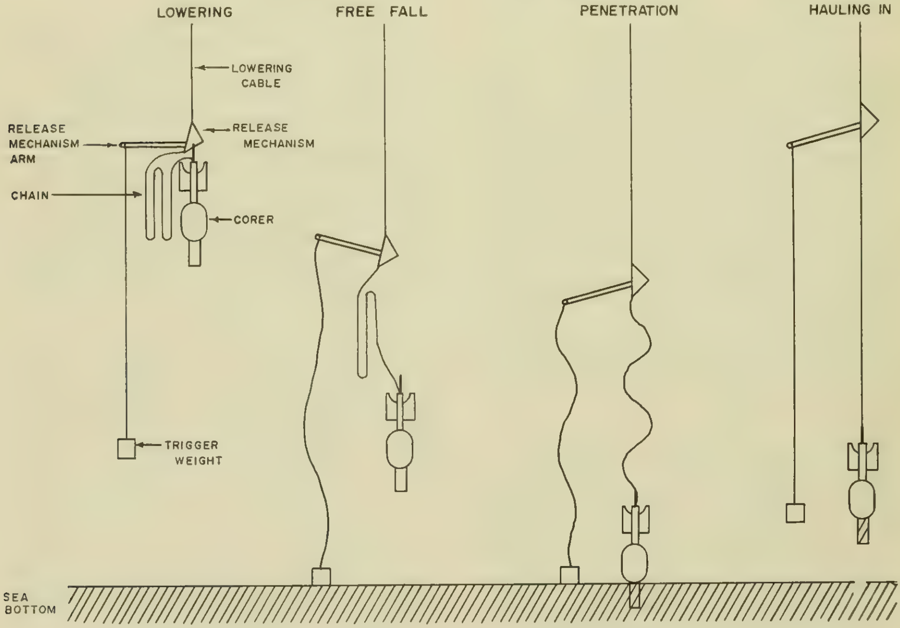


Figure L–1. Principle of operation of gravity-type corers.

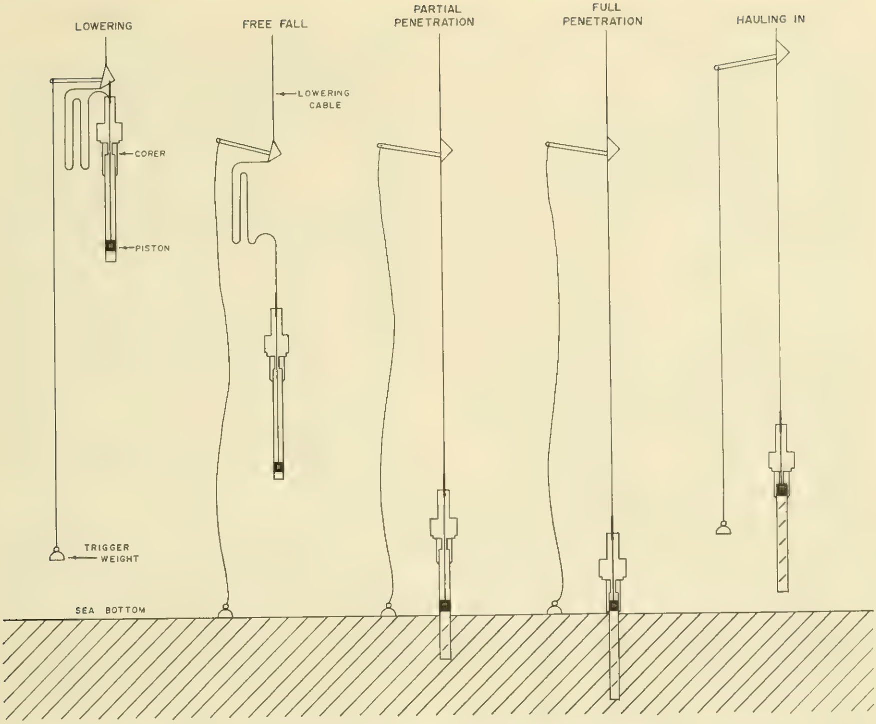


Figure L–2. Principle of operation of piston-type corers.

Figure L–3. Phleger corer assembly.

Step 5. Reinsert liner; insert core catcher; and securely attach core cutter to the bottom of coring tube, with bayonet fitting. Liner should fit with no play.

Step 6. With shackles, attach one end of the chain to the corer bail and the other end of the chain to the release mechanism.

Step 7. With shackle, attach the release mechanism to the end of the lowering wire.

Step 8. Secure one end of the trigger line to the trigger weight and the other end to the release mechanism arm.

Step 9. Insert the corer bail into the slot in the release mechanism, and *insert the safety pin.*

Step 10. Gather the chain in several small coils and fasten it to the bail with sail thread.

Step 11. Suspend the coring assembly over the side. Check to see that the trigger line and weight are hanging properly, *remove the safety pin*, lower the corer to the surface of the water, set the meter wheel counter dials to zero, and commence lowering.

L–7 Obtaining the Phleger Core.—Lowering should be accomplished in accordance with instructions in paragraph L–29, Obtaining the Core. In very deep water, the weight of the Phleger corer is often a small fraction of the total weight of the lowering wire and of variable loads caused by the roll of the ship; hence, no apparent release in tension may be observed when bottom is reached.

L–8 Retrieving the Phleger Corer.—As soon as the winch is stopped, note the amount of wire out, and commence hauling in immediately. The speed of the winch should be slow until the corer is picked up. Do not increase winch speed until the sampling gear is well clear of the bottom, and then exercise caution as the corer approaches the surface. When bringing the Phleger corer aboard, keep it in a near vertical position.

L–9 Removing, Logging, and Labeling the Phleger Core.—When the Phleger corer is aboard, remove the core, and log it in and label as follows:

Step 1. Measure the length of sediment on the outside of the coring tube. Retain this measurement for step 6 below.

Step 2. With the coring device still in a near vertical position, unscrew the coring tube from the main weight, and remove the coring tube and liner from the main weight.

Step 3. Remove the cutting edge from the coring tube, push the liner out of the coring tube, remove the core catcher, and cover the bottom end of the liner with a plastic cap, being careful to keep the sample in the liner.

Step 4. Put any sediment retained by the cutting edge or the core catcher in a sample jar as this sediment is the deepest layer penetrated.

Step 5. With a saw, make a cut through the plastic liner just above the top of the sample. Let the water drain off slowly, then finish cutting of the liner, keeping the core in a near vertical position. Finally, cap the liner with a plastic cap.

Step 6. Next log the samples (liner as one and jar as one) on the Oceanographic Log Sheet-M according to instructions in paragraph L–39, Oceanographic Log Sheet–M Bottom Sediment Data.

Step 7. Label the samples according to instructions given in paragraph L–40, Labeling the Bottom Sediment Sample(s).

Step 8. If the plastic liner used was (CAB), coat liner with wax according to the instructions given in paragraph L–30, Applying Wax to Core Sample Liners.

Step 9. Pack, store, and ship cores in accordance with instructions given in paragraph L–41, Packing, Storing, and Shipping Bottom Sediment Samples.

L–10 Maintenance of the Phleger Corer.—In general, the Phleger corer requires very little maintenance, but each corer's storage cases contain spare core tubes, core catchers, and cutting edges. After each lowering, all sediment should be removed from the corer by washing, and any damaged parts should be replaced. The core-catcher springs are delicate and must be inspected for free play action, and the core cutter may be dented if the core hits a hard or rocky bottom. When the coring operation is completed, any sediment on the corer should be removed by washing, and the entire device should be rinsed in fresh water, and stored in the core assembly shipping cases.

L–11 The Kullenberg Piston Corer.—The Kullenberg piston corer used at the U.S. Naval Oceanographic Office is a modified version of the original Kullenberg corer which was designed to obtain cores up to 65 feet in length. The modified Oceanographic Office model differs from the original not only in the assembly but also in the manner in which it is employed. Throughout the remainder of the chapter, all references to the Kullenberg corer will be understood to mean the model developed by the Oceanographic Office and not the original. The Kullenberg is designed to collect cores up to almost 12 feet in length. It is widely used both as a piston and gravity corer, and it can be lowered with the oceanographic winch using $5/32$- or $3/16$-inch wire.

The Kullenberg piston corer assembly consists of the following components (figs. L–4 and L–5):

Upper assembly or weight stand consisting of main body tube, adapter, bail, and collar;

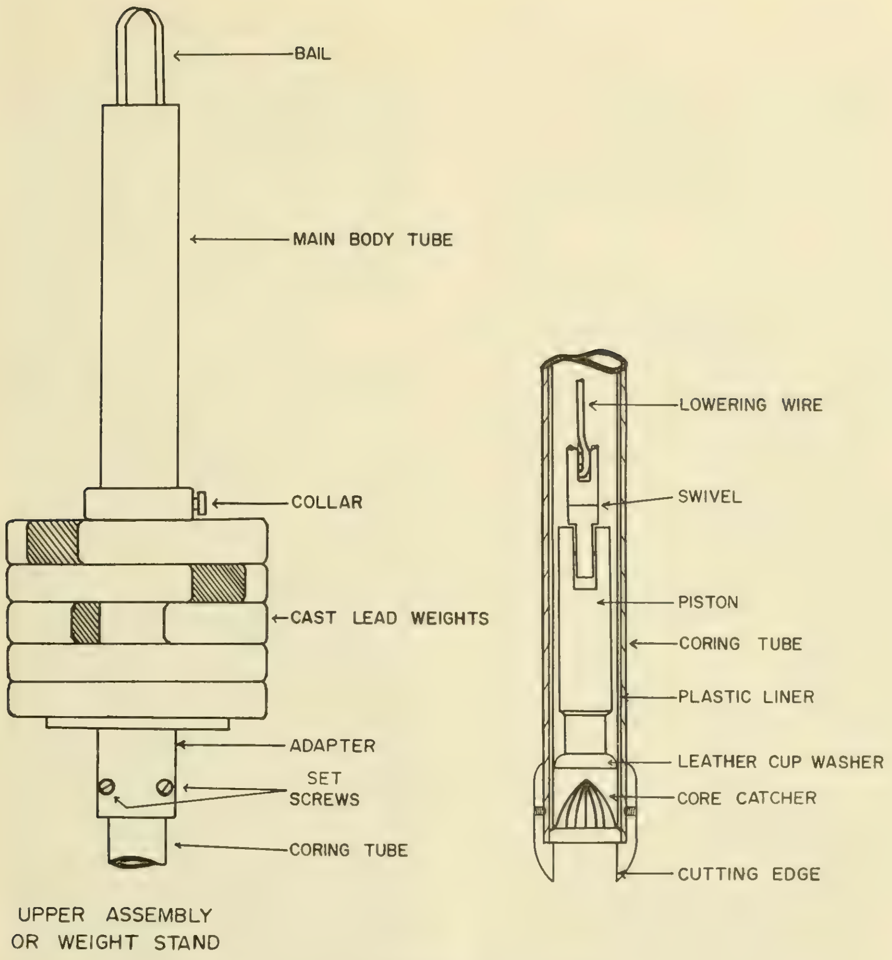


Figure L–4. Kullenberg piston corer assembly.

4 to 6 cast lead weights (50 pounds each);
Coring tube (2-inch inside diameter), which comes in two lengths: 5½ and 11½ feet;
Core catcher;
Core cutting edge;
Piston equipped with a single leather cup washer and a swivel fitting for attaching the lowering wire;
Wire clamp release mechanism with a trigger line and a trigger weight (40 to 80 pounds);
Plastic (cellulose acetate butyrate (CAB) or one of the new type, high density, low permeability plastics) liner 2-inch outside diameter and end caps;
Miscellaneous spare parts and wooden shipping cases.

L–12 Instructions for Assembling and Operating the Kullenberg Corer.—The following tools are needed to assemble and operate the Kullenberg corer:

Pliers, 8-inch combination;
Adjustable end wrench;
Pipe wrench;

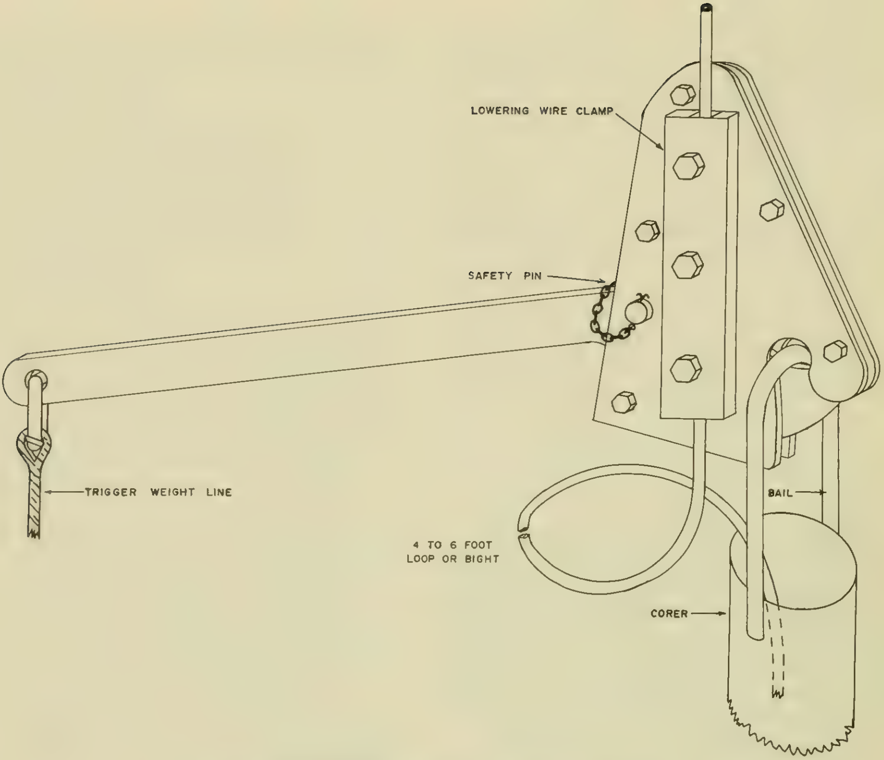


Figure L–5. Kullenberg piston corer release mechanism.

Allen wrench set;
Screwdriver;
Hacksaw.

Step 1. Complete the upper assembly by connecting the adapter to the main body tube with at least three complete turns on the treads.

Step 2. Place the upper assembly on the deck in a horizontal position, insert the coring tube in the adapter and secure it in place with the set screws.

Step 3. Insert a length of 2-inch, outside-diameter, plastic liner into the corer as far as it will go and score a mark on the liner flush with the end of the coring tube.

Step 4. Cut the liner approximately ½ inch shorter than marked.

Step 5. Reinsert liner; insert core catcher; test the fit of the cutting edge; then remove core catcher and cutting edge.

Step 6. Feed the free end of the lowering wire through the main body tube and the coring tube; attach the thimble on the end of the lowering wire to the swivel connection on the piston; pull the piston back into the coring tube, leaving just enough space for the core catcher; replace the core catcher and secure the cutting edge with the set screws.

Step 7. Clamp the release mechanism to the oceanographic wire, leaving a 4- to 6-foot loop or bight above the corer. The exact amount of wire in the loop can best be determined by experience. Insert the corer bail in the release mechanism slot, and *insert the safety pin.*

Step 8. Fasten the trigger weight line to the end of the release arm with an overall length of line and weight equal to the total length of the corer plus the loop of wire (free-fall distance) between the top of the corer and the release mechanism. Then attach the trigger weight.

Step 9. Swing the assembly outboard and suspend it over the side in a vertical position; then, attach 4 to 6 cast lead drive weights on the main body and secure them in place with the collar.

Step 10. Tape the bight of wire between corer and release mechanism to the main body of the corer to prevent kinking or hanging up during free fall (fig. L–6), *remove the safety pin*, lower the assembly to the surface of the water, set the meter wheel counter dials to zero, and commence lowering the corer. **NOTE:** To rig the Kullenberg corer as a gravity corer do not use the piston assembly and substitute the following for step 6: Connect the free end of the lowering wire to the bail, replace the core catcher and secure the cutting edge with the set screws. Adjust the bight of wire between corer and release mechanism accordingly.

L–13 Obtaining the Kullenberg Piston Core.—Lowering should be accomplished in accordance with instructions in paragraph L–29, Obtaining the Core.

Figure L–6. Taping bight of lowering wire to Kullenberg corer.

L–14 Retrieving the Kullenberg Piston Corer.—As soon as the winch is stopped, note the amount of wire out, and commence hauling in immediately. The speed of the winch should be slow until the corer is picked up. During hoisting, the piston supports the entire weight of the corer. Do not increase the winch speed until the sampling gear is well clear of the bottom.

Step 1. When the release mechanism is at deck working level bring in the trigger weight and remove the release mechanism from the wire.

Step 2. Hoist the corer to deck working level, remove drive weights, and bring corer aboard, keeping the bottom end of the corer lower than the main weight.

Step 3. Measure the length of sediment on the outside of the coring tube. Retain this measurement for step 8 below.

Step 4. Loosen the setscrews on the adapter and remove the core tube with liner.

Step 5. Loosen the setscrews on the cutting edge, remove the cutting edge and push the liner down far enough to allow removal of the core catcher. Cover the end of the liner with a plastic cap. Tape the cap in place; then, remove the liner from the core tube, keeping it in an upright position if possible.

Step 6. With a saw, make a cut through the plastic liner just above the top of the core sample. Let the water drain off slowly, then finish cutting off the liner. Finally, cap the liner with a plastic cap. Where the 12-foot liner is used, it may be necessary to section the core for easier handling; however, this is not desirable and should be avoided if possible.

Step 7. Put any sediment retained by the cutting edge or the core catcher in a sample jar as this sediment is the deepest layer penetrated.

Step 8. Log the samples (core as one, jar as one) on the Oceanographic Log Sheet–M according to instructions given in paragraph L–39, Oceanographic Log Sheet–M Bottom Sediment Data.

Step 9. Label samples according to instructions given in paragraph L–40, Labeling the Bottom Sediment Sample(s).

Step 10. If the liner used was CAB plastic, coat it with wax according to the instructions given in paragraph L–30, Applying Wax to Core Sample Liners.

Step 11. Pack, store, and ship cores in accordance with instructions given in paragraph L–41, Packing, Storing, and Shipping Bottom Sediment Samples.

L–15 Maintenance of the Kullenberg Piston Corer.—In general the Kullenberg corer requires very little maintenance. The corer's storage cases contain spare parts. If the core cutter becomes dented or chipped or core catcher springs become damaged, replace the part. If piston leather cup washer becomes worn, put a new washer on the piston. After completion of the operation, the corer (especially set screws and movable fittings) should be rinsed with fresh water, dried, and oiled lightly. Store the equipment in the shipping cases.

L–16 The Ewing Piston Corer.—The Ewing Piston corer is designed for use where longer cores are desired. It is the largest corer in use by the U.S. Naval Oceanographic Office, and several modified versions of the corer have been built that weigh up to 2,000 pounds. Because of their weight and size, Ewing piston corers are operationally limited to ships equipped with a large winch carrying at least ½-inch wire, a boom or crane capable of supporting the corer, and sufficient deck space to assemble the corer.

The Ewing corer (2,000 pound) assembly consists of the following components (Fig. L–7):

The mainweight which includes the main body tube, the tailfin assembly, bail, ring, and 20 shaped cast lead drive weights. The overall length of the mainweight is about 5 feet;

The coring tubes, which are seamless steel tubing 2¾-inch outside diameter and 2½-inch inside diameter, are 20 feet long. Each end of the tube is drilled and tapped to take stainless steel setscrews;

Coring tube connector sleeves;

A piston with three leather washers and a check valve;

A piston stop collar;

A core catcher;

A cutting edge;

A tripping release mechanism and trigger line;

A 250- to 300-pound trigger weight, consisting of a coring device such as the Kullenberg piston corer rigged as a gravity corer (see par. L–12);

Plastic liner in 20-foot lengths with caps;

Miscellaneous spare parts.

L–17 Instructions for Assembling and Operating the Ewing Piston Corer.—The following tools are needed to assemble and operate the Ewing piston corer:

Pliers, 8-inch combination;
Screwdriver, medium;
Screwdriver, large;

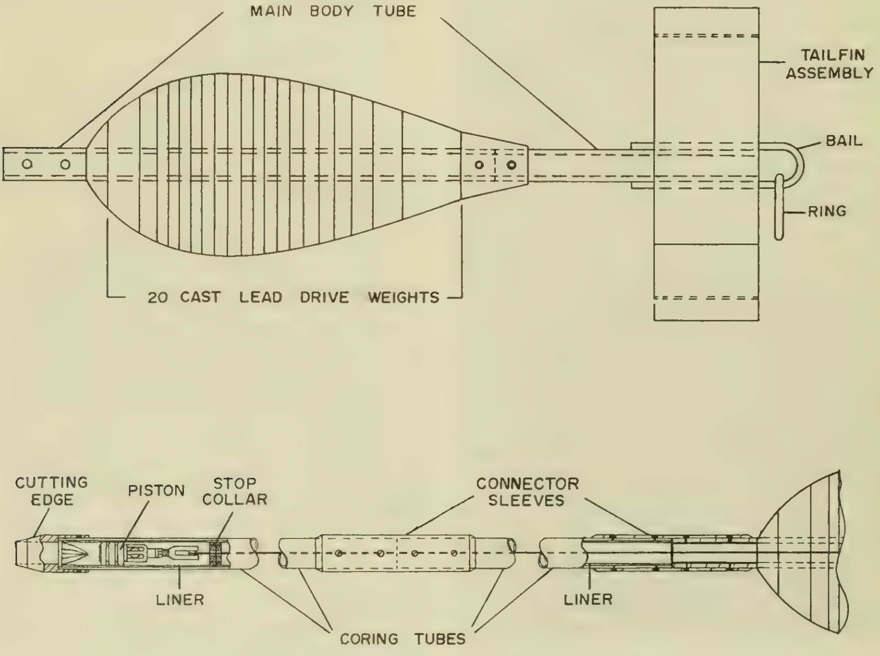


Figure L–7. The Ewing corer (2,000 pound) assembly.

Socket wrench set with ratchet handle;
Adjustable end wrench;
Small saw;
Pipe wrench with 3-inch jaw.

Step 1. Place the mainweight in a horizontal position on the deck or in a cradle, and secure a connector sleeve to the end of the main body tube.

Step 2. Insert and secure a coring tube into the connector sleeve. If more than one length of coring tube is to be used, bolt another connector sleeve at the end of the tube, and insert and secure another length of coring tube, etc. Up to three 20-foot coring tubes can be used. It is very important to bolt every hole in the connector sleeve.

Step 3. Insert a 20-foot length of plastic liner for each coring tube used. The plastic liner should be 2.45-inch outside diameter, 2.38-inch inside diameter, polycarbonate resin (or equal).

Step 4. Attach a suitable fitting to the end of the lowering wire (a Fiege fitting is commonly used), and thread the lowering wire through the main body tube and the coring tubes.

Step 5. Attach the piston to the lowering wire fitting, and connect the piston stop collar to the wire just above the piston. The stop collar consists of two disks that are held together with screws. It prevents the piston from passing through the main body tube and supports the entire weight of the corer during retrieval.

Step 6. Apply a light coat of oil to the leather washers on the piston, and pull the piston back into the coring tube, leaving just enough space for the core catcher.

Step 7. Insert the core catcher and secure the cutting edge in place. Place setscrews in all holes in the cutting edge to insure suction for the piston.

Step 8. Attach the wire clamp of the release mechanism onto the lowering wire 10 feet above the tailfin assembly. This free-fall distance can be increased if desired. Insert the bail into the slot of the release mechanism, and *insert the safety pin* into the release arm.

Setp 9. Assemble the trigger weight gravity corer.

Step 10. Attach the trigger line to the trigger weight corer and the end of the release mechanism arm so that the weight will be suspended the free-fall distance below the cutting edge of the corer.

Step 11. Using the boom or crane, hoist the corer over the side. If the corer has no lifting ring, splice a wire rope sling above and below the lead drive weights. Lower the coring tube(s) into the water with lowering lines, and pay out the boom until the entire coring assembly is suspended vertically from the lowering wire. Lower the trigger weight into the water, check that all lines are tending properly (fig. L–8), *remove the safety pin* from the release mechanism, lower the corer to the surface of the water, set the meter wheel counter dials at zero, and commence lowering.

Figure L–8. The Ewing corer.

L–18 Obtaining the Ewing Piston Core.—Lowering should be accomplished in accordance with instructions in paragraph L–29, Obtaining the Core.

L–19 Retrieving the Ewing Piston Corer.—As soon as the winch is stopped, reverse controls and commence hoisting. During the pull-out, that period when the corer is being pulled out of the bottom, watch the dynamometer for tension changes. Have all hands stand clear of the wire. Be ready to stop the winch if tension appears excessive. Normally, the tension will increase approximately 2,000 to 4,000 pounds during pull-out.

Step 1. When the release mechanism has surfaced, rig in the boom or crane and bring the gear to deck working level. Hoist aboard the trigger weight corer and detach the release mechanism from the wire.

Step 2. Next, bring the mainweight to deck working level and insert the swivel hook into the lifting ring or sling. Take a strain with the hook and slack the lowering cable to raise the coring tube to a near horizontal position. Support the coring tube with handling lines, bring the corer inboard, and lower it into a cradle to prevent it rolling on the deck.

L–20 Removing, Logging, and Labeling the Ewing Core.—The trigger-weight corer takes a sample which is of great importance in determining the surface sediment of the ocean floor. This cannot be determined from the top of the main core because that part usually is unconsolidated owing to piston action. The contents of the cutting edge and core catcher of the main coring tube also are of great importance; they represent the material found at the deepest penetration.

Step 1. Remove the trigger-weight core.

Step 2. Measure the length of sediment on the outside of the Ewing coring tube. Retain this measurement for step 6 below.

Step 3. Remove the screws that connect the cutting edge to the coring tube, and remove the cutting edge and the core cutter. Carefully remove any sediment retained by these pieces and place it in a sample jar.

Step 4. Remove the screws from the connector sleeve on the other end of this section of coring tube to disconnect it from the balance of the corer; then, extrude a few inches of the liner out of the bottom of the tube, and cap the bottom of the liner and seal it with adhesive and/or tape.

Step 5. Slide the liner the rest of the way out of the coring tube, and if the liner is full of sediment, cap and seal it. If the liner is only partially full of sediment, sound the liner to measure the length of the core, and with a saw, make a cut an inch or so above the top of the core to drain off excess water; then, cut off the liner and cap and seal it. Be sure to mark liner so top and bottom are not confused.

Step 6. When all liners are capped and sealed, log the samples (Ewing liners, trigger-weight core, and sample jar) on the Oceanographic Log Sheet–M. For instructions see paragraph L–39, Oceanographic Log Sheet–M Bottom Sediment Data.

Step 7. Label the samples according to instructions given in paragraph L–40, Labeling the Bottom Sediment Sample(s).

Step 8. If trigger-weight core liner is CAB plastic, coat with wax according to instructions in paragraph L–30, Applying Wax to Core Sample Liners.

L–21 Packing, Storing, and Shipping Ewing Cores.—Trigger-weight cores and sample jars are packed, stored, and shipped in accordance with instructions in paragraph L–41, Packing, Storing, and Shipping Bottom Sediment Samples; however, because of the size and weight of Ewing coring tubes, they are stored and shipped in a horizontal position.

L–22 Maintenance of the Ewing Corer.—Owing to its sturdy construction, the Ewing corer generally requires little maintenance; however, when the corer attains only partial penetration, the remaining portion of the core may fall over of its own weight and bend the coring tube beyond repair. In addition, cutting edges are often damaged by striking hard or rocky bottom, but they can be hammered or filed back into shape or replaced. After a coring operation is completed, wash down all parts, and lightly grease all threaded surfaces.

L–23 The Hydro-Plastic (PVC) Piston Corer.—The Hydro-Plastic (PVC) piston corer is a special purpose corer designed by the U.S. Naval Oceanographic Office to obtain semi-undisturbed core samples. The corer utilizes a high-impact grade of polyvinyl chloride (PVC) plastic for the coring barrel or tube. This lighter coring tube has several advantages. It collects a larger diameter core sample; it has a high retention of sediment interstitial water during storage, good sediment penetration, and it can be sectioned easily for sediment engineering property analysis. The PVC corer is widely used both as a piston and as a gravity corer, and it can be lowered with the oceanographic winch using $\frac{5}{32}$- or $\frac{3}{16}$-inch wire.

The Hydro-Plastic piston corer consists of the following components (fig. L–9):

Weight stand assembly including the main body tube, tailfin, bail, weight collar, and six cast lead weights (50 pounds each);

Plastic coring tube (PVC) available in random lengths up to 20 feet, plastic caps for the coring tube, and adhesive for sealing caps on tube;

Piston assembly;

Core catcher;

Cutting edge;

Drill jig;

Wire tripping release mechanism (same as for Kullenberg corer);

Trigger weight and trigger line;

Spare parts, bolts, and shipping cases.

L–24 Instructions for Assembling and Operating the Hydro-Plastic (PVC) Corer.—The following tools are needed to assemble and operate the Hydro-Plastic corer.

Pliers, 8-inch combination;

Screwdriver;

Socket wrench set with ratchet handle;

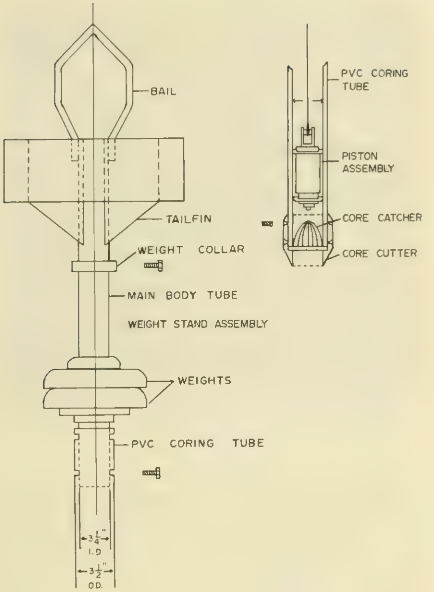


Figure L–9. The Hydro-Plastic (PVC) piston corer assembly.

Electric drill;
Saw;
Adjustable end wrench.

Step 1. Secure the drill jig flush with the end of a section of (PVC) coring tube, and drill ⅜-inch holes in the coring tube according to the jig pattern.

Step 2. With the main body tube in a horizontal position on the deck, secure the coring tube to the assembly with hex-head bolts.

Step 3. Insert the end of the lowering wire through the main body tube and the (PVC) coring tube, and attach it to the piston assembly.

Step 4. Pull the piston back into the (PVC) coring tube. The piston should be about 1 inch behind the leaves of the core catcher. Insert the core catcher. Slip the core cutter over the end of the (PVC) coring tube, and tighten the setscrews until the core cutter is secure.

Step 5. Attach the wire clamp of the release mechanism to the lowering wire the desired free-fall distance above the corer bail; hook the corer bail in the release mechanism slot; and *insert the safety pin.*

Step 6. Fasten the trigger weight line to the end of the arm of the release mechanism. The overall length of the trigger weight line should equal the total length of the corer plus the amount of wire allowed for free fall, then attach the tripping weight (approximately 80 to 100 pounds).

Step 7. Swing the corer outboard and suspend it over the side in a vertical position; then attach four to six cast lead drive weights to the weight assembly stand, and secure them in place with the weight collar (fig. L–10).

Step 8. Tape the bight of free-fall wire between the corer and the release mechanism to the weight assembly stand, to prevent kinking and hanging up, *remove the safety pin*, lower the assembly to the water surface, set the meter wheel to zero, and commence lowering the corer.

NOTE: To rig the Hydro-Plastic corer as a gravity corer do not use the piston assembly and substitute the following for step 3: Connect the free end of the lowering wire to the bail of the corer, insert the core catcher, and secure the cutting edge with the setscrews. A tripping release mechanism can be used if desired.

L–25 Obtaining the Hydro-Plastic (PVC) Piston Core.—Lowering should be accomplished in accordance with instructions in L–29, Obtaining the Core.

Figure L–10. Attaching weights to PVC corer.

L–26 Retrieving the Hydro-Plastic (PVC) Corer.—As soon as the winch is stopped, note the amount of wire out and commence hauling in immediately. The speed of the winch should be slow until the corer is picked up. During hoisting the piston supports the entire weight of the corer. Do not increase the speed of the winch until the corer is well clear of the bottom.

Step 1. When the release mechanism comes to deck working level bring in the trigger weight and remove the release mechanism from the wire.

Step 2. Hoist the corer to deck working level, and remove the weights (fig. L–11).

Step 3. Bring the corer aboard keeping lines on the core barrel to avoid excessive bending (fig. L–12).

Figure L–11. The Hydro-Plastic (PVC) corer at deck working level.

L–27 Removing, Logging, and Labeling the Hydro-Plastic (PVC) Core.

Step 1. Measure the length of sedimentation on the outside of the coring tube. Retain this measurement for step 5 below.

Figure L–12. Bringing the Hydro-Plastic (PVC) piston corer aboard.

Step 2. Remove the core cutter and core catcher, and cap and seal the end of the coring tube, using (PVC) cap and (PVC) solvent cement. Place any sediment on the cutter or catcher in a sample jar.

Step 3. Remove the hex-head bolts; slide the (PVC) core tube off the weight stand assembly; and sound the core tube with a rod to measure the length of the core.

Step 4. With a saw, make a cut through the core tube above the core sample. Let the water drain off slowly, then finish sawing off the excess core tube. Finally, cap and seal the core tube. (This coring tube does not require a wax coating.)

Step 5. Next log the samples (coring tube and sample jar) on the Oceanographic Log Sheet–M according to instructions in paragraph L–39, Oceanographic Log Sheet–M Bottom Sediment Data.

Step 6. Then label the samples according to instructions given in paragraph L–40, Labeling the Bottom Sediment Sample(s).

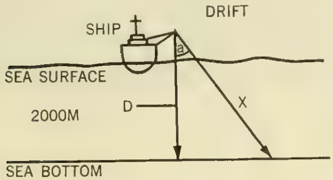
Step 7. Pack, store, and ship cores in accordance with instructions given in paragraph L–41, Packing, Storing, and Shipping Bottom Sediment Samples.

L–28 Maintenance of the (PVC) Hydro-Plastic Corer.—The Hydro-Plastic corer requires very little maintenance. Spare parts are contained in the storage case. Wash the weight stand assembly, core catcher, and core cutter to remove sediment, rinse with fresh water, coat lightly with oil, or wire brush and paint with red lead as necessary.

L–29 Obtaining the Core.—All corers rigged with a release mechanism, large or small, gravity or piston, should be lowered to near the bottom at a medium speed. When near the bottom, slow the winch and lower until an indication is observed that the release mechanism has tripped; then, stop the winch, note the time and the amount of wire out, and commence hauling in immediately.

In order to ascertain when the corer has reached bottom, the oceanographer should (1) estimate the amount of wire that will be required to reach the bottom taking into consideration any wire angle resulting from the ship's drift (2) observe carefully the tension on the lowering wire when it is estimated that the corer is nearing the bottom.

1. How to determine the amount of wire to pay out from the wire angle.—Frequently during bottom sampling operations, high wire angles occur as a result of the ship's drift. It is necessary to know how much wire to pay out so that the corer will reach the bottom without laying an excessive amount of wire. When wire is layed on the bottom, it usually kinks so badly that the kinked portion has to be cut off. By using the cosine of the surface wire angle and the sonic or charted depth, the approximate amount of wire needed to reach bottom can be estimated. Figure L–13 illustrates the problem.



2000M = D = DEPTH OF WATER
30° = a = SURFACE WIRE ANGLE
.866 = COSINE OF SURFACE WIRE ANGLE a
X = ESTIMATED AMOUNT OF WIRE TO PAY OUT

$$\cos a = \frac{D}{X};\ \cos 30° = \frac{2000}{X};\ .866 = \frac{2000}{X};\ X = 2309M$$

Figure L–13. **Determining the amount of wire to pay out from known wire angle.**

This method of estimating the amount of wire to be payed out is, at best, an approximation. It does not give exactly how much wire is required to reach bottom, but it affords a minimum and a maximum working range.

2. How to determine when bottom has been reached by observing wire tension. As the corer is lowered, the wire will exert a steady pressure on the block, and an indication that bottom has been reached will be observed when tension is relaxed owing to wire slack.

In shallow waters, a simple spring scale and block may be used to observe wire tension (fig. L–14). The block is placed on the winch wire; the spring end is secured to a rigid part of the ship, such as a rail stanchion; and tension on the wire is observed as the wire is payed out.

In deep water operations, deep sea dynamometers are used to record tension on the wire. Some of these are built into the oceanographic winches others are rigged for the operation (fig. L–15). When the tripping weight strikes the bottom, it releases the corer; the free fall of the corer causes the wire to slacken and the spring scale or dynamometer to indicate a reduction in tension. The instant the tension is relaxed owing to slack wire, stop the winch, reverse the controls, and commence hoisting. Quick reaction to the reduced tension is very important in obtaining piston corers since the piston action depends on stopping the winch with the piston about 1 foot off the bottom.

Figure L–14. A spring scale dynamometer.

NOTE: The Sonar Pinger, a bottom signaling device, is another method that has proved very satisfactory in deep sea coring. The pinger is attached 20 or 30 meters above the coring device, and the pinger's direct and bottom reflected signals are monitored with a Precision Depth Recorder (PDR) and an oscilloscope to determine when the corer has reached bottom. Chapter R, Sonar Pinger, explains the operation.

Figure L–15. Dynamometer attached to retractable A-Frame.

When using gravity corers without a release mechanism, the corer should be lowered at the maximum payout rate of the winch; however, as soon as an indication (reduction in wire tension) is observed that the corer has reached the bottom, stop the winch immediately to prevent excessive wire being layed on the bottom.

L–30 Applying Wax to Core Sample Liners.—An electrically heated vertical wax bath (fig. L–16) is used by the U.S. Naval Oceanographic Office for coating CAB (Cellulose Acetate Butyrate) plastic sediment core liners. The vertical bath is constructed of copper sheet, and its main cylinder has an inside diameter of about 7 cm. The bath is approximately 130 cm. high and holds about 3.6 kg. of wax. It is heated by a sturdy flexible mantle approximately 180 cm. long by 6 cm. wide that operates on 110 volts a.c. Victory Brown–155 microcrystalline wax is used.

The operation of the wax bath aboard ship is as follows: A liner is withdrawn from the core barrel, capped, wiped dry, labeled, and dipped quickly into the bath. If the core liner is longer than the wax bath and is not completely coated, the remainder can be coated using a brush. Care should be taken to heat the wax only a few degrees above its melting point of 68.33° C. as excess heating changes the properties of the wax.

As a field expedient when wax bath equipment is not available aboard ship, CAB (Cellulose Acetate Butyrate) plastic sediment core liners can be wrapped with several layers of a plastic wrap such as "Saran" Wrap to reduce desiccation.

Figure L–16. Applying wax to a plastic liner.

L–31 Snapper or Grab Samplers.—Various snapper or grab samplers are used to obtain small samples of the superficial layers of the ocean bottom. These samplers are excellent for sampling surface sediments, but they do not provide an undisturbed sample showing structure and microlayering. The sampling operations using snapper or grab bottom samplers are recorded on Oceanographic Log Sheet–M; the samples are stored and shipped in sample jars; and the samples are labeled with the Bottom Sediment Label. The recording, labeling, and shipping procedures are explained in paragraphs L–39, L–40, and L–41. Examples of these bottom samplers include the Orange Peel bucket sampler, the Clamshell snapper, the Van Veen bottom sampler, and the underway Scoopfish.

L–32 Orange Peel Bucket Sampler.—The Orange Peel bucket sampler is one of the grab samplers used by the U.S. Naval Oceanographic Office. It derives its name from its resemblance to the segments of a peeled orange (fig. L–17). The sampler weighs 45 pounds and can be equipped with four lead blocks to increase its weight to approximately 120 pounds. It holds between 200 and 300 cubic inches of sediment when full; however, the fine portion of the sample is subject to washing. Hence, the sediment obtained may not be completely representative of the bottom. The Orange Peel bucket sampler generally is operated from the oceanographic winch using $\frac{3}{16}$-inch wire.

Figure L–17. Orange Peel bucket sampler rigged for lowering.

L–33 Operating the Orange Peel Bucket Sampler.—The Orange Peel bucket sampler is simple to operate, and the only tool required is an adjustable wrench. The sampler usually is shipped to the field completely rigged and ready to attach to the lowering wire (fig. L–18); nevertheless, the complete procedure will be described to familiarize the operator with the process.

Step 1. Open the sampler's jaws by lifting device with the lowering handle hook, and set it upright on the deck.

Step 2. Thread the closing line through the upper sheave and make a thimble loop connection about 18 inches above the sampler, using one wire rope clip.

Step 3. Make a second thimble loop connection about 10 inches above the first loop, using one wire rope clip, and place a wire rope hook on the thimble (point of the hook should be shortened).

Step 4. Midway between the two thimbles place a wire rope clip around the long and short end of the rope from each thimble (three wires).

Step 5. Check the closing mechanism by opening and closing the jaws. Suspend by the closing wire to close; suspend by the handle hook to open. Lubricate ratchet chain, sheaves, and jaw hinges until the sampler operates smoothly.

Step 6. If more weight is desired, attach four lead blocks to the frame using hook bolts. Attach the lowering line to the thimble on the closing line with a shackle.

Step 7. Engage the lowering hook with the lowering handle hook to lock the jaws open during lowering.

Step 8. Suspend the Orange Peel bucket sampler over the side. Lower it to the water's surface. Set the meter wheel counter to zero, and commence lowering at half speed (approximately 60 meters per second) until the bottom is reached.

Step 9. As soon as the sampler reaches bottom, tension on the lowering wire will be relaxed. This will release the lowering hook from the lowering handle hook. Stop the winch immediately to avoid laying wire on the bottom. Reverse the winch and commence hoisting slowly. This will put the weight of the sampler on the closing wire which activates the ratchet chain and lower sheave that close the jaws.

Step 10. When the sampler comes to deck working level, bring it aboard with a boat hook, and dump the sample by lifting the sampler by the lowering handle hook. Examine the sample and place a representative portion of it in a sample jar. Label the jar with a bottom sample label, and record the necessary information on Log Sheet–M. If excessive washing of the sample is encountered, a canvas hood should be placed over the sampler.

L–34 Maintenance of the Orange Peel Bucket Sampler.—After each lowering is completed, wash the remaining sediment from the sampler, rinse with fresh water, dry, and lubricate all moving parts. Check cotterpins, and ratchet chain links; tighten sheave bolts, and weight bolts; and when necessary, wire brush the sampler and paint it to prevent corrosion.

L–35 Clamshell Snappers.—Two general types of clamshell snappers are used by the U.S. Naval Oceanographic Office. One, shown in figure L–19, is about 30 inches long and weighs about 60 pounds. The other is only 11 inches long and weighs only 3 lbs.

The larger clamshell snapper is ruggedly constructed of stainless steel. The cast snapper jaws are closed by heavy arms actuated by a strong spring and a lead weight. In the open position, a foot device extends below the jaws so that it strikes bottom first and triggers the snapper. The impact moves the arms up releasing the jaws which snap shut with considerable force. The jaws trap about a pint of bottom material. This snapper is equiped with tailfins and is lowered from the oceanographic winch with $\frac{5}{32}$-inch wire.

The small type clamshell snapper, called a mud snapper, is attached to the bottom of a

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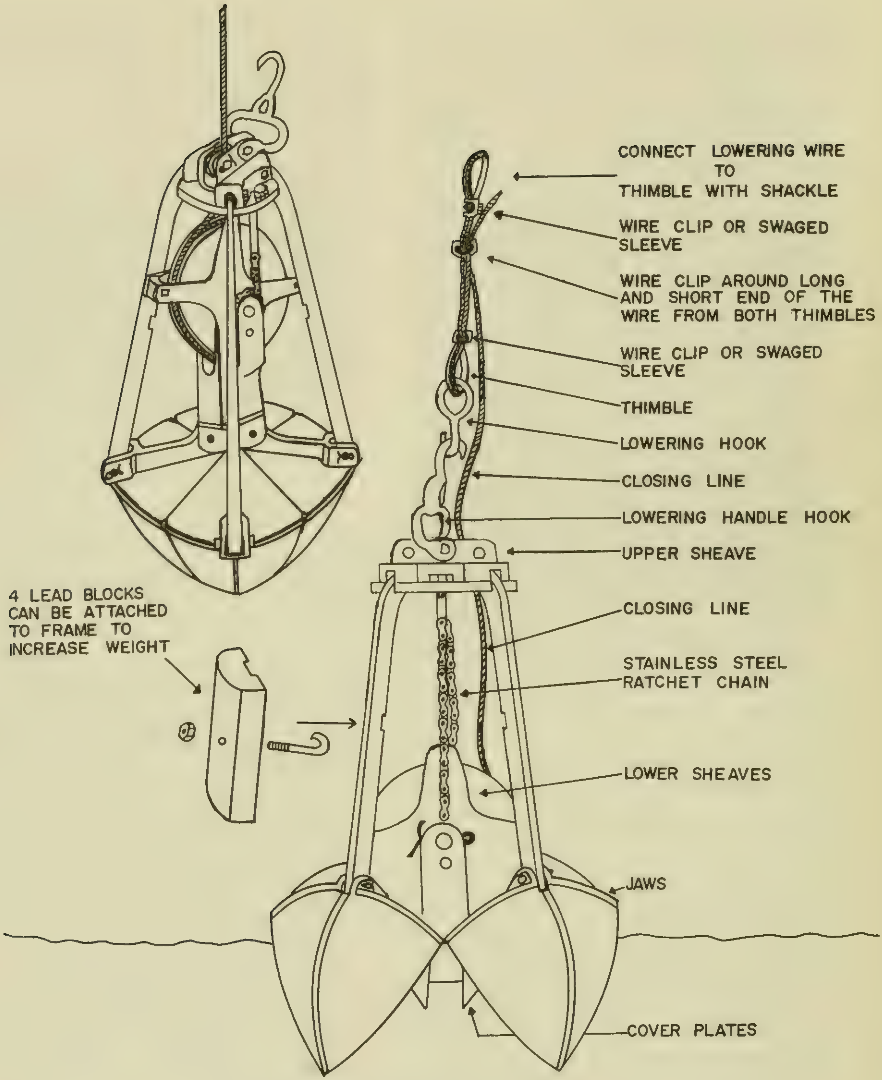


Figure L–18. Orange Peel bucket sampler.

sounding lead by means of a hole drilled in the lead. The jaws are actuated by a spring, and the tension on the spring can be adjusted by tightening or loosening a screwcap. The jaws are held open by engaging two trigger pins within the jaws. The mud snapper may be operated in shallow water by hand lowering or it may be lowered from a bathythermograph or oceanographic winch.

Samples are placed in sample jars, and labeled, and the operation is recorded on the Oceanographic Log Sheet–M.

Very little maintenance is required for the clamshell snappers. After the operation is completed, wash off any remaining sediment, rinse in fresh water, dry, and lubricate any moving parts.

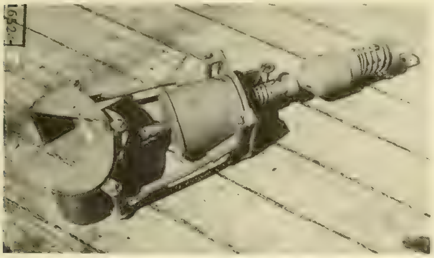


Figure L–19. Clamshell snapper.

L–36 The Scoopfish Underway Bottom Sampler.—The Scoopfish (fig. L–20) is designed to obtain a sample without stopping the ship. It is ideal for rapid reconnaissance sampling of surface sediments, but it does not adequately sample very coarse (gravel or larger) sediments. The sampler weighs 11 pounds and is 15 inches long. It has the capacity to collect 10 cubic inches of bottom sediment. It is lowered from the bathythermograph winch in depths less than 100 fathoms from a ship underway at speeds not over 15 knots. When lowering, care must be taken that the nose lid is not prematurely tripped as the sampler enters the water. The scoopfish is allowed to fall freely in the same manner as the bathythermograph (see ch. C).

During the samplers descent, the towing arm is engaged toward the rear, and the nose lid is hooked back in open position. When the scoopfish strikes the bottom, the sample cup is pushed back releasing the catch on the nose lid and the towing arm. The nose lid snaps shut trapping the sediment sample, and the towing arm rotates forward. The latter movement shifts the center of gravity, allowing the scoopfish to free itself from the bottom and be raised without end-over-end spinning. Once on deck, the cup is removed, and for rapid sampling, another cup inserted, the nose lid and towing arm reset, and the scoopfish lowered at once. The sediment sample from the cup is placed in a jar and labeled, and the operation is recorded on the oceanographic Log Sheet-M. When lowerings are completed the scoopfish is washed down and all moving parts are lubricated.

The scoopfish is used where numerous samples are to be obtained in a limited time.

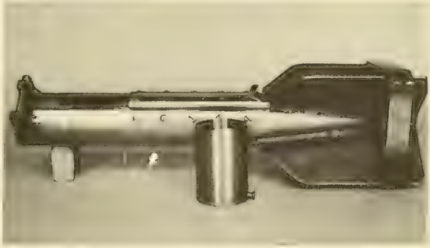


Figure L–20. Scoopfish underway sampler.

L–37 The Van Veen Bottom Sampler.—The Van Veen bottom sampler is shown in figure L–21. It weighs approximately 74 pounds and is capable of collecting 200 or 300 cubic inches of sediment sample. Because the jaws of the sampler overlap, a sample obtained from considerable depth can be brought to the surface with little loss by washout.

To operate the Van Veen sampler, rig the cradle as shown in figure L–21. The sampler trigger hook has been modified to facilitate sampling.

In lowering the sampler, care must be exercised as it is entering the water because any appreciable decrease of tension on the lowering wire will trip the sampler prematurely. Lowering speed should be maintained at about 60 meters per minute.

Van Veen bottom samples are placed in jars or canvas bags and labeled, and the operation is recorded on the oceanographic Log Sheet–M. When lowerings are completed, the sampler is rinsed with fresh water, dried, and all moving parts are lubricated.

L–38 Dredges.—Dredging operations for bottom sediments, usually, are conducted only when coring and grab sample devices have failed to obtain a bottom sample. Dredges used aboard U.S. Naval Oceanographic survey ships include triangular shaped, box shaped (fig. L–22), and pipe dredges.

Dredges are constructed of $\frac{1}{4}$-inch or heavier steel plate, and they vary in size and weight. The forward end of the dredge is open and the aft end is covered with a heavy grill which is designed to retain a certain size material.

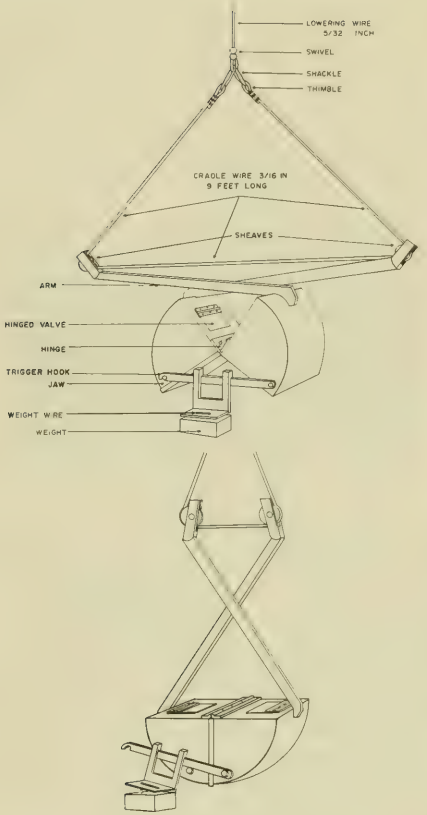


Figure L–21. The Van Veen sampler with modified trigger.

The dredge is operated from a heavy duty winch or boom using ½-inch diameter lowering wire. During dredging operations, the ship is lying to as the dredge is lowered; then, the ship slowly tows the dredge along the bottom at 2 or 3 knots.

While the dredge is being towed, the deep sea dynamometer must be watched for irregular tension on the towing wire. If the tension is very irregular, the dredge probably is skipping, and more wire should be payed out to increase the scope. Also, if rocky irregularities such as ledges are encountered, the dredge will tend to foul. If this occurs, the ship is stopped and, if possible, reversed and maneuvered to free the dredge. If this maneuver fails, a weak link in the dredge bridle usually gives way, and upsets the apparatus dumping the sample and freeing the dredge; thus, saving both the dredge and the lowering wire.

Rocks and representative samples of other bottom material obtained should be packed in wooden boxes, canvas bags, or sample jars, labeled, recorded on the oceanographic Log Sheet-M, and shipped in accordance with instructions contained in paragraphs L–39, L–40, and L–41.

Figure L–22. Box shaped dredge.

L–39 Oceanographic Log Sheet-M Bottom Sediment Data.—The Oceanographic Log Sheet-M is used for recording bottom sediment samples. The following items of information are recorded on the M-sheet; (fig. L–23):

Vessel. Enter the name of the ship from which the sample is being collected.

Cruise. Enter the number of the cruise or the project designator.

Checked by. Enter the name of the person checking M-sheet against core samples.

Date Checked. Enter date, e.g., 12 Jan. 1965, samples were checked against M-Sheet.

Bottom Sediment No. (*BS–*). Enter Bottom Sediment Number assigned to Sample. (This number must agree with sample number on Sample Label.)

Date (*19*). Enter year at top of column and Day and Month, e.g., 10 Jan., for date sample was collected.

Sample Position (*Latitude Longitude*). Enter position of ship at time sampler reached bottom.

OCEANOGRAPHIC LOG SHEET–M
BOTTOM SEDIMENT DATA
PRNC-HNO-3167 13 (Rev. 4-61)

Return To
U S NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D C

VESSEL USS ATKA (AGB-3)			CRUISE O-191								CHECKED BY R. Stewart	DATE CHECKED 29 August 1962
BOTTOM SEDIMENT NO (BS-)	DATE (1962)	SAMPLE POSITION LATITUDE (N)	LONGITUDE (W)	DEPTH (Fathoms)	GEOMORPHOLOGY OF IMMEDIATE AREA	TYPE OF SAMPLER	WEIGHT OF SAMPLER	APPROX PENETRATION	LENGTH OF CORE	ROCK COLOR CHART CORE NUMBERS CORE TOP	CORE BOTTOM	FIELD DESCRIPTION OF CORE AND REMARKS	OBS IN T
1	9 Aug.	71°00′	015°00′	1,107	GREENLAND SEA OFF EAST COAST OF GREENLAND	EWING CORER (2) 20FT TUBES	2,000 lbs	750 cm	721 cm	5YR 5/2	5Y 4/1	PALE BROWN FINE SILT GRADING DOWNWARDS TO DARK OLIVE FINE SAND AND SILT. 2 SECTIONS	GK
1A	9 Aug	71°00′	015°00′	1,107	GREENLAND SEA OFF EAST COAST OF GREENLAND	EWING CORER TRIGGER WT	80 lbs	25 cm	20 cm	5Y 4/1	5Y 4/1	DARK OLIVE SAND AND SILT.	GK
1B	9 Aug	71°00′	015°00′	1,107	GREENLAND SEA OFF EAST COAST OF GREENLAND	EWING CORER CUTTER & CATCHER						DARK OLIVE SAND AND SILT.	GK
2	11 Aug	72°57′	011°00′	1,105	GREENLAND SEA OFF EAST COAST OF GREENLAND	HYDRO PLASTIC (GRAVITY)	200 lbs	200 cm	140 cm	5YR 5/2	10YR 2/2	PALE BROWN TO DUSKY YELLOWISH BROWN COARSE SANDY SILT. (NO SEDIMENT ON CUTTER OR CATCHER.)	GK
3	12 Aug	74°58′	009°57′	1,064	GREENLAND SEA OFF EAST COAST OF GREENLAND	ORANGE PEEL GRAB	90 lbs					PALE BROWN COARSE SANDY SILT.	GK
4	15 Aug	70°58′	005°00′	601	SOUTH GREENLAND SEA	PHLEGER CORER	80 lbs	61 cm	54 cm	10YR 4/2	10YR 4/2	SILTY CLAY W/SOME PEBBLES; UNIFORM COLOR THROUGHOUT.	GK
5	16 Aug	73°59′	000°08′	963	CENTRAL GREENLAND SEA	KULLENBERG CORER	250 lbs	275 cm	245 cm	10YR 4/2	10YR 2/2	DARK YELLOWISH BROWN TO DUSKY YELLOWISH BROWN COARSE SANDY SILT. (NO SEDIMENT ON CUTTER OR CATCHER)	GK
6	19 Aug.	76°54′	000°13′	936	CENTRAL GREENLAND SEA	ORANGE PEEL GRAB	90 lbs					MAINLY SAND AND SILT; SOME PEBBLES.	GK
7	21 Aug	78°58′	002°55′	686	NORTH GREENLAND SEA	ORANGE PEEL GRAB	90 lbs.					SOME SILT, SAND, GRANULES, PEBBLES, AND COBBLES	GK
8	22 Aug	80°48′	006°42′	326	NW OF SVALBARD	ORANGE PEEL GRAB	90 lbs					LARGE BOULDER IN CLAYEY SILT, WORM TUBES, SOME SMALL MOLLUSCS.	GK
9	24 Aug.	79°00′	008°30′	213	WEST OF SVALBARD	PHLEGER CORER	80 lbs.	80 cm	74 cm	5YR 4/4	5YR 5/2	SMALL PEBBLES ON TOP OF CORE; SOME SAND IN TOP FEW INCHES GRADING TO SILT AND CLAY.	GK
9A	24 Aug.	79°00′	008°30′	213	WEST OF SVALBARD	CUTTER & CATCHER						CLAY	GK
10	28 Aug	74°58′	010°00′	738	CENTRAL GREENLAND SEA	KULLENBERG CORER	250 lbs.	275 cm	245 cm	10YR 4/2	10YR 2/2	DARK YELLOWISH BROWN TO DUSKY YELLOWISH BROWN; COARSE SANDY SILT. (NO SEDIMENT ON CUTTER OR CATCHER.)	GK

Figure L–23. Oceanographic Log Sheet–M.

Depth (Fathoms). Enter sonic depth at time sampler reached bottom.

Geomorphology of Immediate Area. Enter any information concerning the land or submarine relief features of the area.

Type of Sampler. Enter the name and type Sampler, e.g., Kullenberg (gravity), Hydro-Plastic (Piston), Orange Peel, Pipe Dredge.

Weight of Sampler. Enter the approximate total weight of the device (corers only).

Approx. Penetration. For core samples only, as soon as the corer is brought aboard, measure the length of sediment visible on the outside of the coring tube, and enter the measurement in feet and inches or centimeters. *Indicate the unit of measurement.*

Length of Core. For core samples; measure the length of the core sample in the coring tube or plastic liner. Enter the measurement in feet and inches or centimeters. *Indicate the unit of measurement.*

Rock Color Chart Core Numbers, Core Top, Core Bottom. Examine the sediment at the top and bottom of the core, and if a Geological Society of America Rock-Color Chart is available, enter the matching color code number. If a rock-chart is not available, leave blank.

Field Description of Core and Remarks. Enter field description of bottom sediment sample. Enter remarks concerning operational difficulties or instrument damages such as degree of wire angle, dented core cutter, most of sample washed out, sample retained on core catcher and cutting edge, core in sections (1, 2, 3), etc.

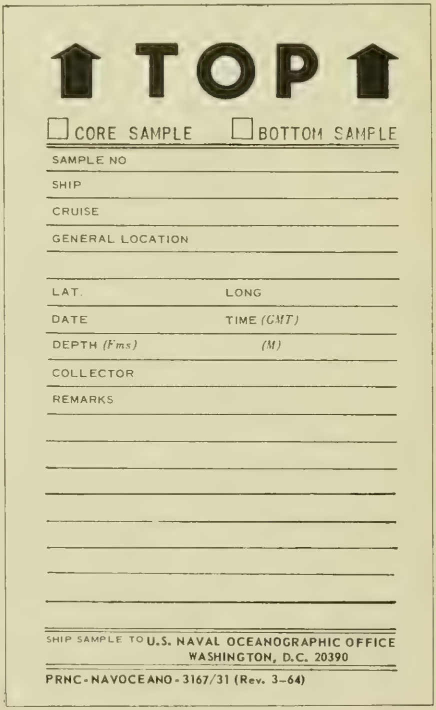
Field Description.—A complete description of a bottom sample consists of: One or more adjectives descriptive as to size, composition, or consistency; one or more adjectives designating color; and one or more nouns naming the class of bottom material. The descriptions should be based on the nouns and adjectives of table L–1, should indicate grain diameters determined by comparison or estimation, and should utilize the standard abbreviations given in the Classification table for bottom samples to be symbolized on nautical charts (table L–1) and in part "S" of H.O. Chart No. 1, Nautical Chart Symbols and Abbreviations, September 1963. Descriptive terms needed, which are not included in the chart, should be written in full. Indicate the nature of the bottom material by an adjective such as soft, hard, or sticky and the size as coarse, fine, or medium. Indicate the form of occurrence (reef, bank, whole shells, or fragments) for shell and coral. When consistency of the bottom is determined by feeling with a leadline or pole and without visual examination; it should be described by an adjective, hard or soft, without a noun. The use of "rocky" should be avoided for this purpose and should be used only when it is known that the bottom consists of material larger than stones, but no specimen can be obtained for examination.

The color of the specimen should always be noted while it is wet, using the color names of Part "S" of Chart No. 1. The terms "dark" and "light" should never be used alone but should indicate the intensity of a color. (When warranted for special operations, rock-color charts of the Geological Society of America will be furnished for determination of coloration.) The description should be recorded in the following order: size or consistency, color, composition, and classification.

OBS. INIT. Enter observers initials.

The original M-Sheet *should not* be packed and shipped with the samples. It should be hand carried or mailed separately.

L–40 Labeling the Bottom Sediment Sample(s).—The bottom sediment sample label, shown in figure L–24, should be securely attached to all bottom sediment samples (core liners, sample jars, wooden boxes, or canvas bags). The items on the sample label should


TOP

☐ CORE SAMPLE ☐ BOTTOM SAMPLE

SAMPLE NO

SHIP

CRUISE

GENERAL LOCATION

LAT. LONG

DATE TIME *(GMT)*

DEPTH *(Fms)* *(M)*

COLLECTOR

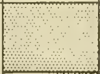
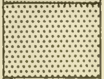
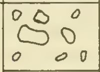
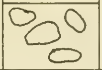
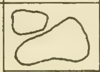
REMARKS

SHIP SAMPLE TO U.S. NAVAL OCEANOGRAPHIC OFFICE WASHINGTON, D.C. 20390

PRNC-NAVOCEANO-3167/31 (Rev. 3–64)

Figure L–24. Bottom sediment sample label.

Table L-1. Classification table for bottom samples to be symbolized on nautical charts

FIELD CLASS	TYPE	SIZE in mm.	VISUAL GUIDE	APPROX. SIZE (inches)	FIELD CRITERIA
Mud (M)	Clay (Cl)	less than .005			Smooth, plastic, and sticky
	Silt (Slt)	0.1 0.005			Somewhat gritty.
Sand (S)	Fine (f)	0.1-0.3			Individual particles can be distinguished easily by eye.
	Medium (med)	0.3-0.5			
	Coarse (crs)	0.5-2.0			Roundness or angularity of particles can be determined easily by eye.
Gravel (G)	Fine (f)	2.0-4.0			
	Coarse (crs)	4.0-6.0			
Pebbles (P)	Fine (f)	6.0-10		1/4-1/2	
	Medium (med)	10-20		1/2-3/4	
	Coarse (crs	20-64		3/4-2½	
Stones (St)		64-256		2½-10	
Boulders (Blds)		greater than 265		greater than 10	
	Shell (Sh)	Calcium carbonate fragments which may be of any size but are visually identifiable when gravel-sized or larger. Idiciate size as well as composition; e.g., gravel-sized Shell, or pebble-sized Coral.			
	Coral (Co)				
	Rock (Rk)	Visible reefs or rock outcrops.			

agree with those entered on the M-Sheet, as this is the only means of identifying the samples when they arrive at the laboratory. A feature of the label is that when it is properly attached the top of the core liner is indicated by the word "top" and two flanking arrows. Labels should be taped to sample containers, and in those cases where the core liner is waxed, the coat of wax should be applied over the label. Because the waxing process often obscures the writing on the label, it is good practice to duplicate the label before waxing and to tape the duplicate label over the waxed surface.

L–41 Packing, Storing, and Shipping Bottom Sediment Samples.—All cores should be stored aboard ship in an upright position to prevent disturbance to the structure of the sediment. Cores to be analyzed for engineering properties, however, should be handled with extra care, and the engineering properties analysis should be performed at the first available shore facility. When sediment samples are taken off the ship and will require packing for shipment to a laboratory, special shipping cases should be used for the cores, and the sample jars should be packed carefully to reduce the possibility of breakage during shipment. The cases for the cores should be provided with a screw-fastened top and should be plainly marked *HANDLE WITH CARE* and *THIS SIDE UP.*

Cases of cores and bottom samples to be shipped to the Oceanographic Office should be addressed as follows:

To: Commander
U.S. Naval Oceanographic Office
Attention: Geological Laboratory
Washington, D.C. 20390

CHAPTER N

UNDERWATER PHOTOGRAPHY

N–1 General Remarks.—Recent years have seen a marked increase in the development and use of underwater photography. Location and identification of sunken ships and other submerged objects, studies of bottom topography, studies of fish and other biological life, studies of reefs and coral growth, and studies of the ocean bottom in relation to its sediment structures are a few of the many applications of underwater photography.

N–2 Underwater Cameras.—Underwater cameras may be classified under two categories: Those operated in shallow water by divers, and those automatic deep sea systems that are lowered from ships. Both groups use either color or black and white film. The deep sea underwater camera systems are automatic systems that are lowered from ships or installed on deep sea submersible vehicles. The Edgerton, Germeshausen, and Grier (EG&G) deep sea underwater camera systems (fig. N–1) used by the Oceanographic Office to produce stereo, double-camera, or single-camera photography make use of the following components: (1) Camera, 35 mm., Still, Electrically-driven; (2) Light Sources; (3) Battery Pack; (4) Mounting Rack; and (5) Sonar Pinger.

N–3 Camera (EG&G Model 204).—This camera (fig. N–2) is an electrically-driven, 35-mm., still camera encased in a watertight steel housing tube. The housing tube is designed to operate to a maximum pressure depth of 17,500 psi. The camera takes about 500 separate exposures on a standard 100-foot roll of film. The lens, an f/4.5 Hopkins, is specially designed to correct for the distortion introduced when light passes from the water through the housing window to the air inside the camera housing. The lens is prefocused to give a depth of field in water of about 3½ to 20 feet. The maximum distance above bottom at which photographs of the bottom are possible is determined by the film speed, light intensity, and lens aperture.

N–4 Light Source (EG&G Model 214).—Illumination for underwater photography is provided each camera by an accompanying 200 watt-second, electronic flash (strobe) unit (fig. N–3). The unit is enclosed in a water-tight steel housing tube and utilizes a Xenon flashtube which is fired by a bank of capacitors. These strobe units are designed to work in synchronization with the camera advance motor. Approximately each 15 seconds, the capacitors discharge and fire the strobe light; then, during the next 6 seconds, the film advance motor moves the film to the next frame; meanwhile, the capacitors are being charged to repeat the cycle.

N–5 Battery Pack (EG&G Models 280 and 281).—Power for the light source and the camera motor is supplied by two battery packs (fig. N–4). They are contained in steel tubes similar to those of the camera and the light source. Each battery pack contains two series connected six-volt, silver zinc wet cell batteries (fig. N–5). Model 280 contains a clock-driven mechanical time delay switch, and Model 281 contains a 15-second cycling device. Batteries usually must be recharged after each lowering.

N–6 Mounting Rack.—U.S. Naval Oceanographic Office survey ships use 6-, 8-, and 12-foot long Unistrut (a registered trade name) mounting racks for underwater photography. The racks are designed to accommodate a variety of camera arrangements. The rack is constructed of galvanized or stainless steel channel members, brackets, spring-loaded nuts, bolts, and instrument holders. The spring-loaded nuts slide to any position in the channel members so that cameras, light sources, battery packs, and pinger can be mounted to suit the project at hand.

N–7 Sonar Pinger.—The Sonar pinger is a battery powered, automatic-cycling, submersible, sound-generator unit for positioning oceanographic equipment within measured distances of the ocean floor. Chapter R gives a complete description of the Sonar pinger. This unit operates independently of the camera components.

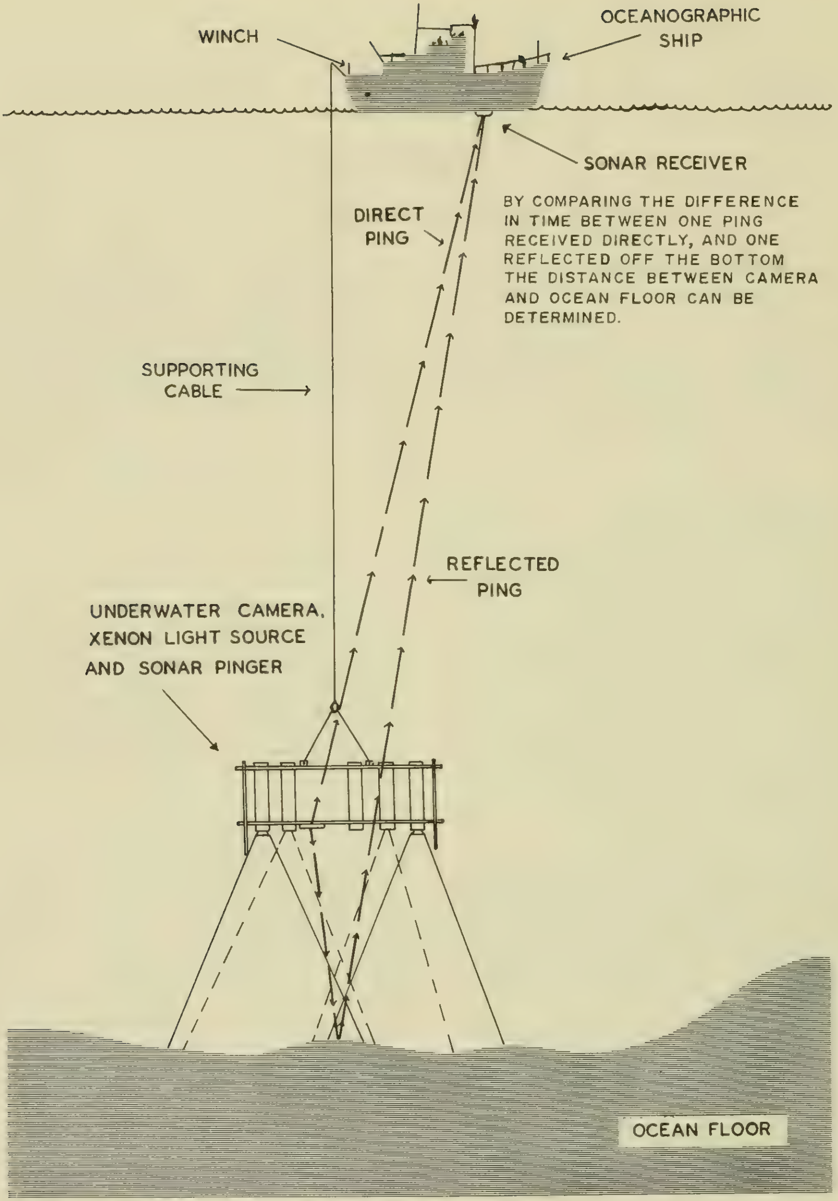


Figure N–1. Deep sea underwater camera system.

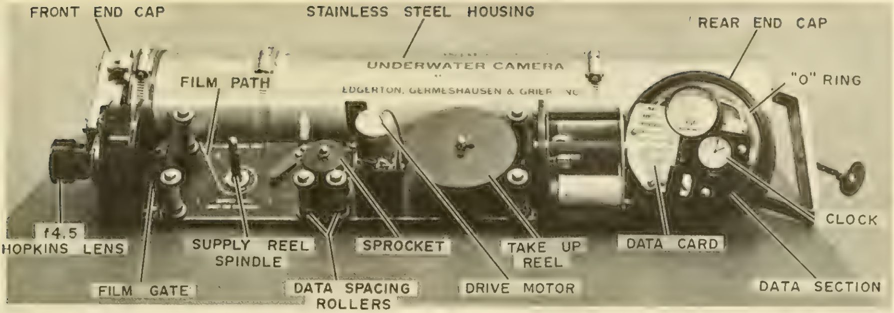


Figure N–2. Underwater camera (EG & G Model 204).

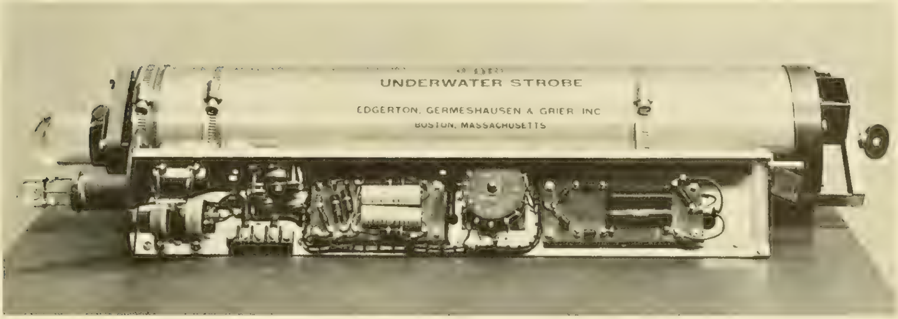


Figure N–3. Underwater light source (EG & G Model 214).

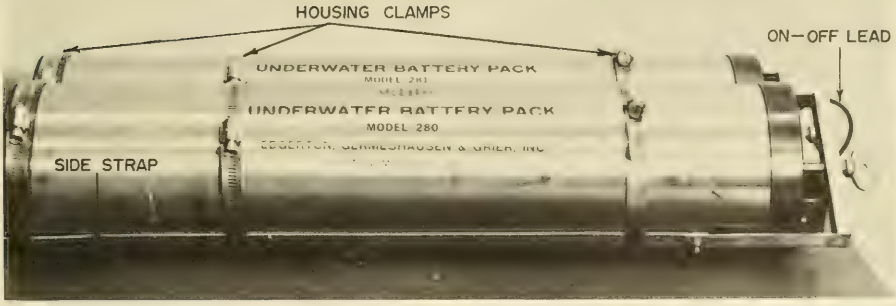


Figure N–4. Underwater battery packs (Model 280 contains time delay unit and Model 281 contains 15-second cycling device).

Figure N–5. Silver zinc wet cell battery and filling kit.

N-8 Instructions for Assembling Mounting Rack.—The parts for the mounting rack are listed and described in table N–1:

Table N-1. Unistrut (A registered trade name) mounting rack parts

Part No.	Number required	Description (hot dip galvanized steel or stainless steel)
1	6	Cross Member, Channel, 13″ Long.
2	4	Horizontal Member, Channel, 72″, 96″, or 144″ Long.
3	4	Leg, Channel, 30″ Long.
4	20	Angle Bracket, 90° Angle Fitting.
5	8	Jointer, "Z" Shape Fitting.
6	4	Shackle Plate.
7	16	Channel, End Cap.
8	134	Hexagonal Head Bolt, ½″ (assorted).
9	134	Split Lockwasher and Flat Washer, ½″.
10	134	Spring-Loaded and Standard Nut, ½″.
11	4	Frame Strut, Right.
12	4	Frame Strut, Left.
13	8	Frame Cross Piece.
14	8	Housing Clamp with Thumb Screw.

Directions for assembling mounting rack are illustrated in figures N–6 and N–7.

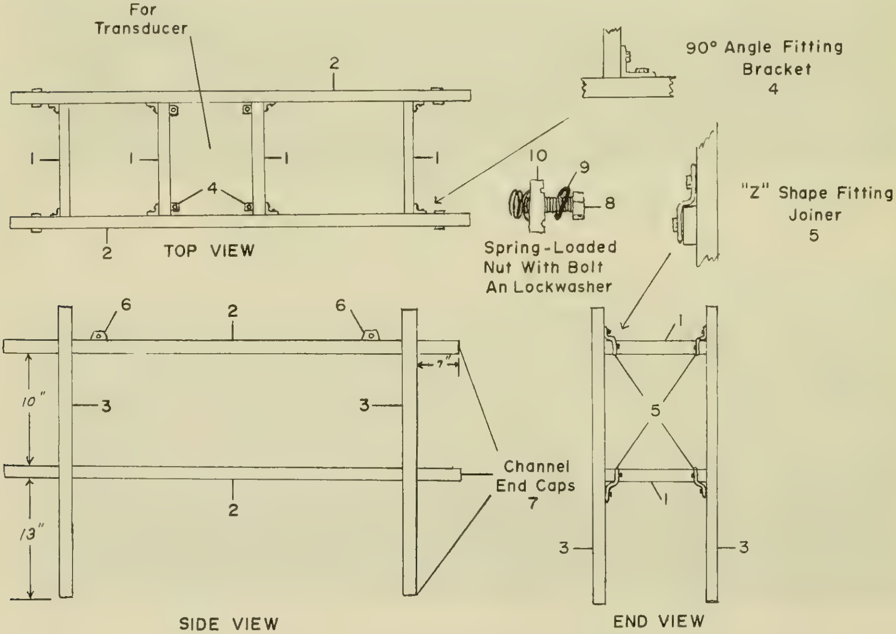


Figure N–6. Top, side, and end view of mounting rack.

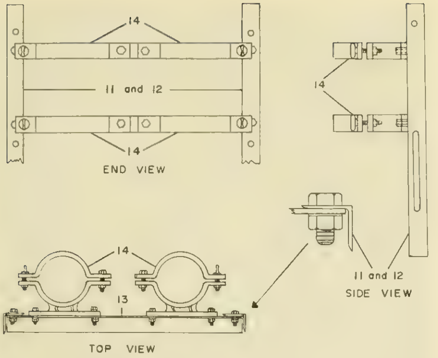


Figure N–7. Top, side, and end view of instrument holder assembly.

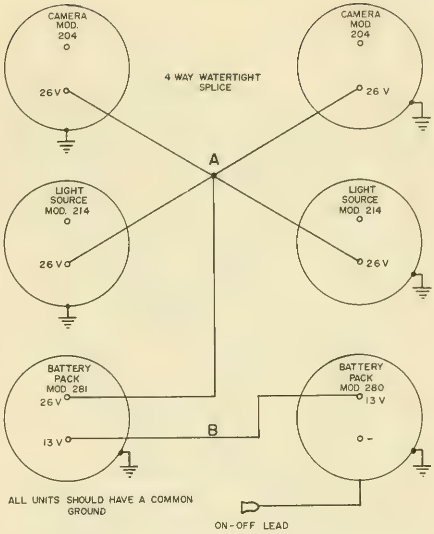


Figure N–8. Wiring diagram for cameras, light sources, and battery packs.

N–9 Checkout of the Underwater Camera System.—At the beginning of a survey operation, the camera system should be checked out to be certain that all components are functioning properly. The instruction manual for the camera should be on hand as a reference to supplement the following instructions:

Step 1. Remove rear end caps from the housings, and remove chassis from cameras, light sources, and battery packs. *CAUTION:* The end caps and housings for all units must be kept mated or flooding could result.

Step 2. Remove end caps from housings. Inspect "O" rings and sealing surfaces of front end caps for cuts, scratches, dirt, etc.; apply a light coating of grease on the "O" rings and the sealing surfaces. Replace front end caps, being sure to tighten housing clamps and side straps. Rear end caps must be temporarily replaced with wing nut tightened in order to secure front end caps.

Step 3. Load film (use dummy film to familiarize operator with film loading technique) by threading through the camera in accordance with film path marked in white on the baseboard (fig. N–2).

CAUTION: Do not bend the spring plate of the film gate away from film gate block when inserting film. Press lower edge of film into the slight groove between the top of the block and the spring plate and the film then slides down into position. The bronze guide rollers locate the film vertically.

Step 4. Connect a ground wire between all chassis, and connect all units as shown in the wiring diagram (fig. N–8).

Step 5. Set the time delay unit in battery pack (Model 280) to zero, and connect the On-Off lead. The system is now activated, and the light source lamp and the data lamp should flash approximately every 15 seconds, and the film in the camera should advance one-half revolution of the film drive sprocket beween flashes. If malfunctions occur, refer to the instruction manual.

N–10 Preparing Underwater Camera Components for Installation on Mounting Rack.—Before cameras, light sources, and battery packs are installed on the mounting rack perform the following steps:

Step 1. Load the camera with fresh film (for film selection, see fig. N–9) in subdued light in accordance with Step 3, paragraph N–9. Test film spools (supply and take-up) in the clearance gage on the camera chassis, and replace if faulty. Snap film spools in place, and tape the film leader to the take-up spool. Remove the drive belt from the take-up spool pulley, allowing take-up spool to rotate freely and wind several turns of film on the spool. Replace drive belt, insuring that film is snug.

Step 2. Fill out a paper data card, using India ink or a ballpoint pen, and secure it in place over the permanent plastic data card. *NOTE:* Penciled data on permanent card will not photograph satisfactorily.

Step 3. Wind the clock and set it to the nearest second GMT time.

Step 4. Check the data lens for cleanliness and open to maximum aperture.

Step 5. Check the objective lens and window for cleanliness, and for operations deeper than

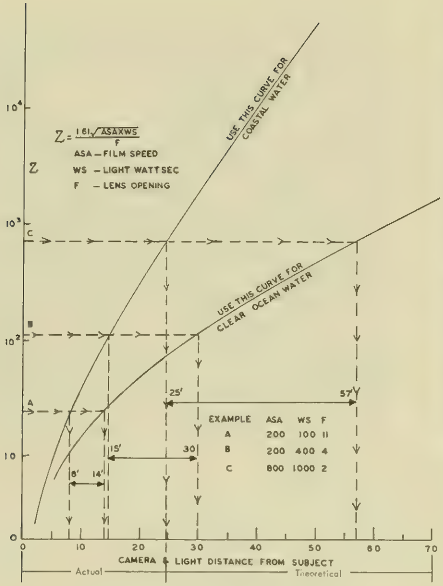


Figure N–9. Film selection graph.

300 meters, lock the shutter open. Set the aperture according to lens setting guide (fig. N–9). For shallow water operation, unlock shutter and refer to instruction manual for external wiring.

Step 6. Replace cameras, light sources, batteries, and timing devices in their housings.

Step 7. Inspect "O" rings and sealing surfaces of housing ends and rear end caps for freedom from cuts, scratches, dirt, etc.; apply a light coating of grease on the "O" rings and the sealing surfaces. Install rear end caps and tighten down thumbscrews (thumb tight only). It is important that good seals be maintained because an implosion in deep water will destroy the instrument. See figure N–10.

N–11 Positioning Underwater Camera Components on Mounting Rack.—For stereo operation, the components usually are mounted as shown in figure N–11. The cameras are mounted, using a straightedge to aline their end caps. Clamps are placed around the main housing cylinder of the components and not over the end caps. Reflectors are placed as far back as possible on the flashtube covers and secured with hose clamps and electrical tape. All components are positioned to balance the rack. The pinger transducer is mounted in the center of the rack, and the driver and transformer are positioned near the transducer.

Figure N–10. The unit at the top of the photograph was imploded at depth because of a faulty seal. Note the total destruction of internal components.

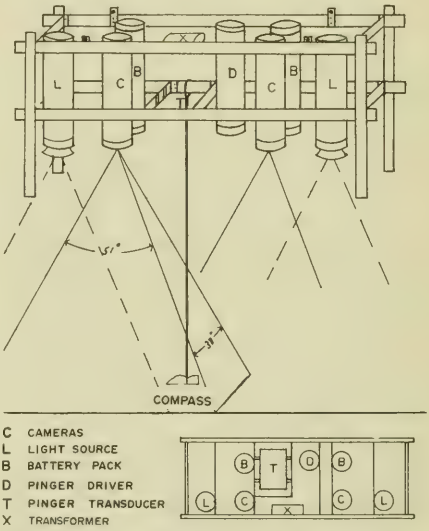


Figure N–11. Relationship of components for a standard stereo mounting arrangement.

N–12 Electrical Connections Between Components.—After the components are positioned on the mounting rack, the external electrical connections are made as follows:

Step 1. Using connector wires with female fittings, construct two watertight splices, a five-way splice at A and a two-way splice at B as shown in figure N–8, and connect components.

Step 2. Connect ground terminals on all end caps by a common ground wire.

Step 3. Connect external wires for Sonar pinger (see ch. R).

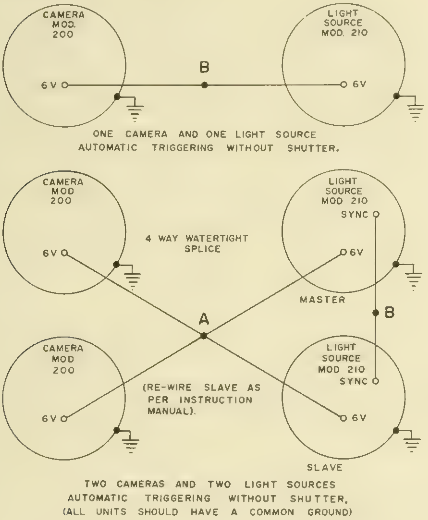
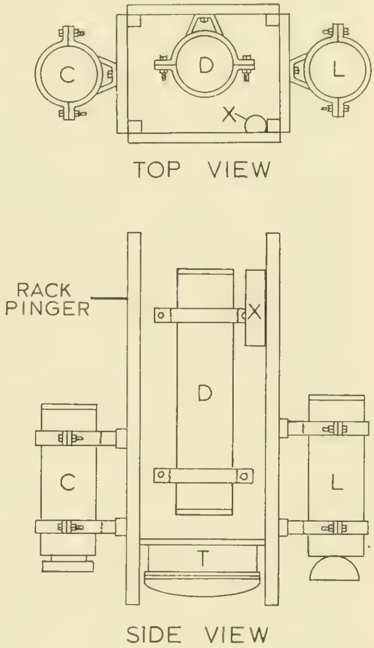


Figure N–12. External wiring diagrams for Model 200 camera and Model 210 light source.

N–13 Other Camera Systems.—In addition to the system described above, other camera systems are employed. Two are described below:

1. EG&G Model 200 Camera with EG&G Model 210 Light Source.—This system is almost identical to the one incorporating the model 204 camera. It consists of two cameras, two light sources, and a Sonar pinger; and is powered by one 6-volt battery that is contained in one of the light source housings. Since no battery packs are necessary, one camera, one light source, and the Sonar pinger from the system can be mounted on a pinger rack for single-plane photography. Because the pinger rack set up is compact and light weight, no boom or crane is needed to hoist it overboard. External electrical connections are shown in figure N–12. Mounting arrangement on the pinger rack is shown in figure N–13. Otherwise, the preimmersion instructions in paragraphs N–9, N–10, and N–11 also pertain to this system.

2. EG&G Model 205 Camera with EG&G Model 206 Light Source.—This system consists of one camera and one light source, each of which are about half the size of their counterparts in the other systems. The light source is powered by a 510-volt dry cell battery, and the camera is powered by a 30-volt dry cell battery. This camera will take 20 to 25 exposures at 6-second intervals during one lowering. It usually is mounted on a pinger rack, and it is activated by sliding a messenger down the lowering wire to trip a mercury switch or by bottom contact. Refer to the instruction manual for operation and maintenance.



C CAMERA

L LIGHT SOURCE

D PINGER DRIVE

T PINGER TRANSDUCER

X PINGER TRANSFORMER

Figure N–13. Pinger rack mounting arrangement for single-plane photography.

N–14 Immersion of the Underwater Camera System.—Figure N–14 presents a standard supporting arrangement. The winch and wire used should have a capacity of several times the weight of the camera. U.S. Naval Oceanographic Office personnel lower the camera system with oceanographic winches, using $\frac{3}{16}$-inch or larger oceanographic wire, depending on

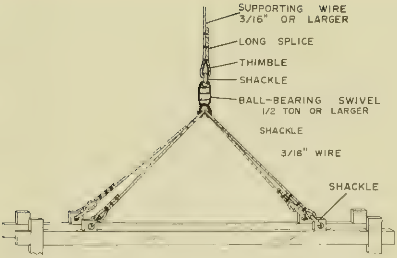


Figure N–14. Standard supporting arrangement.

depth of operation. Perform the following steps after the rack is shackled to the lowering wire:

Step 1. Activate the camera system, and check the light sources for the 15-second flashes and the camera system for the sound of the film advance motors. Disconnect the On-Off lead.

Step 2. Activate the pinger and audibly determine that it is functioning.

Step 3. Suspend the magnetic compass below the mounting rack within the field of both cameras (fig. N–11).

Step 4. Fill in appropriate items as shown on the suggested format for a camera lowering log sheet (fig. N–15).

CAMERA LOWERING LOG

SHIP	CRUISE	LOWERING NO.	DATE (GMT)
U.S.S. SAN PABLO		2	24 JUN. 1967

PROJECT	SONIC DEPTH (M)	OPERATORS
201	2707	WILLIAMS, BELLER

SERIAL NO.	39	41
CAMERA TYPE	EG&G 204	EG&G 204
TYPE FILM	KODAK – TRI .X	
NO. OF EXPOSURES		
f STOP	6.3	6.3
FOCUS		

DISTANCE OF COMPASS BELOW CAMERAS (FT)	12
FILM PROCESSOR	

ASSOCIATED BOTTOM SAMPLES
CORE #3
GRAB #2

TIME (GMT) START	TIME (GMT) STOP	NAVAID
1020	1225	LORAN C

TIME	LATITUDE S	LONGITUDE W
1015	15° 10.0′	120° 30.0′
1030	15° 10.1′	120° 30.7′
1045	15° 10.1′	120° 31.5′
1100	15° 09.9′	120° 32.3′
1115	15° 09.8′	120° 33.0′
1130	15° 10.0′	120° 33.8′
1145	15° 10.0′	120° 34.5′
1200	15° 10.0′	120° 35.2′
1215	15° 10.1′	120° 36.0′

REMARKS:
Include associated Nansen station number — STATION #7
TIME IN WATER 0935
Time camera reaches bottom — TIME ON BOTTOM 1023
Time camera comes off bottom — TIME OFF BOTTOM 1225
TIME OUT OF WATER 1300

Figure N–15. Suggested format for camera lowering log sheet.

Step 5. Remove rear end cap from the Model 280 battery pack, and set the time delay switch to allow enough time to lower the camera to the ocean bottom. Camera system normally is lowered at approximately 60 meters per minute. Replace end cap. Connect On-Off lead.

Step 6. With the ship lying to, hoist the camera system over the side with a boom or crane, and commence lowering (fig. N–16).

N–15 Bottom Positioning Techniques.—When lowering the camera system, the descent is controlled by monitoring the pinger-to-bottom distance. During the cameras drift across the area to be photographed, the distance above bottom also is controlled by monitoring the pinger-to-bottom distance. Chapter R, Sonar Pinger, should be reviewed by the operator before attempting a camera lowering. It is most important that the camera be kept within 20 feet of the ocean floor throughout the operation, yet care must be taken to avoid striking into the bottom.

Record the time the camera reaches the bottom, and while the camera is photographing the bottom (approximately 125 minutes), record the ship's position at 15-minute intervals if possible. When the run is completed, bring the camera system to the surface, and complete the camera lowering log.

N–16 Emersion of Camera and Removal of Film.—When the camera is at the surface, hoist the camera and place it on deck with a boom or crane, insuring that it is well secured. First the pinger should be unplugged, and then the camera should be checked by listening to determine whether the film advance motor is still running. If the motor is still running, it is a good indication that the lowering was successful. Permit the unit to come to ambient temperature or rinse the camera housing with hot water before it is opened; otherwise, the difference in temperature between the interior of the mechanism and the surrounding air will cause condensation on the camera chassis and the film. Usually, the camera housing is not removed from the mounting rack between lowerings; therefore, a changing bag should be used for removing the chassis from the housing. Exposed film container and reel should be labeled with the lowering number, camera serial number, and time and date (GMT).

If the camera motor is not running, check the camera housing window to see if flooding has occurred. If flooded, drain the water from the camera by opening the lower end cap. Remove the chassis from the housing. Rinse with fresh water and dry in an oven before attempting repairs.

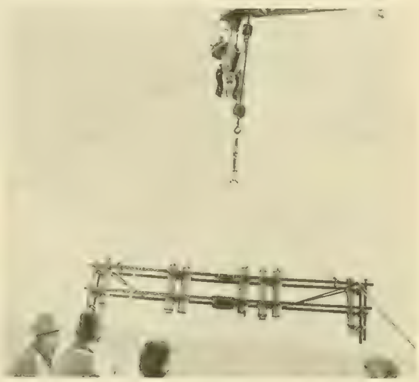


Figure N–16. Hoisting underwater camera system over the side.

N–17 Processing of Film.—A few exposures of each roll of film usually are processed aboard ship to insure that the camera is functioning properly (fig. N–17); however, better quality pictures generally can be obtained by processing film at a shore installation.

N–18 Selection of Film.—The selection of film to be used is dependent on several factors: Quality of photograph desired, amount of light available, the desired distance above bottom, and the limits of the aperture settings. Black and white or color film can be used. The graph in figure N–9 is presented as a guide.

223-812 O - 68 - 11

Figure N–17. Underwater photographs. Note compass.

CHAPTER O

BIOLOGICAL SAMPLING

O–1 General.—Biological organisms can be obtained from the ocean in several ways. Drifting micro-organisms such as zooplankton and phytoplankton are collected by towing nets through the water. Swimming animals (nekton) are obtained by towing trawls at various depths in the ocean. Bottom dwelling animals (benthos) are collected by towing dredges along the ocean bottom. And specialized attaching and boring organisms are obtained by exposing arrays of fouling panels.

O–2 Biological Sampling Nets.—Biological sampling nets are designed for various purposes. Some nets can be used only when the ship is stopped or at anchor, and other nets are designed to take samples while the ship is drifting or underway. Certain nets can be used to obtain samples only at the surface, and still others can be used to collect samples from any depth desired. Net mesh sizes vary. The selection of the mesh size depends on the organisms sought. Qualitative samplers sieve organisms from the water, but they do not measure the volume of water that passes through the net. On the other hand, quantitative samplers not only sieve organisms, they also measure the volume of water filtered. Biological sampling nets used by the U.S. Naval Oceanographic Office are described below. Biological towing observations are recorded on Biological Log Sheet-O (fig. O–1).

O–3 Qualitative Plankton Sampling Net.—A qualitative plankton sampling net is shown in figure O–2. The net is cone shaped, and its opening at the large end is fitted with reinforced eyes and lashed to a metal ring. The small, or cod, end of the net is attached to the sample bucket. Qualitative plankton sampling nets used by the U.S. Naval Oceanographic Office have one-meter, half-meter, and 30 centimeter metal rings, and are approximately 5 meters, 3 meters, and one meter long, respectively.

O–4 How to Operate the Qualitative Plankton Sampling Net.—The qualitative plankton sampling net is simple to operate, and the only tool required is a medium sized screwdriver. The qualitative plankton net may be towed either vertically, obliquely, or horizontally.

Step 1. Bridle the net to the towline with three lines attached at equidistant points on the metal ring. For a horizontal tow, use any line or wire available for the towline; for a vertical or oblique tow, use the oceanographic winch and $\frac{5}{32}$- or $\frac{3}{16}$-inch wire.

Step 2. Check to assure that the mesh size of the net agrees with the mesh size number on the bottom of the sample bucket, and tighten the screw-type base clamp to secure the sample bucket to the small end of the net.

Step 3. Lower the net over the weather side of the ship if the ship is drifting or moving, or stream the net to leeward if the ship is anchored.

Step 4. When the net is open and streaming, towing can commence. In some instances, it may be necessary to add weights to the sampler bucket or towing line to attain the desired depth. Recommended towing speeds are 2 to 4 knots.

Step 5. Stream the net for 30 to 60 minutes if taking a horizontal tow, or lower it from surface to the desired depth and back to surface if obtaining an oblique or vertical plankton sample.

Step 6. To retrieve the net, haul it in by a slow steady pull on the line, and in bringing it aboard, avoid turning the net inside out.

Step 7. When retrieved, any plankton clinging to the side of the net should be rinsed into the bucket with sea water. Then, detach the bucket and empty its contents into a sample jar. If the bucket is full of specimens, reduce towing time on next tow. If less than one-fourth full increase towing time.

O–5 Maintenance of the Qualitative Plankton Net.—After the operation is completed, rinse the net and bucket in fresh water to remove any plankton that may have adhered to the sampler; then, dry the net in the shade. (Keep oil and grease off net.)

O–6 The Clarke-Bumpus Quantitative Plankton Sampler.—The Clarke-Bumpus quantitative plankton sampler is shown in figure O–3. It is designed to be opened and closed at a desired depth, and it is equipped with a flow meter that measures the volume of water passing through the net. Thus, a quantitative plankton sample can be taken at a desired depth by means of this sampler without contamination from plankton in overlying water strata.

SHIP SAN PABLO CRUISE NO. 243

COLLECTOR'S NAME J.B.C.

BIOLOGICAL LOG SHEET – O

US NAVAL OCEANOGRAPHIC OFFICE

WASHINGTON, D. C. 20390

TYPE OF PRESERVATIVE 4% FORMALIN

CONSEC STA NO	ASSGN STA NO	SAMPLE NO	DATE 1965	TIME GMT	LATITUDE N	LONGITUDE W	TYPE OF SAMPLER	MESH NO	START TIME	WIRE ANGLE	END TIME	DURATION OF TOW	METER READING START	METER READING END	TOTAL REV.	WATER DEPTH (M)	DEPTH OF TOW (M)	TEMP. AT DEPTH (C°)	SALINITY ‰ AT SURFACE	SALINITY ‰ AT DEPTH	REMARKS AND TYPE OF TOW
8	8	1	6 July	1000	40°12′	32°42′	PLANKTON TOW ½ METER	#8	1000	80°	1030	30 MIN.	—	—	—	900	3	23.3°	34.03	34.15	HORIZONTAL TOW
9	9	2	7 July	1200	35°23′	30°10′	MIDWATER TRAWL	#36	1200	55°	1300	60 MIN.	—	—	—	900	50	20.4°	34.06	34.43	HORIZONTAL TOW
10	10	3	8 July	0100	35°26′	31°15′	CLARKE-BUMPUS ½ METER	#8	0100	04°	0130	30 MIN.	01099	03789	02690	1200	200	17.9°	34.07	34.93	VERTICAL TOW

NAVOCEANO 3167/83

Figure O–1. Biological Log Sheet–O.

Figure O–2. The half-meter qualitative plankton net.

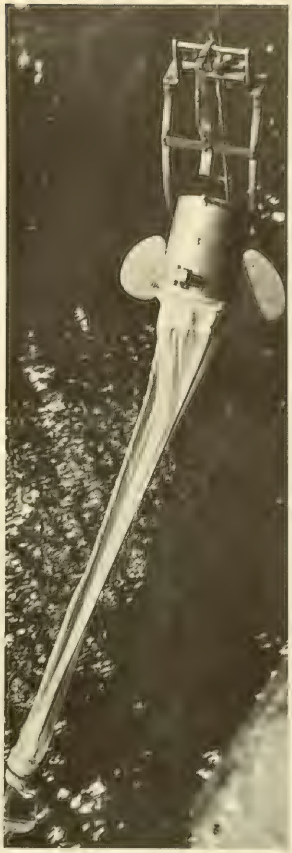


Figure O–3. Clarke-Bumpus quantitative plankton sampler.

O–7 Assembling and Operating the Clarke-Bumpus Sampler.—The Clarke-Bumpus sampler consists essentially of a frame that attaches to the lowering wire, a brass main tube (5 inches in diameter and 6 inches long) that contains a shutter and impeller, a plankton net about 3 feet long, and a sample bucket (fig. O–4). A screwdriver and a small adjustable wrench are the only tools required to assemble and operate the sampler.

Step 1. Attach the net to the sampler, and fasten the sample bucket to the cod end of the net with the screw clamps. Then, install the net rod to keep the net open and to prevent it from becoming fouled on the instrument or lowering wire during towing.

Step 2. Set the shutter (A) in the closed position; then rotate it 90° counterclockwise, looking down on the sampler. At the same time, rotate rod (B), clockwise until the edge of the shutter engages the first of the two finger lugs (C). At this point, the tripping mechanism should engage finger lugs (D) locking the shutter open.

Step 3. Next rotate the shutter (A) through a second 90° arc, and also rotate the shutter rod (B) clockwise as before until a second finger lug (C) engages the semicircular frame on the shutter, which now is closed, and a second finger lug (D) engages the tripping mechanism.

Step 4. Shackle a 100-pound lead weight to the $\frac{5}{32}$- or $\frac{3}{16}$-inch lowering wire and lower the weight over the side into the water.

Step 5. Connect a safety line to the sampler to prevent the accidental loss of the instrument while attaching it to wire. Secure the wire clamp (F) to the lowering wire, and attach the sampler to the wire by means of the spring pin (G) at the top and gate lock (H) at the bottom. The frame should swivel freely around the wire.

Step 6. Record the reading of the digital counter, remove the safety line, lower the sampler to the desired depth, and commence towing. Drop a messenger to open the shutter and

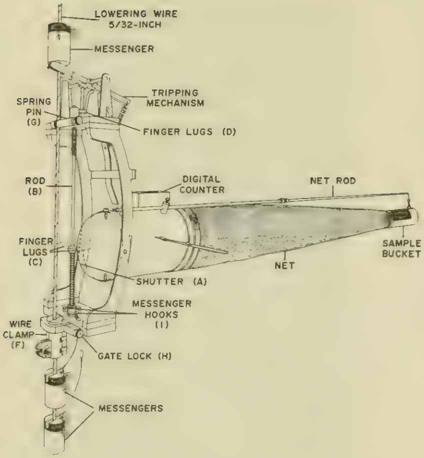


Figure O–4. Side view of Clarke-Bumpus plankton sampler.

release the impeller. Record the time the messenger was released. Recommended towing speed is 2 to 4 knots.

Step 7. When the tow is completed (usually 10 to 30 minutes) drop a second messenger to close the shutter. Record messenger time; hoist the sampler to the surface; attach a safety line to the sampler; and remove the assembly from the wire. Record the reading of the digital counter.

Step 8. Wash any plankton clinging to the net into the sampler bucket with sea water, and empty its contents into a sample jar. If the sampler bucket is full of specimens, reduce towing time on the next tow. If less than one-quarter full, increase towing time.

If more than one sampler is to be used on the same wire, the following additional steps must be performed after the second or third sampler is attached to the wire.

Step 1. Remove the safety line from the sampler and connect it to the lowering wire below the sampler. This will prevent accidental tripping of the sampler(s) already in the water.

Step 2. Attach two messengers from hooks (I) at the base of rod (B). The wire of one messenger should be 10 inches long, the loop at its upper end should be passed through the right slot (facing sampler) in the base of the frame, and then slipped over the larger of the hooks. The wire from the other messenger should be about 13 inches long. Pass its loop through the left slot and connect it to the shorter hook.

O–8 Maintenance of the Clarke-Bumpus Sampler.—After the operation is completed, rinse the sampler in fresh water, dry, and lubricate all metal parts with a light coating of oil. Remove the net and dry in shade before storing. (Keep oil off net.)

O–9 The Midwater Trawl.—The Isaccs-Kidd midwater trawl shown in figure O–5 was developed at the University of California, Scripps Institution of Oceanography. It is capable of collecting some of the large and more active nekton forms found in the ocean. As implied by its name, the trawl was primarily designed for use in midwater, that is, ocean water below the surface layers. An ordinary net will surface behind the towing vessel unless hauled at extremely slow speeds. To counteract this tendency, the midwater trawl has an inclined plane surface rigged in front of the net entrance. This surface or vane acts as a depressor, in a manner opposite to the elevating action of a kite surface.

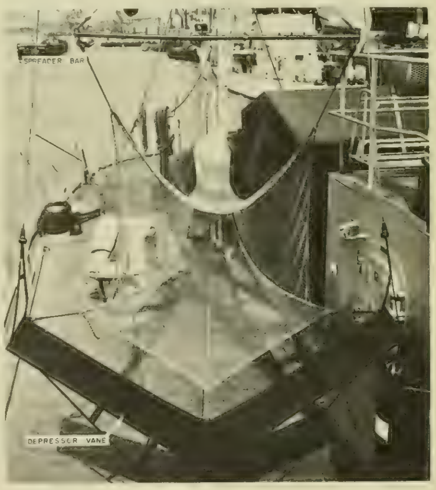


Figure O–5. The midwater trawl.

The midwater trawl is essentially an asymmetrical cone of 2½-inch stretch mesh. It has a 10- or 15-foot pentagonal mouth; it is 31- or 72-feet long; and it has a round opening at the cod end. From a point 3 feet from the end, an additional netting of ½-inch stretch mesh is attached as a lining, and a perforated sample container is fastened to the cod end of the trawl by draw strings.

Table O–1 lists some of the specifications for the 10- and 15-foot trawls.

Table O–1. Trawl specifications

	10-foot trawl	15- foot trawl
Bridle:		
Material	0.250-inch wire rope.	0.380-inch wire rope.
Spread (feet)	10	15.
Vane:		
Area (square feet).	21	64.
Weight (lbs.)	150	400.
Material	0.125-inch steel	0.75-inch marine plywood.
Net:		
Length (feet)	31	72.
Inlet area (square feet).	80	160.
Material	2.5-inch stretch, No. 24 medium lay seine.	2.5-inch stretch No. 36 medium lay seine.
Liner: Material	0.5-inch stretch bait netting.	0.5-inch stretch bait netting.
Cod end can:		
Material	Steel	Aluminum.
Length (inches)	13.5	24.
Diameter (inches).	9.5	16.
Number baffles.	None	2.

O–10 Assembling the Midwater Trawl.—As a guide in assembling the midwater trawl the following procedures are listed:

Step 1. Attach the net at three points to the trailing edge of the depressor vane.

Step 2. Attach the upper two hauling points of the net to the ends of the spreader bar.

Step 3. Attach two lines of the bridle to the hinged side arms of the depressor; attach the divided arms of the third bridle line to the ends of the spreader bar.

Step 4. Attach the bridle to a ½-inch towing line with a ring and swivel.

Step 5. Stream the net off the stern of the towing vessel using a boom or from a boat crane off the side. Install a dynamometer in the towing system according to instructions given in chapter L, paragraph L–30.

O–11 Streaming the Trawl.—Placing the trawl in the water is dependent upon the characteristics of the towing ship and upon the number of men and equipment available for handling. Generally speaking, however, the cod end is put over the side with bare way on. As soon as the cod end is streamed and the net is flowing freely, the depressor should be lowered just below the surface. If the trawl is lowered over the side rather than the stern, fouling in the ship's screws can be avoided by making a gradual inside turn until the trawl is streaming well aft.

If properly streamed, the V-shaped depressor will not only cause the net to dive, but will funnel additional water into the mouth of the net, keeping the net billowed out. As soon as this occurs, and the net is well clear of the ship, the ship's speed should be increased to that desired for trawling, plus the speed of the winch as it pays out the towing cable. A continuous watch on the dynamometer should be maintained, especially during lowering and retrieving, or during changes in weather conditions, to avoid straining or parting the towing cable or trawl.

An alternate and perhaps better way of streaming the net is to pay out cable with the ship having just enough way on to prevent the trawl from fouling itself. This method allows the trawl to sink more rapidly to the desired trawling depth. When it is estimated that this depth has been reached, the ship's speed should be increased to the desired trawling speed. The trawl will then stabilize itself at a depth dependent upon the trawling speed, cable diameter, etc.

O–12 Towing the Trawl.—When it is estimated that enough cable has been payed out to place the trawl at the desired trawling depth, the ship's speed should be slowed to the intended trawling speed simultaneously as the winch is stopped. Reasonable maneuvering can be accomplished by the ship during trawling. The length of the trawling period should be at least several hours. At an early point in operations, a trial series of tows should be run so that a graph can be drawn showing the necessary amount of cable to be payed out for a certain depth when hauled at a certain speed.

O–13 Retrieving the Trawl.—After the trawling period is over, the ship should be slowed to the desired trawling speed less the speed of cable recovery by the winch. The slowing of the ship as the winch begins to retrieve the wire must be a smooth operation so that the actual net speed always remains the same. Any time the retrieving action is stopped, the ship's speed should be increased again to the desired trawling speed. Caution should be taken at all times to see that the actual trawling speed of the net is kept constant to avoid excessive strain from an increase in speed, and to avoid allowing entrapped animals to escape with a decrease in speed.

O–14 Additional Instructions.—Any increase in trawling speed may cause the trawl to dive more steeply. This additional deepening must be taken into consideration if tows are being made close to the bottom.

Because of the additional strains due to the surging of the towing ship during heavy swells, the trawl normally will be used in fair weather. Special emphasis should be placed on trawling when a pronounced deep scattering layer is indicated on the echo sounder.

The depth of towing is of prime importance, and any depth gage available and suitable should be used if possible. Experimentation may be desirable such as the use of explosives or fish poison (a seepage container of rotenone) in front of the net entrance, the use of a half-meter plankton net of coarse mesh in place of the cod-end can, or the installation of several truncated cones of netting within the cod end (similar to a fish weir) to prevent fish from escaping the net.

O–15 Removal of Specimens.—Carefully and immediately remove *all* specimens from the net. Small specimens should be kept in addition to larger specimens. Immediately place specimens in containers of sea water for subsequent preservation. Color photographs in daylight should be taken of each catch if possible, but must be taken almost immediately, as fish lose their color rapidly when exposed to air or when preserved. Photography may best be done by placing the specimens in sea water in a shallow tray which has been marked off with painted 1-inch squares or other suitable scale. Print the trawl serial number on a slip of paper and place it in a corner of the tray to be photographed, in order to provide positive identification.

O–16 Maintenance of Midwater Trawl.—After using the net, it is not necessary to rinse it in fresh water, but it should be spread out, thoroughly dried, and then stored. *Precaution:* Never store the net in a damp condition.

O–17 Benthos Sampling.—Biological samples of bottom dwelling organisms (benthos) are obtained by towing dredges along the ocean bottom or by means of Van Veen samplers, Clamshell snappers, and Orange Peel bucket samplers. These samplers are described in chapter L, Bottom Sediment Sampling.

O–18 Preservation of Biological Specimens.—Specimens taken by plankton tows and small nekton specimens taken by midwater trawls are stored in quart- or pint-size jars in a 5-percent solution of formalin (fig. O–6). Fill the jar only one-third full of specimens drained of excess liquid, place label shown in figure O–7 in the jar, then add 5 percent buffered formalin to *completely fill the jar.*

Directions for preparing 5 percent buffered formalin follow:

To make 1 pint (460 ml.) of 5 percent buffered formalin, place 24.2 ml. of commercial formaldehyde (37 percent) in a pint jar, add 0.5 grams of sodium bicarbonate, then fill the remainder of the jar with sea water.

Directions for filling out the biological sample labels for plankton tows and nekton and benthos samples are as follows:

Figure O–6. Preserving plankton and small nekton and benthos specimens.

Fill out the label with pencil (No. 2½ or 3H is most desirable) and place inside the container, facing out. If samples are split into more than one container, label each container and explain in the remarks section of the label and indicate on Biological Log Sheet–O.

Benthos specimens obtained with bottom sediment sampling equipment are stored in quart- and pint-size jars in 70 percent ethyl alcohol. Kill specimens by immersing in fresh water for approximately 3 minutes, and drain specimens of excess liquid. Fill storage jar only one-third full of specimens, place label shown in figure O–7 inside jar, and then add 70 percent ethyl alcohol to *completely fill the container.*

Specimens more than 3 inches long should have some of the 5 percent formalin or 70 percent ethyl alcohol injected into the body cavity before being stored in the solution. If the specimen is too large to be stored in a jar, it should be soaked in preservative, wrapped in cheesecloth, and packaged in a waterproof material.

Marine plant specimens should be pressed and dried between layers of absorbent paper such as blotting paper or newspaper. Before pressing, the leaves and fruiting bodies of the plant should be arranged so the plant's identifying morphological characteristics are apparent. The paper should be changed as necessary to insure thorough drying, and a layer of cheesecloth should be placed between the plant and the upper paper to prevent damage to the specimen.

PLANKTON TOW SAMPLE

Sample # 1 Project 243

General Location North Atlantic

Lat 40° 12′ N Long 32° 42′ W

Date 6 July 1965 Time (GMT) 1000

Temp 74 °F. at 10 feet Depth of Tow 10 feet

Sampler: Clarke-Bumpus 1/2 Meter ✓ Other

Type Tow: Horizontal ✓ Vertical Oblique

Time: begin 1000 end 1030 Duration of tow 30

Counter: begin end Total rev.

Net Mesh # Collector JBC

SHIP SAN PABLO

REMARKS

PRNC–NAVOCEANO–3167/65 (Rev. 6–63)

NEKTON OR BENTHOS SAMPLE

Sample No: 2

Date: 7 July 65 SAMPLER: MIDWATER

Start: Time (GMT): 1200

Latitude: 35° 23′

Longitude: 30° 10′

End: Time (GMT): 1300

Latitude: 35° 23′

Longitude: 30° 12′

Depth of Tow: 50 meters

Average Depth of Bottom: fms.

Depth of Deep Scattering Layer, if present: fms.

Observer: JBC

Remarks: USS SAN PABLO

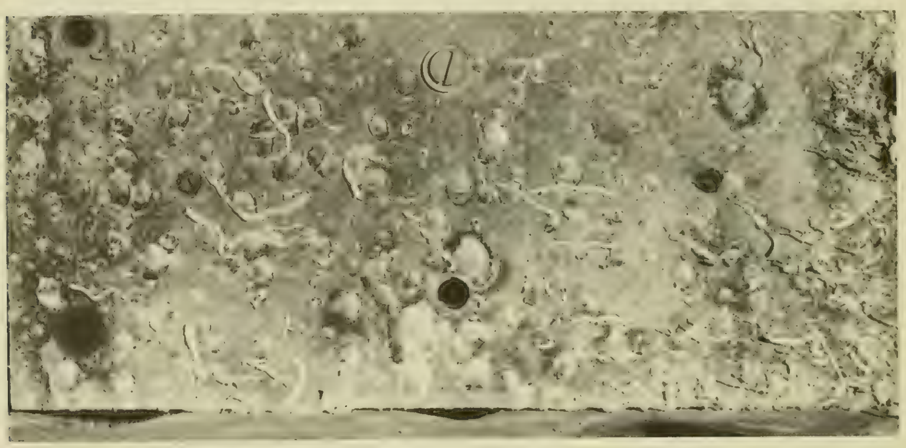
NAVOCEANO-3167/82 (8-66)

Figure O–7. Biological sample labels.

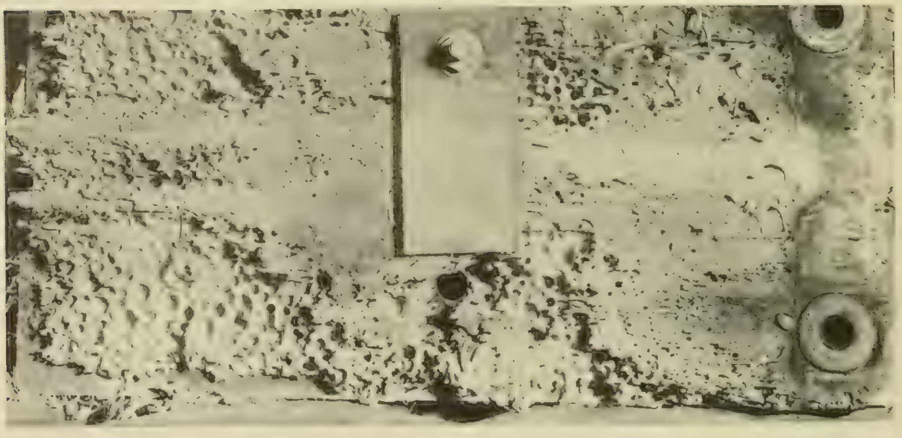
O–19 Marine Fouling Observations.—Marine Fouling observations are conducted by the U.S. Naval Oceanographic Office to determine the composition and intensity of marine biological fouling communities in the coastal waters of the world. These observations usually are taken over a 12-month period. Since temperature appears to be the principal condition limiting the distribution and abundance of marine flora and fauna, the geographic areas often are selected because they are representative of established biotic provinces, whose boundaries can be defined in terms of sea surface temperature. Also, observations are taken at selected locations to determine the effects of fouling and biological deterioration on oceanographic sensors or other equipment.

A long range objective of obtaining marine fouling observations is to develop a capability for describing the life history of derelict objects recovered from the sea, by examination of the attached organisms. Organisms which are found to have a limited horizontal or vertical distribution can be particularly useful as indicators of specialized habitats or environment.

Marine fouling observations are made by exposing test panels in coastal waters for specified periods of time. Figure O–8 shows a test panel



Accumulation of fouling organisms on asbestos board.



Destruction of white pine board by marine borers.

Figure O–8. Exposed test panel, Fort Lauderdale, Fla.

that was exposed at 295 feet (5 feet above bottom) for 12 months off Fort Lauderdale, Fla.

O–20 Equipment Required for Obtaining Fouling Observations.—The following equipment and materials are required for obtaining fouling observations:

1. Test panels; 6 by 12 inches, composed of ¼-inch asbestos board and ¾-inch white pine board, connected back to back. The asbestos provides a fibrous surface for the collection of fouling organisms, and the pine board is an ideal collector for marine borers.
2. Polypropylene line; ⅜- or ⅝-inch diameter or ¼-inch wire rope.
3. Shackles, swivels, wire clips, and plastic sleeve insulators. When attaching panels to steel wire rope, insulators must be used.
4. Modified split bolt connectors; brass, S–1/0 and S–4/0, for attaching panels to line or wire rope.
5. Panel holder; six panels, with modified split bolt connectors and brass panel bolts.
6. Concrete anchors; 40 and 1,000 to 1,500 pounds with steel chain.
7. Navy-type holding anchors; 15 and 65 pounds with chain.
8. Toggle floats; 8-pound buoyancy plastic and 500-pound buoyancy steel.
9. Bathythermograph and Frautschy water sampling bottles, or Nansen bottles with reversing thermometers for obtaining water temperatures and salinity samples.
10. Plastic bags for storing and preserving test panels.
11. Ethyl alcohol (100 percent) for preserving organisms on test panels.
12. Water sample bottles.

O–21 Selection of Fouling Sites in a Geographic Area.—Observation sites are selected as close to shore as critical depths (50, 100, 300, and 600 feet) will allow. The range of salinity should be from 25–35 ‰. Harbors and other areas where polution levels are high are avoided. Four test sites, whenever possible, are selected in each geographic area (fig. O–9)—one shallow site (50 feet) and three deep sites (100, 300, and 600 feet). Also, several control sites are selected in the vicinity of the test sites.

O–22 Planting the Fouling Arrays.—At each site, observations are obtained by planting arrays of panels. The number of arrays at a site and the number of panels per array depend on the depth of water. On shallow water arrays (50 feet), one panel on each array is always exposed 5 feet above the bottom, and one is always within 10 feet of the surface (fig. O–9). Panels are connected to the shallow water array line with modified split-bolt connectors (fig. O–10). These arrays are planted in clusters of 15 at each site. The distance between arrays is approximately 10 meters. Shallow water arrays with 40-pound concrete anchors usually are planted from small vessels as they do not require boom or winch equipment.

At each deep site, two deep water arrays with 1,000- to 1,500-pound concrete anchors are planted. The deep water arrays have clusters of six panels at each of the standard intervals shown in figure O–9.

At the time the arrays are planted, the following information should be recorded for each panel: Panel number, geographic area, site number, latitude and longitude, array identification, location of panel on array, date panel was submerged, and water depth (measured at time of plant). In addition to the above information, the water temperature and a salinity sample from the submerged depth of each panel must be obtained. A suggested format for recording marine fouling and boring test panel data is given in figure O–11.

The water temperature can be obtained with a BT (chapter C, Measuring Water Temperature and Depth with a Bathythermograph) or reversing thermometers (chapter E, Taking an Oceanographic Station), and the salinity sample can be obtained with a Nansen bottle or other suitable water sampling devices such as the Frautschy bottle (fig. O–12). Record the initial water temperature in degrees Celsius or Fahrenheit, and the initial salinity sample bottle number. For the shallow water arrays, usually only a surface temperature and water sample are obtained.

Under remarks, enter navigation information, e.g., fix on tower and lighthouse, electronic navigation coordinates Red 653–Green 121, sea and swell conditions, etc. Draw sketches as required.

O–23 Recovering the Test Panels.—Each month (on approximately the same day), the sites are visited, and certain panels are removed and in some instances replaced. SCUBA divers are used to locate the toggle floats, connect lines to the deep arrays, and in some cases, to remove and replace panels down to the 100-foot level. The shallow arrays can be hoisted aboard the recovery vessel by hand for recovering the panels.

Two systems of test panel exposure are employed (fig. O–13). Long-term (series I) panels are exposed for 1 month and cumulatively longer periods up to 12 months. This type exposure provides data on rates of organic production and growth, periods of dormancy, and progressive changes of communities. Short-term (series II) panels are exposed for 1-month intervals and provide data on the seasonal settlement of organisms.

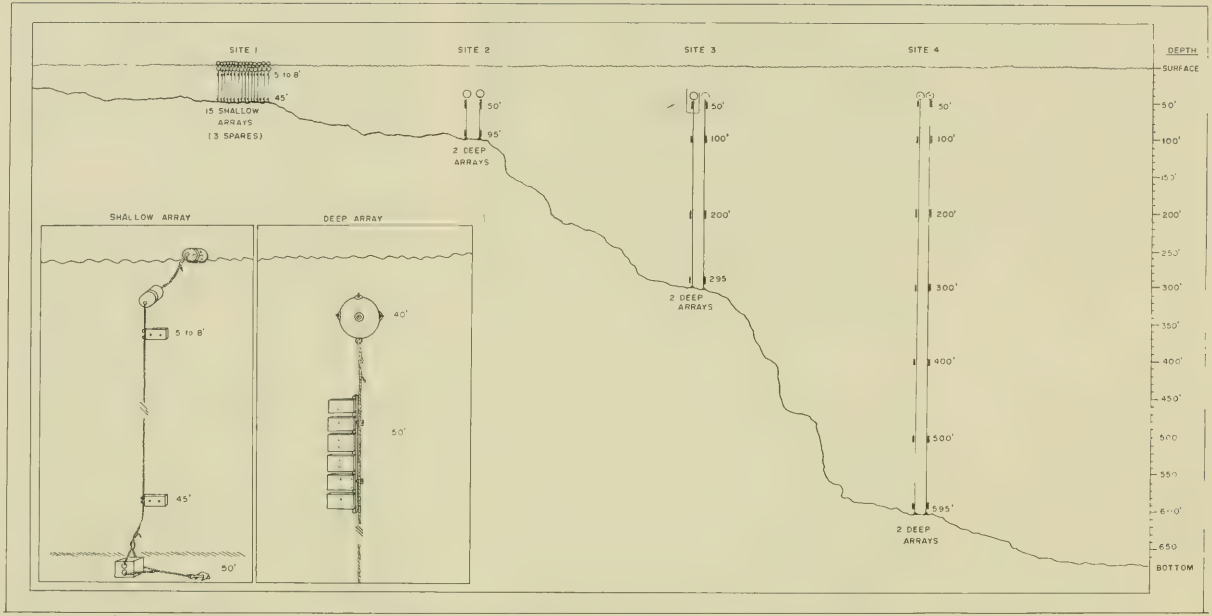


Figure O–9. **Diagram showing site depths, standard intervals, and deep and shallow arrays at a geographic area.**

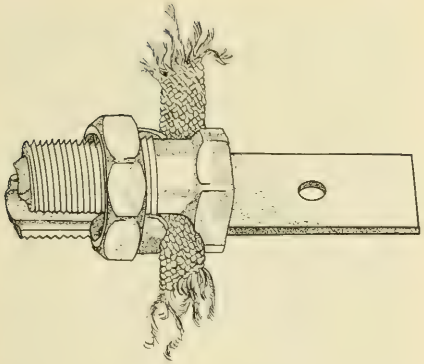


Figure O–10. Modified split bolt connectors (S–1/0) for attaching panels to line.

At the time a panel is recovered, water temperature measurements again are taken and salinity samples also are collected as during planting. The panel number, geographic area, site number, latitude and longitude (arrays sometimes are moved by currents), array identification, location of panel on array, and depth of water at array are verified and changes noted on data sheet. Also, the date panel was recovered and final water temperature and salinity sample bottle number are entered in the appropriate spaces. If a new panel is attached to replace the one recovered, a new data sheet is prepared.

O–24 Preserving Biological Specimens on the Test Panels.—After the panel is recovered, it is placed in a plastic bag and treated with approximately 200 ml. of ethyl alcohol. The line, especially at the shallow sites, is often covered with organisms. These organisms on the line also may be retained for analysis by storing and treating the line with the organisms in an appropriate metal container.

O–25 Analysis of Test Panels.—Panels are returned to the U.S. Naval Oceanographic Office Biological Laboratory for analysis where the organisms are identified, counted, measured, and weighed.

MARINE FOULING AND BORING TEST PANEL DATA

PANEL NUMBER K-20 . GEOGRAPHIC AREA FORT LAUDERDALE, FLORIDA

SITE NUMBER. #1 LATITUDE 26° 04′ LONGITUDE 80° 04′

ARRAY IDENTIFICATION RED BUOY (K)

LOCATION OF PANEL ON ARRAY: SURFACE, 50, 100, 200, 300, 400, 500, BOTTOM
(CIRCLE ONE)

DATE PANEL WAS SUBMERGED 13 JANUARY 1963

DEPTH OF WATER AT ARRAY (MEASURED AT TIME OF PLANT) 300 FEET

INITIAL WATER TEMPERATURE 21.3 °C 70.3 °F

INITIAL SALINITY SAMPLE BOTTLE NUMBER #1801

OBSERVER De Palma SALINITY 34.61 ‰

REMARKS:

SKETCH OF ARRAY OR AREA (IF REQUIRED)

DATE PANEL WAS RECOVERED 10 JANUARY 1964

FINAL WATER TEMPERATURE 22.1 °C 71.8 °F

FINAL SALINITY SAMPLE BOTTLE NUMBER 2230

OBSERVER De Palma SALINITY 34.83 ‰

Figure O–11. Suggested format for recording marine fouling and boring test panel data.

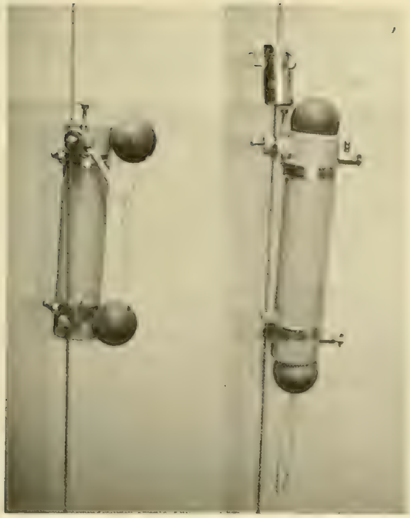


Figure O–12. Frautschy water sampling bottle before and after tripping.

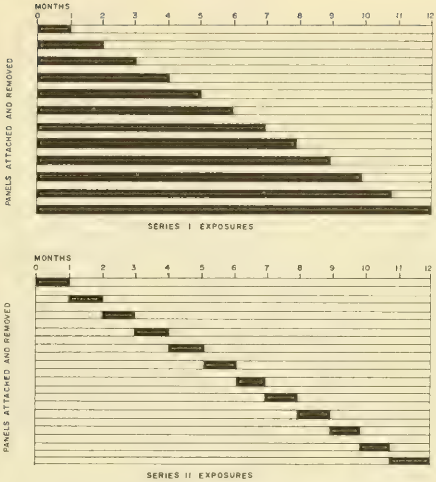


Figure O–13. Test panel exposure systems.

O–26 General Biological Observations.—Marine life in the oceans is important to the conduct of naval operations and is of interest to the oceanographic community in general; therefore, the visual sightings of biological life should be recorded by the oceanographic observer. A suggested format for a biological observation sheet is given in figure 0–14.

O–27 Deep Scattering Layer.—The presence of the deep scattering layer (DSL) often can be observed with echo-sounding equipment. When evidence of these biological phenomenon are observed on the echogram, the echo sounder should be adjusted to obtain a good signal at the deep scattering layer depth, and the chart should be annotated with appropriate information to indicate DSL. Enter the observation under remarks on the biological observation sheet, indicating depth of DSL, depth of water, date, time, position, and echogram roll number.

Instruction for obtaining DSL data with the AN/UQN–1 echo sounder follow:

Step 1. At 0400 (local time) each day, turn the recorder on, press the EVENT MARK, and using a soft lead pencil, annotate the chart paper with date, local time, latitude, and longitude.

Step 2. Switch the recorder to the 600-fathom scale, and advance the GAIN control to the point of blackening the paper; then, reduce the GAIN until the contrast is suitable for recording the scattering layer. Record the GAIN control setting on the chart paper.

Step 3. At each hour, press the EVENT MARK and annotate the local time, and at least once during each watch, record the injection line temperature on the chart. In addition, mark significant course changes and points where ship's track crosses a parallel or meridian that is a multiple of 5°. Make necessary GAIN control adjustments, from time to time, to improve contrast. Alway annotate new GAIN settings.

Step 4. Secure the recorder at 2100 (local time).

Step 5. At the end of an exercise, annotate the sounding records with the ship's name, fold the chart in an accordian pleat, and forward to Commander, Naval Oceanographic Office, Washington, D.C. 20390.

O–28 Seabird Observations.—The presence or absence of pelagic seabirds in an ocean area constitutes a seabird observation. A suggested format for logging seabird observations is given in figure O–15.

Seabird observations, if possible, should include species (followed by P for positive identification, U for uncertain); size of bird (body, wingspread); common name; age (adult, juvenile, immature); sex; color description of plumage, bill, feet, and eye; sketches showing plumage patterns, wing shape, shape of bill, etc.; and the approximate number of birds in a flock. Figure O–16 is a suggested format for a field identification of seabirds.

Binoculars, a camera with telephoto lens, and ornithological publications such as W. B. Alexander's "Birds of the Ocean" (1928, G. P. Putnam's Sons, New York, republished 1954), G. E. Watson's "Seabirds of the Tropical Atlantic Ocean" (1965, Smithsonian Institution, Washington, D.C.), or R. T. Peterson's "A Field Guide to the Birds" (1947, Houghton Mifflin, Boston) will be helpful to the observer.

BIOLOGICAL OBSERVATION SHEET

LOCATION (General)____________________ DATE______________ HOUR___________

LATITUDE_________________ LONGITUDE____________ SHIP______________________

CRUISE___________ WIND DIRECTION___________ WIND SPEED________ SEA STATE____

INJECTION WATER TEMPERATURE_____________.

BIOLUMINESCENCE

TYPE (Circle one): SHEET SPARK GLOWING BALL. DURATION_______________
LOCATION (Circle one): BOW WAVE WAKE GENERAL AREA
BRIGHTNESS (Circle one): DULL MODERATE BRIGHT BRILLIANT
MOON (Circle one): BRIGHT DIM OBSCURED BY CLOUDS NONE
SAMPLE OBTAINED: YES SAMPLE NO._______ NO
APPROXIMATE AREAL EXTENT (Square yards or miles):____________________

SEAWEED

APPROXIMATE AREAL EXTENT (Square yards or miles):____________________
CONCENTRATION (Circle one): SCATTERED MODERATE DENSE
TYPE DRIFTING____
TYPE ATTACHED BEDS (Circle one): SUBMERGED EMERGENT
SPECIES____
SAMPLE OBTAINED: YES SAMPLE NO.__________ NO

MARINE MAMMALS

TYPE (Circle one): WHALE PORPOISE SEAL WALRUS SEA LION
SPECIES OR DESCRIPTION:____
ESTIMATED SIZE IN FEET:____
NUMBER SIGHTED__________ DIRECTION ANIMALS WERE SWIMMING_______________
PHOTOGRAPHS TAKEN: YES NUMBER_________ NO

DISCOLORED WATER

COLOR_________________ OTHER DESCRIPTION____________________________
APPROXIMATE AREAL EXTENT (Square yards or miles):____________________
SHAPE OF AREA (Circle one): PATCHES NARROW STREAK WIDE STREAK
SAMPLE OBTAINED: YES SAMPLE NO._______________ NO

FISH SCHOOLS

SIZE OF SCHOOL (Square yards):____________ TYPE OF FISH________________
SIZE OF FISH (Average in inches):______________________________________
FLOCKS OF BIRDS FISHING: YES NO
NUMBER OF BIRDS IN FLOCK (Circle one): LARGE MODERATE SMALL

REMARKS:____

____

____

____

OBSERVER

Figure O–14. Suggested format for a biological observation sheet.

223-812 O - 68 - 12

USS SAN PABLO (AGS-30)
Ship

DATE AND TIME			POSITION		REMARKS	OBS
DAY	MON YR	HR (GMT)	LAT N	LONG W		
20	Aug. '65	1000	60°22'	30° 15'	NO BIRDS OBSERVED	KBP
21	Aug. '65	1500	61° 10'	29° 02'	SIGHTED FLOCK OF ABOUT 50 SOOTY SHEARWATER (U)	KBP
22	Aug. '65	1000	62° 00'	30° 04	Young ICELAND SEA GULL (P) WING SPREAD 18" (LARUS LEUCOPTERUS) PALE COLOR (SEE LOG SHEET)	JEB
23	Aug. '65	1000	63° 00'	30° 00'	NO BIRDS OBSERVED	JEB

Figure O-15. **Suggested format for a seabird log.**

FIELD IDENTIFICATION OF SEABIRDS

TIME: 1000 SHIP SAN PABLO OBSERVER JEB WEATHER CLEAR

LAT. 62° 00′

LONG. 30° 04

DATE 22 AUG. 65

WIND DIR. W. WAVE HEIGHT 4′

Feather areas (color)	white	black	gray	brown	yellow	buff	red	orange		streaked	spotted	barred	solid
crown		X											
nape													
throat	X												
side of head		X											
breast			X										
belly			X										
tail			X										
under tail coverts													
wing (upper surface)			X										
primaries													
secondaries													
coverts													
wing (lower surface)													
back													
rump			X										
Feet and legs													
Bill													

Tail (shape)	
rounded	
square	
forked	
pointed	
length	
shorter than body	X
longer than body	
same length as body	
Bill (shape)	
curved	
straight	
spear-shaped	
awl-shaped	
(length)	
longer than head	
length of head	
shorter than head	

Wing (shape)	
short	
long	
extremely long/narrow	
rectangular	
Direction of flight	X

Comparative Size	length	wing spread			length	wing spread
warbler	5"	7"		large gull	26"	5'
bluebird	7"	11"		eagle	33"	6.5'
pigeon	12"	2'	X	albatross	45"	11'
crow	19"	3'				

W	NW	N	NE	E	SE	S	SW
		X					

Legs and feet in flight
- extending much beyond tail ______
- shorter than tail ______
- length of tail ______

Flock composition: All one species ______
Two or more species ______
Number (by count estimate) ______ If long, passing flock estimate number passing per minute times number of minutes required to pass ______

Flock formation
- compact: (distance between birds not over 2 times wingspan) ______
- open: (distance between birds not over 10 times wingspan) ______
- scattered: (distance between birds over 10 times wingspan) ______
- streaming: (large numbers following a narrow flight path in one direction) ______

Activity	catching flying insects	swimming or drifting	diving from flight	diving from surface	swimming underwater
feeding		X			

resting ____ preening X pairing ____

Flight pattern height above water	fluttering	skimming touching water	wheeling wings set	scaling upwards	direct on a course
1'-5'					
5'-40'					
above 40'					

following ship ______

Figure O–16. Suggested format for field identification of seabirds.

CHAPTER R

SONAR PINGER

R–1 General.—The Sonar pinger is a battery-powered, automatic cycling, submersible sound generator unit. It is used for positioning oceanographic equipment within measured distances of the ocean floor. At the U.S. Naval Oceanographic Office, the Sonar pinger has been used successfully in underwater photography (chapter N) and Nansen cast operations (fig. R–1). The pinger transmits sonar pulses at precisely timed intervals. As the pinger is lowered toward the bottom, the transmitted pings are received on a sonar receiver (hydrophone, etc.) and displayed on a monitor (strip chart recorder, oscilloscope, etc.) to produce a continuous visual record of the pinger-to-bottom distance. Since each sound pulse (ping) is transmitted directly to the ship and also is reflected by the bottom back to the ship, the interval between the time the direct and the reflected pings are received is

$$T_{dif} = \frac{2D}{V} \qquad D = \frac{V\,T_{dif}}{2}$$

where D = pinger-to-botton distance (feet)
V = velocity of sound in water (feet/second)
T_{dif} = time interval between direct and reflected signals (seconds)

For example, if the pinger is 1,250 feet above the bottom and velocity of sound in water is assumed to be approximately 5,000 feet per second, the reflected ping will be received one-half second after the direct ping;

$$T_{dif} = \frac{2 \times 1250}{5000} = .5 \text{ seconds}$$

likewise, a 2 millisecond difference would indicate a distance of 5 feet above the bottom

$$D = \frac{5000 \times .002}{2} = 5 \text{ feet}$$

(see fig. R–2).

Figure R–1. Sonar pinger replaces weight on Nansen cast.

R–2 Description of the Sonar Pinger.—The Sonar pinger described here is the Edgerton, Germeshausen, and Grier (EG&G), Mark 1, Sonar Pinger. Other types are available and have been used by the Naval Oceanographic Office. The Sonar pinger is composed of three main subassemblies: Driver, pulse transformer, and transducer. The driver generates an electrical pulse once every second; the pulse transformer steps up the voltage of the pulse; and the transducer converts the high-voltage electrical pulse into a high intensity 12 KHz sound. The pinger driver disassembled is shown in figure R–3. It consists of main driver circuitry, battery, end caps, and driver housing. The pulse transformer is shown in figure R–4. It consists of two windings housed in a rubber-stoppered clear plastic tube filled with transformer oil. The transducer is shown in figure R–5; it contains

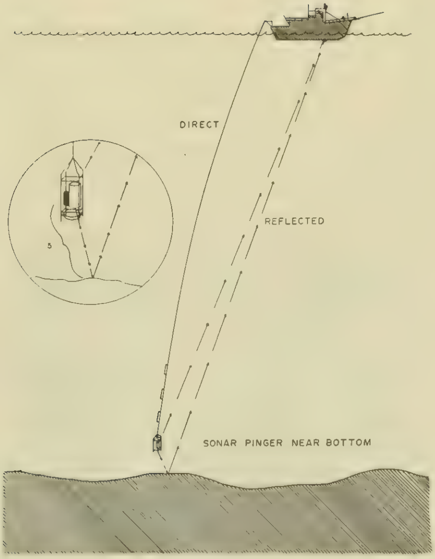


Figure R–2.—Sonar pinger bottom positioning technique for Nansen cast bottom temperature measurements.

ADP (Ammonium di-hydrogen phosphate) crystals mounted in parallel on a backing plate. To achieve good acoustic coupling with the water, the aluminum transducer housing is filled with dehydrated castor oil and is closed with a special rubber diaphragm. In addition to the pinger, a hydrophone and its amplifiers (or echo sounding equipment used in the passive manner), paper-chart recorders, and a triggered-sweep oscilloscope are required in the Sonar pinger operation to receive and visually or graphically display the pinger signal.

R–3 Assmbling Rack and Mounting Sonar Pinger.—The Sonar pinger is mounted on a Unistrut (a registered trade name) pinger rack. See chapter N for Sonar pinger mounting for deep sea photography. The parts of the pinger rack are listed and described in table R–1.

Table R–1. Unistrut pinger rack parts

Part No.	Number required	Description (hot dip galvanized steel or stainless steel)
1	4	Vertical Member, Channel, 48″ long.
2	4	Horizontal Member, Channel, 12″ long.
3	10	Angle Bracket, 90° Angle Fitting.
4	4	Joiner, "Z" Shape Fitting.
5	4	Shackle Plate.
6	34	Hexagonal Head Bolt, ½″.
7	34	Split Lockwashers and Flat Washers, ½″.
8	34	Spring-loaded and Standard Nuts, ½″.
9	2	Housing Clamp.
10	2	Hose Clamp.
11	1	Wooden Block, 12″ x 2″ x 2″.
12	2	Horizontal Member, Double Channel, 12″ long.

The assembled pinger rack is illustrated in figure R–6.

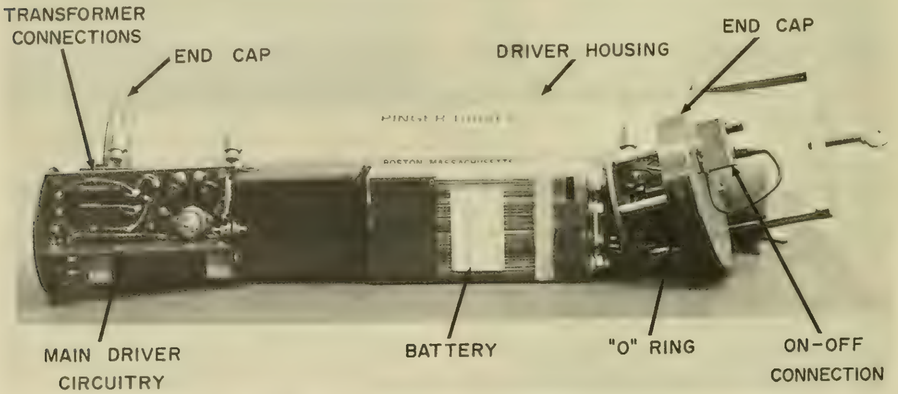


Figure R–3. The pinger driver disassembled.

Mount the transducer in the bottom of the pinger rack with four bolts. Handle with care. Rough handling could cause damage to the crystals, the electrical leads, or the rubber diaphragm.

Mount the pulse transformer in a vertical position with output leads down. (On the camera rack, the transformer is mounted in a horizontal position.) Place the hose clamps over the rubber stoppers at the ends to prevent magnetic coupling. Use the 2-inch wood spacer block to separate transformer from the rack. Further secure the transformer to the rack with electrical tape, to prevent loss of the transformer when it contracts at depth.

Remove the front end cap of the pinger driver before mounting. Check the "O" ring for freedom from cuts, scratches, dirt, etc.; inspect sealing surfaces for cleanliness; and apply a light coating of grease to the "O" ring and sealing surfaces. To remove the front end cap, the rear end cap must be removed along with the side straps and hose clamps. To insure proper seal when replacing the front end cap, replace side straps and rear end cap. Tighten rear end cap wing nut; replace hose clamps and tighten.

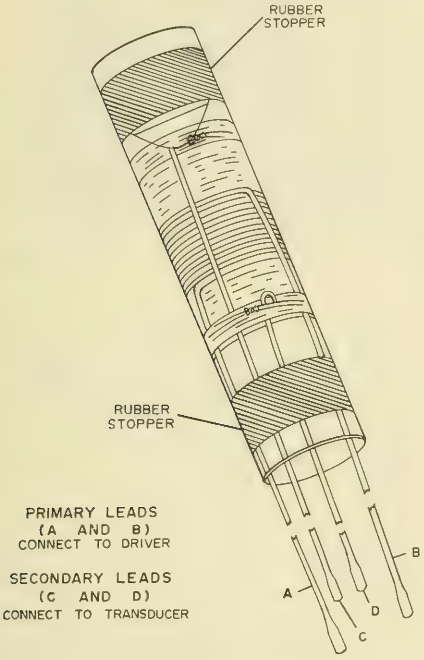


Figure R–4. Sonar pinger pulse transformer.

Figure R–5. Sonar pinger transducer.

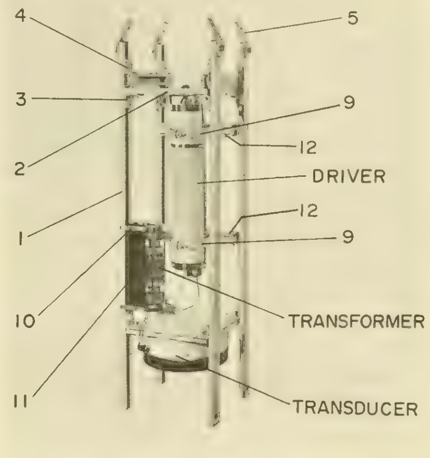


Figure R–6. Sonar pinger and mounting rack.

Mount the driver by housing clamps with the end cap nearest the battery facing up. Place clamps around main housing cylinder, not end caps. Make sure that end caps clear structural members. Leave enough clearance to allow for insertion and removal of battery.

R–4 Electrical Connections.—After the driver, transformer, and transducer are mounted on the rack, complete the electrical connections between components as follows:

Step. 1. Connect sockets on transformer primary cables to male pins at bottom of driver. These connections may be interchanged. Use waterproof grease on pins.

Step 2. Connect sockets on transformer secondary cables to male pins on transducer cables. These connections may be interchanged. Use waterproof grease on pins.

Step 3. Remove the end cap from the driver and insert battery base first.

Step 4. Disconnect On-Off connection on driver cap. *CAUTION: Never work on circuits with this socket connected. High voltages (8,000 v.) are generated when the system is operating.*

Step 5. Attach female socket from battery to driver male plug on underside of end cap. Inspect "O" ring for freedom from cuts, scratches, dirt, etc.; inspect sealing surfaces for cleanliness; and apply a light coating of grease to the "O" ring and the sealing surfaces. Make sure "O" ring is seated properly. Replace end cap and tighten the wingbolt thumb tight.

Step 6. To activate the Sonar pinger connect the On-Off lead. If the pinger is operating, the .5 msc pings will be heard at 1 second intervals; each 10th ping will be blanked. Do not operate the pinger in air longer than 15 minutes.

R-5 Theory of Operation.—Operation of the Sonar pinger is automatic. Once the pinger is activated the unit will generate a sound pulse once per second until the battery is discharged or until the unit is turned off. Every 10th pulse is blanked so that the direct and indirect ping can be matched.

When activated, 6 volts from the battery are applied to the precision-interval, timing-switch motor and to the two transformer coupled transistors. They oscillate at approximately 2 KHz, creating a 6-volt alternating current which is raised to about 420 volts in the toroidal power transformer. The 420-volt alternating current is rectified to 840 volts direct current which charges a capacitor. When the capicitor discharges into the pulse transformer, an 8,000-volt pulse is generated and transmitted to the transducer. The secondary of the transformer and the crystals of the transducer form a tuned circuit which oscillates at about 12 KHz for approximately 0.5 millisecond (about 6 cycles) every second. The sound energy created by the oscillation of the crystals is transmitted through oil to the rubber diaphragm and into the water.

R-6 Applications of the Sonar Pinger.—The Sonar pinger described in this chapter has been used at the U.S. Naval Oceanographic Office to position the underwater camera (see chapter N) and to obtain Nansen cast bottom temperature observations (see paragraph R-7). Other types of pingers which are more compact and lighter weight can be used in the above applications and also can be used in coring operations to determine when the corer touches bottom. These pingers usually are attached to the oceanographic wire in the same manner as a Nansen bottle.

R-7 Nansen Cast Bottom Positioning Techniques.—Figure R-7 presents a standard supporting arrangement for the Sonar pinger on a Nansen cast. The pinger assembly, which weighs about 150 pounds, replaces the 100-pound lead weight normally used (R-1). Two or three Nansen bottles (2 meters apart) are placed on the wire, with the bottom bottle as near as practical to the pinger. During the lowering of the cast and while the messenger is sliding down the wire, the pinger-to-bottom distance is monitored so that the Nansen bottles with the reversing thermometers will be tripped when they are very near the ocean floor.

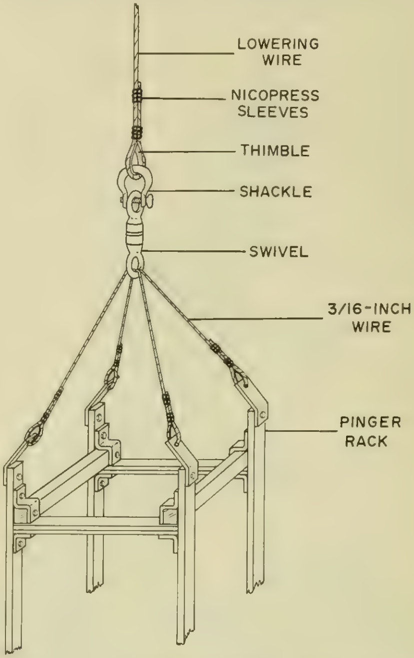


Figure R-7. Standard supporting arrangement for Sonar pinger used on Nansen cast.

R-8. Bottom Positioning Technique.—After the pinger is activated and over the side, the lowering should be monitored with the ship's echo sounding equipment, a Precision Depth Recorder (PDR), and an oscilloscope (figs. R-8, R-9, and R-10).

Step 1. With the ship's echo sounding system, determine the approximate depth of water in fathoms, and compute the largest multiple of 400 it contains (400, 800, 1,200, 1,600, 2,000, 2,400, 2,800, . . .). For example 2,603 contains 2,400 as the largest multiple of 400.

Step 2. Set the ship's echo sounding system to the listening mode, and the PDR to the 0 to 400 fathom scale. Turn on the oscilloscope, and vary scale illumination by turning control knob

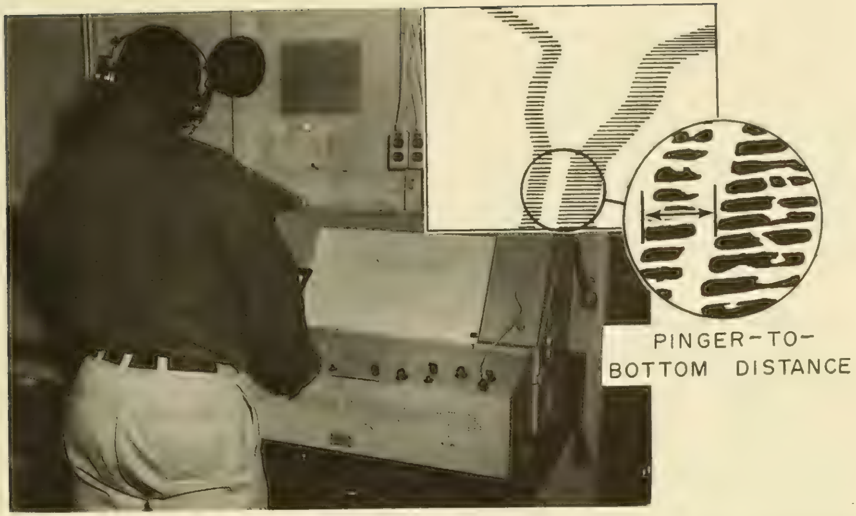


Figure R–8. NAVOCEANO scientist using the Mark 15A Precision Depth Recorder to determine pinger-to-bottom distance.

8 clockwise. (See figure R–9a. The Tektronix Model 310A controls are shown.) Set controls 1, 2, 3, 9, 10, 11, 12, 13, and 14 as shown in the figure. Adjust controls 15 and 16 to obtain a continuous signal trace across the grid. Adjust controls 4, 5, 6, and 7 for desired positioning, focus, and intensity of the trace. Connect the oscilloscope input to the PDR phone output, and commence lowering the pinger.

Step 3. Observe the signal going to the oscilloscope. Adjust the vertical amplitude dial (1) to obtain a readable trace, and set the Secondary Time/Division dial (9) to .2 seconds. Adjust the Stability dials (15 and 16) until the direct ping is on the zero, 5, and 10 of the scope grid (fig. R–9b).

Step 4. Determine the pinger-to-bottom distance. As the pinger is lowered, the signal traces on the strip chart will either diverge or converge, will automatically shift when they reach the edge of the chart, and will cross when the pinger-to-bottom distance is equal to the largest multiple determined in step 1. The traces will continue to diverge and converge as bottom is approached and at each crossing the pinger-to-bottom distance will be less by 400 fathoms (fig. R–10).

Step 5. Continue lowering until the pinger is approximately 100 fms off bottom (when traces are separated by about one-fourth the full scale of the PDR); then, reduce winch speed and lower the pinger with caution.

Step 6. When the pinger is approximately 20 fms off bottom, stop the winch. From this point, rely mainly on the oscilloscope.

Step 7. Begin to lower slowly. Turn the Time/Division dial (9) to 5 milliseconds; the unit now is set up to measure pinger-to-bottom distance from 37.5 meters down to 3.8 meters (see table R–2). When the pinger-to-bottom distance decreases to 15 meters, turn the Time/Division dial (9) to 2 milliseconds; the unit then is set up to measure between 15 and 1.5 meters.

Step 8. Continue to monitor the pinger-to-bottom distance, paying out and taking up wire as required until the operation is completed.

R–9 Maintenance of Pinger.—Should the pinger cease to function during an operation, it should be raised immediately. The pinger may be flooded, the leads may have fouled, or one of the components may have failed.

Step 1. If flooding is suspected, the unit should be hoisted inboard and drained, by loosening the driver lower end cap. Check "O" rings for nicks or cuts.

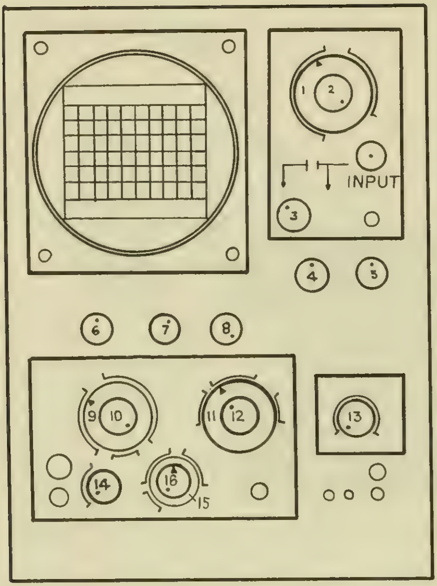
Step 2. If flooding has taken place, wash the parts with fresh water and dry.

Step 3. If malfunction of a component caused the trouble, refer to the instruction manual.

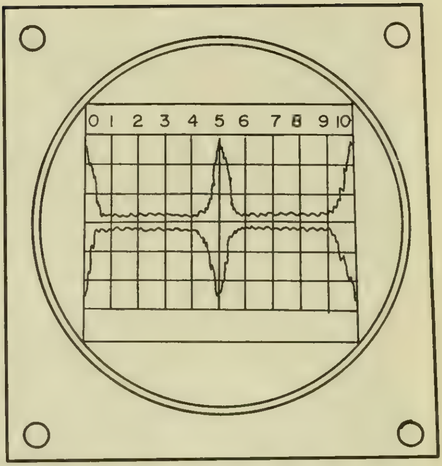
Step 4. If a lead was fouled and disconnected, cover the connection with electrical tape and lower again.

Step 5. Battery voltage should be checked after each lowering.

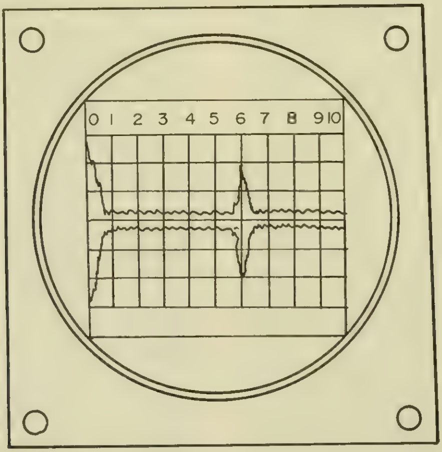
Step 6. To bench test the driver, connect the output leads across the transformer primary or across a 1-ohm 10-watt resistor.



(a) Diagram of oscilloscope panel



(b) Oscilloscope grid showing direct ping at 0, 5, and 10.



(c) Oscilloscope grid, showing direct ping at 0 and reflected ping at 6. (With dial (9) set at 5 milliseconds, pinger-to-bottom distance is 23 meters. With dial (9) set at 2 milliseconds, distance is 9 meters.)

Figure R-9. Oscilloscope monitoring of pinger-to-bottom distance.

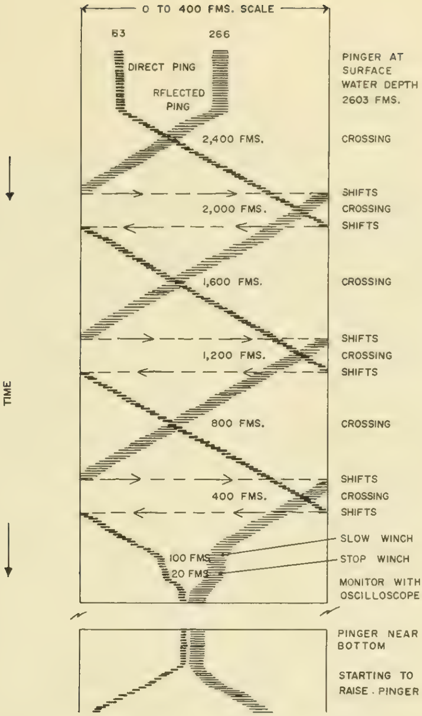


Figure R–10. **PDR strip chart of Sonar pinger signals.**

Table R–2. Sonar pinger-to-bottom distance

Table based on sound velocity of 1,500 meters per second (820 fathoms per second)

Secondary time/division dial 9 settings (milliseconds)	Oscilloscope grid divisions									
	1	2	3	4	5	6	7	8	9	10
1	0.75m	1.5m	2.25m	3.0m	3.75m	4.5m	5.25m	6.0m	6.75m	7.5m
2	1.5m	3.0m	4.5m	6.0m	7.5m	9.0m	10.5m	12.0m	13.5m	15.0m
5	3.8m	7.5m	11.2m	15.0m	18.8m	22.5m	26.2m	30.0m	33.8m	37.5m
10	7.5m	15.0m	22.5m	30.0m	38m 20fms	45m 25fms	52m 29fms	60m 33fms	68m 37fms	75m 41fms
20	15m	30m	45m 25fms	60m 33fms	75m 41fms	90m 49fms	105m 57fms	120m 66fms	135m 74fms	150m 82fms
50	38m 20fms	75m 41fms	112m 61fms	150m 82fms	188m 102fms	225m 123fms	262m 143fms	300m 164fms	338m 184fms	375m 205fms
100	75m 41fms	150m 82fms	225m 123fms	300m 164fms	375m 205fms	450m 264fms	525m 287fms	600m 328fms	675m 369fms	750m 410fms

CHAPTER S

OCEANOGRAPHIC STATION SUMMARY AND PLOTTING SHEETS

S–1 General.—Observed Oceanographic Station data obtained by taking a Nansen cast such as temperature, salinity, dissolved oxygen, various nutrients, and depth should be consolidated or summarized on one log sheet and plotted on Oceanographic Station Plotting Sheets. The Station Summary, Oceanographic Log Sheet–E, PRNC–NAVOCEANO–3167/5 (Rev.–1–63), (fig. S–1) is used to consolidate and summarize the observed oceanographic surface observations, temperatures, and depths from the Log Sheet–A and the water sample analysis results from the Various Log Sheets–C, D, etc. In addition, space is provided on the E–Sheet for recording computed density (σ_t), sound velocity, and dynamic calculations and for recording standard depth interpolated data values.

The Oceanographic Station Plotting Sheet, PRNC–NHO–3167/55 (3–62) (fig. S–2), is used for plotting profiles of various oceanographic data. These graphs and profiles serve many uses in studies and interpretation of the data. For example, some of the immediate important shipboard applications include checking for possible errors in computations, sample analyses, and Nansen bottle spacing; determining which thermometer of a pair to accept when they differ by more than .06° C.; and interpolating standard depths from the plotted observed values.

S–2 Station Summary of Observed Oceanographic Values.—After the A-Sheet computations are completed and water sample analysis results are computed, consolidate the oceanographic station data on the Station Summary, Log Sheet–E; then, have another person check each entry to make certain the data have been transcribed correctly. The following checking procedure is recommended: As each item is verified, the checker should place a dot (with a colored pencil) over the correct entry on the E–Sheet. *Do not erase to correct.* With a colored pencil, enter the correct value above the incorrect item. *Do not code items on the E–Sheet.* Space limitations in several of the blocks on the E–Sheet heading may require that further information be given on the back of the log sheet.

Density (σ_t) for each observed temperature-salinity value can be computed using table 10, Determining Density of Sea Water, in Special Publication 68 (SP–68), Handbook of Oceanographic Tables, U.S. Naval Oceanographic Office; and sound speed for each observed temperature-salinity-depth value also can be computed using table 12, Sound Speed, in (SP–68). Enter density in *Observed Values* σ_t column and sound velocity in the right hand column on the E-Sheet.

S–3 Plotting Observed Oceanographic Values.—After the surface observations, serial numbers, accepted depths, temperatures, and water sample analysis results have been entered on the E–Sheet and verified, plot the observed oceanographic values on the Oceanographic Station plotting sheet. All graphs and profiles should be drawn with great care. Use a pencil no softer than a number 3H drawing pencil. Keep the point sharp and draw fine clear lines. Plot all data accurately.

To aid in the interpretation of data, use the U.S. Naval Oceanographic Office standard set of data symbols given in table S–1, Standard oceanographic data symbols. The point in the symbol indicates the data value, and the symbol indicates the type observation.

Use french or ship curves to construct lines. Draw curves through the plotted points in such a manner that the points appear to lie on the curve rather than being connected by curved lines. This can be done easily with a little practice.

If the station depth exceeds the length of the graph, extend the plot by attaching part of another sheet to the bottom with rubber cement. A longer version of the plotting sheet (NDW NAVOCEANO 3167/56 (Rev. 3–66) is available for very deep oceanographic stations.

S–4 Temperature-Salinity (T-S) Curves.—The T–S curves are useful in detecting possible errors in the determination of temperature and

Table S–1. Standard oceanographic data symbols

TYPE OF OCEANOGRAPHIC DATA:	SYMBOL:
TEMPERATURE (°C or °F)	-⊹-
SALINITY ‰	△
OXYGEN ml/L	⊙
SOUND VELOCITY (ft./sec. or m/sec.)	⊡
DENSITY (σ_t)	▽

OCEANOGRAPHIC LOG SHEET-E
PRNC-NAVOCEANO-3167/5 (Rev. 1-63)

U. S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON 25, D. C.

STATION SUMMARY
FOR USE WITH H.O. PUB. NO. 607

SHIP . REF . CRUISE	STATION NUMBER	DATE MONTH	DAY	YEAR	GMT (Hr)	LATITUDE °	'	N-S	LONGITUDE °	'	E-W	SONIC DEPTH TO BOTTOM	MAX. SAMPLE DEPTH	LAYER DEPTH	SPEC OBS	VESSEL
DAVIS	3	July	23	1965	23:20	42	54	N	167	10	W	4755 meters	866 meters	—		DAVIS

INFO	WC	TYPE BTM	WIND SPEED (m/s)	DIR.	FORCE	ANEMO HGT (M)	BAROMETER (MBS)	TEMPERATURE DRY BULB	WET BULB	HUMIDITY	WW (CODE)	CLOUD TYPE	AMT.	SEA DIR.	AMT.	SWELL DIR	AMT	VSBY	WATER COLOR	TRANS.	CONSECUTIVE STATION NUMBER
			9kts	079°	—	—	1031.3	19°C.	17°C.	—	DRIZZLE	Sc	10/10	081°	1'	166°	3'	3 Mi	—	—	3

COMPUTED BY [illegible]
CHECKED BY [illegible]
APPROVED BY [illegible]

OBSERVED VALUES: SERIAL NO.	ACCEPTED DEPTH	T_w °C	SALINITY ‰	σ_t	O_2 ml/L			STD DEPTH	T °C	SALINITY ‰	σ_t	DYNAMIC CALCULATIONS: δ	MEAN δ	ΔD	ΣΔD	O_2 ml/L	SOUND Velocity m/sec
35	00	15.49	33.49	24.73				0000	15.49	33.49	24.73						1507.0
36	08	15.50	33.49	24.72				0010	14.44	33.55	25.00						1507.2
37	12	13.56	33.60	25.22				0020	12.63	33.67	25.46						1501.1
38	25	12.13	33.71	25.59				0030	11.72	33.74	25.68						1496.7
39	42	10.96	33.80	25.88				0050	10.70	33.82	25.93						1492.9
40	63	10.43	33.84	26.00				0075	10.42	33.94	26.07						1491.5
41	83	10.42	33.99	26.12				0100	10.28	34.03	26.17						1492.0
42	125	10.08	34.07	26.24				0150	9.95	34.06	26.25						1491.6
43	166	9.74	34.06	26.29				0200	8.87	33.92	26.31						1490.9
44	207	8.75	33.91	26.33				0250	8.39	33.95	26.42						1487.8
45	248	8.41	33.95	26.42				0300	7.84	33.95	26.51						1487.2
46	331	7.42	33.95	26.56				0400	6.19	33.94	26.71						1484.7
47	415	5.98	33.94	26.75				0500	5.15	33.94	26.85						1480.3
48	499	5.16	33.94	26.85				0600	4.47	33.99	26.95						1478.5
49	674	4.08	34.10	27.09				0800	3.64	34.21	27.22						1477.1
50	866	3.52	34.26	27.27				1000									1478.2
								1200		↑							
				↑				1500									↑
			Computed	using				2000	Interpolated values							Computed using	
			SP-11					2500	from Oceanographic							SP-58	
								3000	Station Plotting Sheet.								
								4000									
								5000									
								6000									

NAVY OPPO PRNC WASH DC

Figure S-1. **Oceanographic Log Sheet-E.**

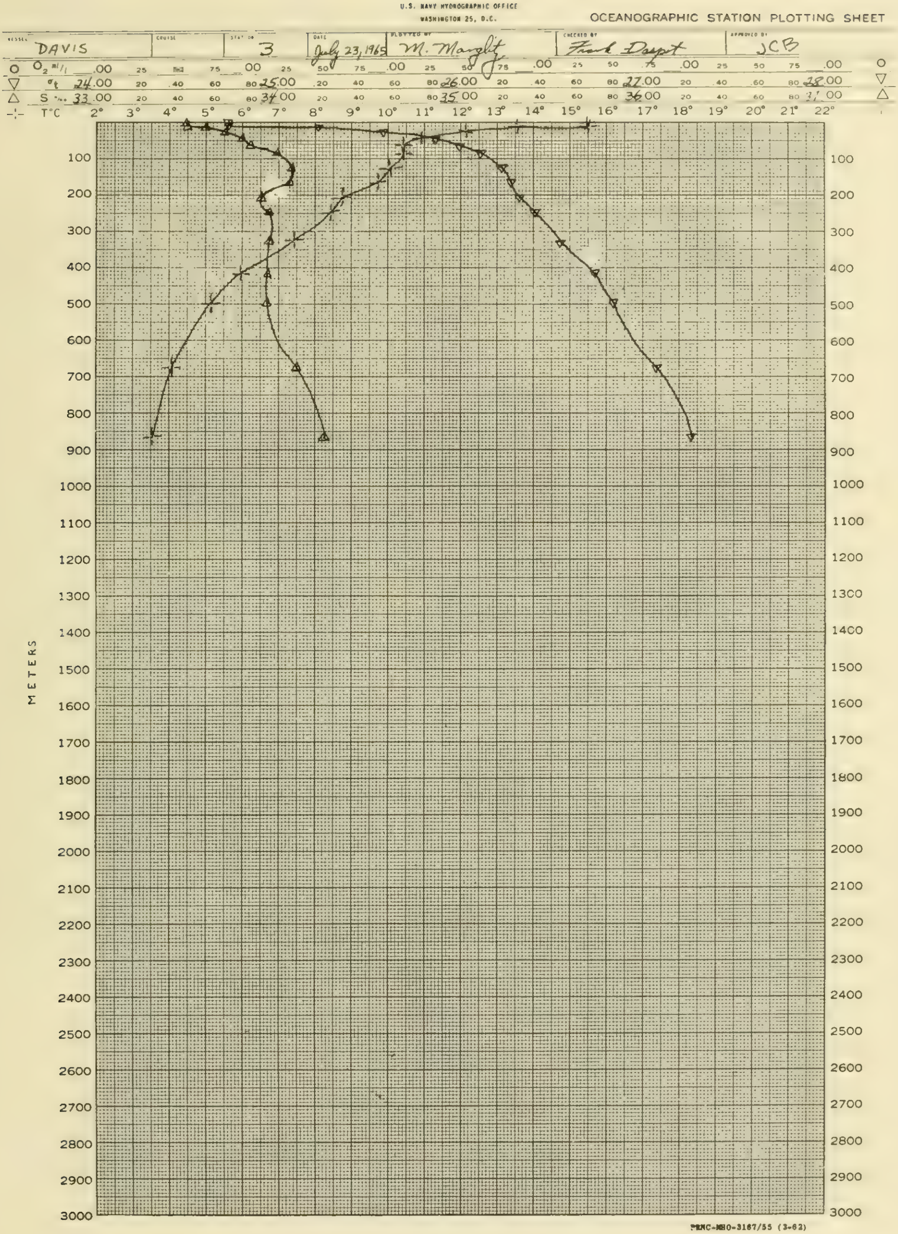


Figure S–2. Oceanographic Station Plotting Sheet.

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D. C.

TEMPERATURE—SALINITY PLOTTING SHEET

VESSEL	CRUISE	STATION	DATE	PLOTTED BY	CHECKED BY	APPROVED BY
Davis		3	25 July 65	Daspit	KBP	JCB

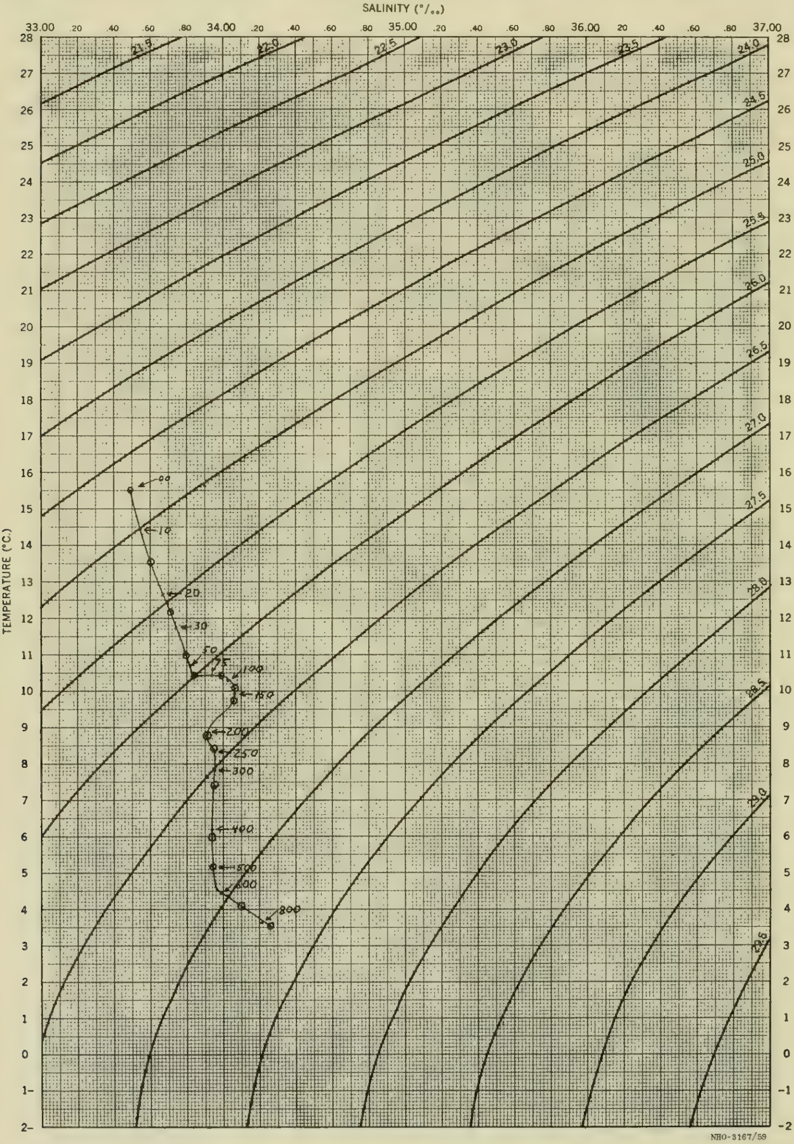


Figure S–3. Temperature-Salinity Plotting Sheet.

salinity; water masses, and their characteristics; and the variation of temperature and salinity with depth. To plot temperature-salinity relationships, the U.S. Naval Oceanographic Office uses the Temperature-Salinity Plotting Sheet, NHO-3167/59 (fig. S-3). This graph indicates density values for the range of temperature and salinity it covers.

Using the data for observed temperature and salinity values, plot each point and draw a smooth curve through the plotted points. When interpolated values at standard depths have been determined (see par. S-5), indicate the points on the T-S curve, and enter the standard depth to the right of the curve.

S-5 Obtaining Interpolated Values.—Oceanographic data values of temperature, salinity, dissolved oxygen, sound velocity, and density (σ_t) for standard depths (par. D-10) may be interpolated from plotted observed value curves, or they may be obtained by electronic computer data analysis.

To find an interpolated value on the Oceanographic Station plotting sheet, simply locate the intersection of the curve and the horizontal line which represents the desired standard depth, and read the corresponding value at the top of the graph. Enter interpolated values on the E-Sheet.

To obtain interpolated values by electronic computer data analysis, *CODE THE DATA* on the Physical and Chemical Data Form for Oceanographic Stations, NODC-EXP-3167/25 (3-64), (fig. S-4), and forward to the National

PHYSICAL AND CHEMICAL DATA FORM
FOR OCEANOGRAPHIC STATIONS

NATIONAL OCEANOGRAPHIC DATA CENTER
WASHINGTON, D C 20390

SURFACE ENVIRONMENTAL INFORMATION (MASTER CARD)

COUNTRY	SHIP	LATITUDE	LONGITUDE	MARSDEN SQUARE	DATE YEAR	MONTH	DAY	TIME GMT HR	1/10	SHIP'S CRUISE NO	SHIP'S STATION NO	DEPTH TO BOTTOM M	MAX SAMPLE
31		4254-N	16710-W		65	07	23	23	3		003	4755	09

ADD OBS CODE	WATER COLOR	TRANS	WAVE DIR	HT	P	WIND DIR	SPEED	BAR MBS	AIR TEMPERATURE DRY B	WET B	WEATHER	CLOUD T	A	VIS	SPECIAL OBS	PROCESSING
16			08	2		08	09	313	190	170	0X	5	6	8	6	

COUNTRY	INSTITUTE	VESSEL	CRUISE OR PROJECT NO
USA	NAVOCEANO	DAVIS	

SUBSURFACE OBSERVATIONS (DETAIL CARDS)

MESSENGER TIME	DEPTH M	TEMP °C	SAL ‰	O	PO₄-P	TOTAL P	NO₃-N	NO₂-N	SiO₄	pH		80
240	0000	1549	3349									3
	0008	1550	3349									
	0012	1356	3360									
	0025	1213	3371									
	0042	1096	3380									
	0063	1043	3384									
	0083	1042	3399									
	0125	1008	3407									
	0166	0974	3406									
	0207	0875	3391									
	0248	0841	3395									
	0331	0742	3395									
	0415	0598	3394									
	0499	0516	3394									
	0674	0408	3410									
	0866	0352	3426									3

REMARKS

NODC-EXP-3167/25 (3-64)

Figure S-4. Physical and Chemical Data Form for Oceanographic stations.

223-812 O - 68 - 13

NODC STATION DATA

REFERENCE: COUNTRY CODE	REFERENCE: IDENTITY NUMBER	SHIP CODE	LATITUDE ° ′1/10	LONGITUDE ° ′1/10	DRIFT INDICATOR	MARSDEN SQUARE 10°	MARSDEN SQUARE 1°	STATION TIME (GMT) MONTH	STATION TIME (GMT) DAY	STATION TIME (GMT) HR 1/10	YEAR	ORIGINATOR'S CRUISE NUMBER	ORIGINATOR'S STATION NUMBER	DEPTH TO BOTTOM	MAX. DEPTH OF SAMPLES	WAVE OBSERVATIONS DIR.	WAVE OBSERVATIONS HGT	WAVE OBSERVATIONS PER	WAVE OBSERVATIONS SEA AMT	WEATHER CODE	CLOUD CODES TYPE	CLOUD CODES AMT.		NODC STATION NUMBER
31	589	CD	4254 N	16710 W		161	27	07	23	233	1965		003	4755	09	08			2	X5	6	8		0003

WATER: COLOR CODE	WATER: TRANS. (m)	WIND: DIR	WIND: SPEED OR FORCE	BAROMETER (mbs)	AIR TEMP. °C DRY BULB	AIR TEMP. °C WET BULB	VIS. CODE	ADD'L OBS.	SPECIAL OBSERVATIONS
		08	509	313	19	17	6	16	

MESSENGER TIME HR. 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA—T	SPECIFIC VOL. ANOMALY — $\times 10^{-5}$	ΣΔD DYN. M. $\times 10^3$	SOUND VELOCITY	O_2 ml/l	PO_4—P µg-at/l	TOTAL—P µg-at/l	NO_2—N µg-at/l	NO_3—N µg-at/l	SiO_4—Si µg-at/l	pH
		STD	0000	1549	3349	2472	0032319	0000	15071							
240		OBS	0000	1549	3349	2472			15071							
240		OBS	0008	1550	3349	2472			15073							
		STD	0010	1444	3355	2500	0029741	0031	15040							
240		OBS	0012	1356	3360	2522			15012							
		STD	0020	1263	3367	2546	0025378	0059	14983							
240		OBS	0025	1213	3371	2558			14967							
		STD	0030	1172	3374	2568	0023234	0083	14954							
240		OBS	0042	1096	3380	2587			14930							
		STD	0050	1070	3382	2593	0020962	0127	14922							
240		OBS	0063	1043	3384	2599			14915							
		STD	0075	1042	3394	2607	0019632	0178	14918							
240		OBS	0083	1042	3399	2611			14920							
		STD	0100	1028	3403	2617	0018782	0226	14918							
		STD	0125	1008	3407	2623	0018209	0272	14915							
240		OBS	0125	1008	3407	2623			14915							
		STD	0150	0995	3406	2625	0018093	0317	14915							
240		OBS	T0166	0974	3406	2628			14909							
		STD	0200	0887	3392	2631	0017545	0407	14881							
240		OBS	T0207	0875	3391	2633			14877							
240		OBS	0248	0841	3395	2641			14872							
		STD	0250	0839	3395	2641	0016686	0492	14871							
		STD	0300	0784	3395	2649	0015961	0574	14859							
240		OBS	0331	0742	3395	2655			14847							
		STD	0400	0619	3394	2671	0013901	0723	14810							
240		OBS	0415	0598	3394	2674			14804							
240		OBS	T0499	0516	3394	2684			14785							
		STD	0500	0515	3394	2684	0012723	0856	14784							
		STD	0600	0447	3403	2699	0011342	0977	14774							
240		OBS	T0674	0408	3410	2708			14771							
		STD	0700	0397	3412	2711	0010204	1084	14771							
		STD	0800	0364	3421	2722	0009244	1181	14775							
240		OBS	T0866	0352	3426	2727			14781							

Figure S–5. Computer listing of oceanographic station data with template.

Oceanographic Data Center (NODC). *Code the data* in accordance with Publication M–2, Processing Physical and Chemical Data from Oceanographic Stations, National Oceanographic Data Center.

After the data are computer processed by NODC, a computer listing (fig. S–5) will be available, and the data will be on file on punchcards for use in computer analysis programs.

A comparison of interpolated values taken from the graphs and the computer listing, indicates that slight differences may exist because of the choice of the curves used in the determinations.

CHAPTER T

SEISMIC PROFILING SYSTEMS

T–1 Seismic Profiling Systems.—Seismic profiling systems are used to map acoustically the geologic structures buried beneath the ocean floor. These systems consist of a repetitive broad-band sound source and compatible receiving, amplifying, filtering, and recording equipment. The sound source and the hydrophones are towed behind the ship, and the data are recorded aboard the ship on a special graphic recorder. Several seismic sound sources, hydrophone arrays, and receiving systems are in use at the U.S. Naval Oceanographic Office, and the state-of-the-art is undergoing constant modification.

The sound sources include the following:

1. The Boomer is an electro-magnetic sound source. Discharge of a capacitor bank establishes eddy currents in a set of parallel plates, resulting in rapid repulsion between the plates and generation of a shock wave in the water (fig. T–1).

2. The Sparker is an acoustic pulse generator which produces a small controlled underwater explosion by discharging a capacitor bank across spark electrodes, causing the water to vaporize into steam and generating a shock wave in the water (fig. T–2 and T–3).

3. Other sound sources that are under development include gas and compressed air guns and the line source. The gas and air guns work by discharging a bubble into the water through special valves, and the line source consists of elongated coils of cable that operate by repulsion as do the boomers.

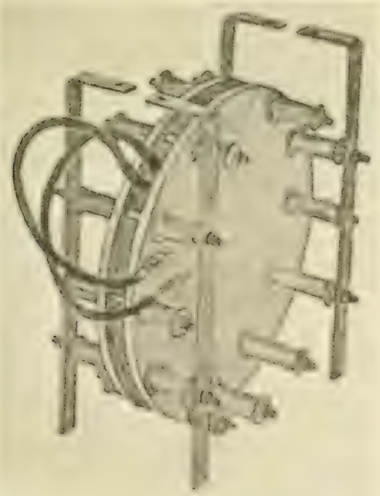


Figure T–1. Boomer sound source (EG&G Model 238).

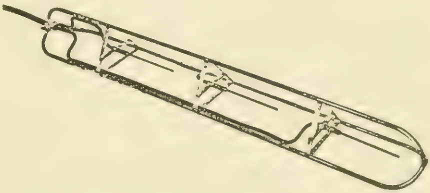


Figure T–2. Sparker acoustic pulse generator (EG&G Model 267 Sparkarray).

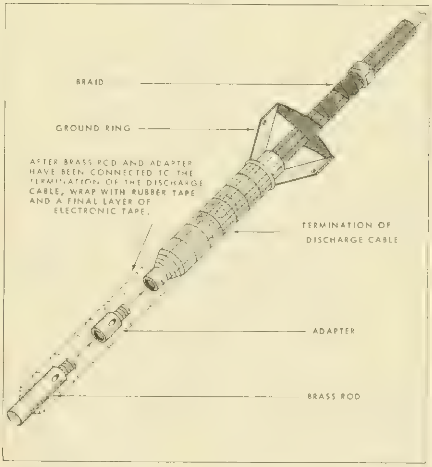


Figure T–3. The "bared cable" sparker acoustic pulse generator.

The hydrophone receiving systems employed in seismic profiling operations are designed to reduce sensitivity to ship noise, to control directivity, to develop frequency characteristics, and to cancel acceleration effects. Descriptions of several hydrophone arrays follow:

1. One hydrophone array being used has 10 hydrophones; its length is 10 feet. This array utilizes variable reluctance, pressure sensitive hydrophones. Their frequency response curve peaks at approximately 1 kc., and they have a wide variation in response and sensitivity. Five hydrophones are series connected, and the two strings of five are parallel connected.

2. Another hydrophone array being used has 10 hydrophones, but its length is 128 feet. This array utilizes piezoelectric hydrophones that are arranged specially to receive a one octave band, utilizing two or more hydrophones per octave. This array has a high signal-to-noise ratio, and it contains an impedance matching transformer and a calibrate relay.

3. Also being used is a 48 hydrophone array which is 250 feet long, and the hydrophone streamer used with the Shipboard Survey System (see ch. V) is a 200-foot long tube, containing 21 cylindrical lead zirconium titanate crystals arranged in a spatially weighted array to provide minimum pick-up noise.

Each of the above hydrophone arrays has its own audio, low-noise, high-gain amplifier with selectable automatic gain control and 20 to 2 K cps band pass filter; however, the Precision Echo Sounder (PESR), Precision Graphic Recorder (PGR), or a modified Precision Depth Recorder (PDR) may be used to record the acoustical data for either hydrophone array.

T–2 Operating the Seismic Profiling System.—In a seismic profiling system, either of the sound sources is compatible with either of the hydrophone arrays; therefore, the selection of the devices to be used will be governed by ship's equipment such as winches and booms, hydrophone arrays and sound sources available, and the purpose for which the data are to be collected.

In general, the sound source is towed aft near the ship and the hydrophone array is towed aft of the ship at a distance of 500 to 1,800 feet. Both sound source and hydrophone array are towed at a depth of 6 to 10 feet. The towing speed of the ship is 5 to 7 knots, but this is governed by sea state and signal-to-noise ratio of the receiving system. The sound source pulses are regulated by the operator to conform with the water depth, and the reflections of the pulses occur at the interfaces separating material of different acoustic impedance in the subsurface sediment structure. Velocity and density in unlithified sediments depend on sediment structure; grain size, shape, porosity, and mineral composition; and interstitial water properties.

The following instructions are presented as a guide to the operator in making seismic profile observations:

1. Launching the Boomer Sound Source.—The boomer sound source is used in various combinations. The single-plate boomer is used in shallow water operations (up to 600 fathoms); the double-plate boomer is used in mid-depth operations; and multiple, double-plate boomers are used where maximum power is required. In all applications, the boomer is mounted on a towing sled. The following tools are required to assemble the sled, mount the boomer(s), and launch the sound source:

Adjustable wrench;
Electric drill.

Components of the sled include:

4 channel members 7½′;
Deflectors (one for each boomer);
1 brace (improvised);
1 marine plywood 3′ x 2′ x 1″;
3 or 4 sash weights 90 lb. each;
1 galvanized pipe 2″ x 12′;
2 pipe clamps;
1 towing clamp;
2 weight clamps;
Necessary spring loaded bolts and nuts;
2 channel members 4″ x 7½′.

Step 1. Assemble the multiple boomer sound source sled in accordance with diagram shown in figure T–4.

Step 2. Suspend sled by towing cable, and adjust position and number of sash weights until sled hangs in a horizontal position.

Step 3. Connect boomer leads in parallel with power cable (solder copper fittings to power cable leads) and make a watertight splice, using rubber electronic tape.

Step 4. With marline, marry power cable, and tow cable at 3-foot intervals.

Step 5. Hoist boomer sound source sled over the side, and tow 15 to 30 feet aft and starboard of ship with boomers 6 to 10 feet beneath the water surface.

Step 6. Connect the boomer cable to the triggered capacitor bank of the sound source instrumentation (Mod 231) as shown in the block diagram (fig. T–5).

WARNING: The output cable from the triggered capacitor bank to the transducer should be protected where it passes over the edge of the deck, and all personnel should be warned to stay clear of the cable during seismic operations. Do not fire the transducer when it is out of the water.

2. Launching the Sparker Sound Source.—The sparker sound source can be launched and retrieved easily by two men without the use of booms or A-Frame. The three-electrode sparker frame weighs 28 pounds. It is 79 inches long,

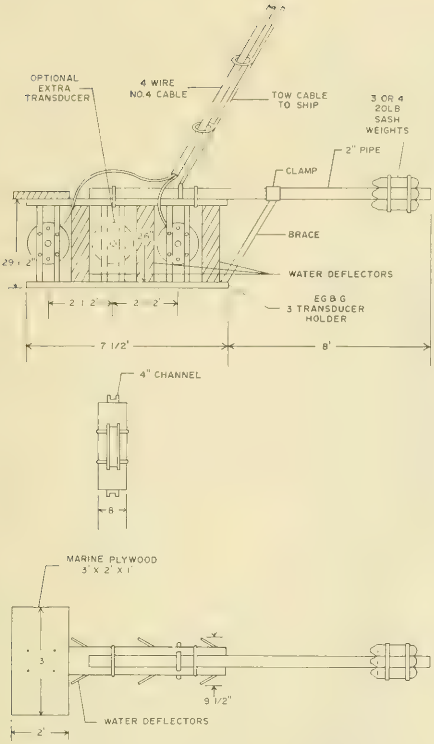


Figure T–4. Boomer sound source sled.

10 inches wide, and 10 inches high. If greater power is desired, a six-electrode assembly can be made by fastening two three-electrode frames together, side by side; also, if maximum power is required, a special nine-electrode sparker frame is available.

Instructions that follow are specifically for the three-electrode frame; however, they are applicable also to the six- and nine-electrode assemblies:

Step 1. Tighten all bolts that secure the electrodes to the stainless steel frame.

Step 2. Coat the electrode sockets with silicone grease, snap the electrodes in place, and wrap the socket and about 1 inch of the electrode with rubber tape to reduce the possibility of the electrode separating from the socket.

Step 3. Connect the power cable of the sparker to the output socket of the triggered capacitor bank (Mod 231) sound source instrumentation shown in figure T–5, allowing a maximum of 2500 joules per electrode.

Step 4. Lower the frame over the side and tow 15 to 25 feet aft port with the power cable snubbed to a cleat on the fantail. If the frame fails to tow properly (6 to 10 feet beneath the surface), attach two manila lines, one forward and one aft on the frame and adjust until the frame tows at a depth of 6 to 10 feet.

3. Launching and Retrieving the Hydrophone Array.—Either hydrophone array can be used to receive either sound source. The hydrophone array (10 hydrophones, 10 feet in length) is towed approximately 500 feet aft of the ship; the hydrophone array (10 hydrophones, 128 feet in length) is towed approximately 1,800 feet aft of the ship. Both arrays are launched and retrieved by hand, and several (five to seven) persons are required for the operation.

These arrays, usually, attain their proper towing depth (6 to 10 feet) because of the buoyant liquids contained in their acoustically transparent vinyl plastic outer sheath; however, if a depressor is necessary, it should be placed 50 to 100 feet forward of the hydrophones.

The hydrophone array is connected to the hydrophone tow cable with a joy plug, and the array is lowered over the side while the ship is underway. The cable is reeled off and payed out by hand until the desired distance aft of the ship is attained. The cable is snubbed around a cleat on the aft starboard fantail during the towing.

4. Obtaining Seismic Profile Data.—When the sound source and the hydrophone array have been launched and are towing at 6 to 10 feet beneath the surface, the system is ready to operate. For satisfactory results, sound source instruments and receiving instruments should not be supplied by the same power generators.

Step 1. Connect the hydrophone cable to the input of the amplifier, set the band pass filter to 70–150 cps for sparker source or 100–200 cps for boomer sound source, connect the output leads of the band pass filter to a recorder (PGR, PESR, or PDR), and connect the recorder's trigger switch lead to the triggered capacitor bank (Mod 231).

Step 2. Adjust the gain of the amplifier to obtain a readable signal on the recorder; figure T–6 presents an example of a good signal. Annotate the strip chart at 30-minute intervals with a time mark, the date, and the ship's name. In addition, maintain a logbook with the above information, all instrumentation control settings, and any explanations pertinent to the operation.

Step 3. During seismic profile operations, the sound source requires periodic inspections and maintenance. Retrieve the boomer once each 12 hours and inspect the aluminum plates for holes, check the area between the plates and coil for small pieces of metal, and examine the towing sled for broken parts or loose nuts. Re-

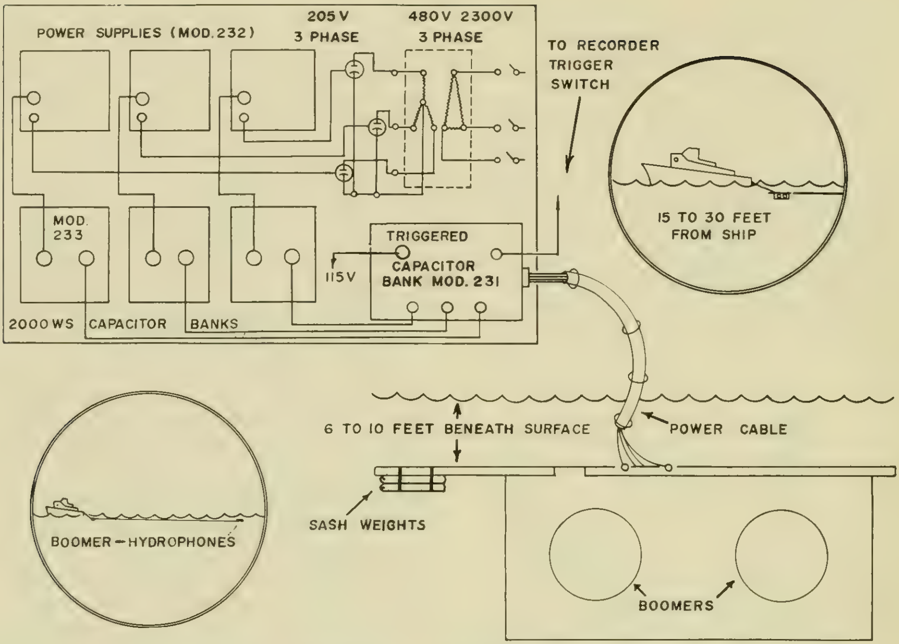


Figure T–5. **Block diagram of Boomer and triggered capacitor bank.**

place seriously abraded aluminum plates; remove pieces of metal found between coil and plates; and tighten bolts. Retrieve the sparker once each 24 hours, and inspect it for missing and worn electrodes, loose bolts, and broken frame. Replace missing and worn electrodes, repair broken frame by welding, and tighten bolts.

Step 4. The hydrophone array need not be retrieved during seismic profile operations unless signals are not being received. If the 10-foot hydrophone array is damaged and its buoyant fluid is lost, it can be patched and refilled with transformer oil. If the 128-foot array is damaged and loses its fluid, small holes can be taped to prevent further loss, but no attempt should be made to add fluid.

T–3 Securing Seismic Profiling Equipment.—When the operation is completed, retrieve the sound source and the hydrophone array. Rinse the sound source and the hydrophone array with fresh water. Store the hydrophone array on a reel where it will not be exposed directly to the sun.

T–4 Seismic Profiling Data.—Seismic profiling strip charts, logbooks, and a smooth plot of the ship's track should be returned to the Oceanographic Office for analysis.

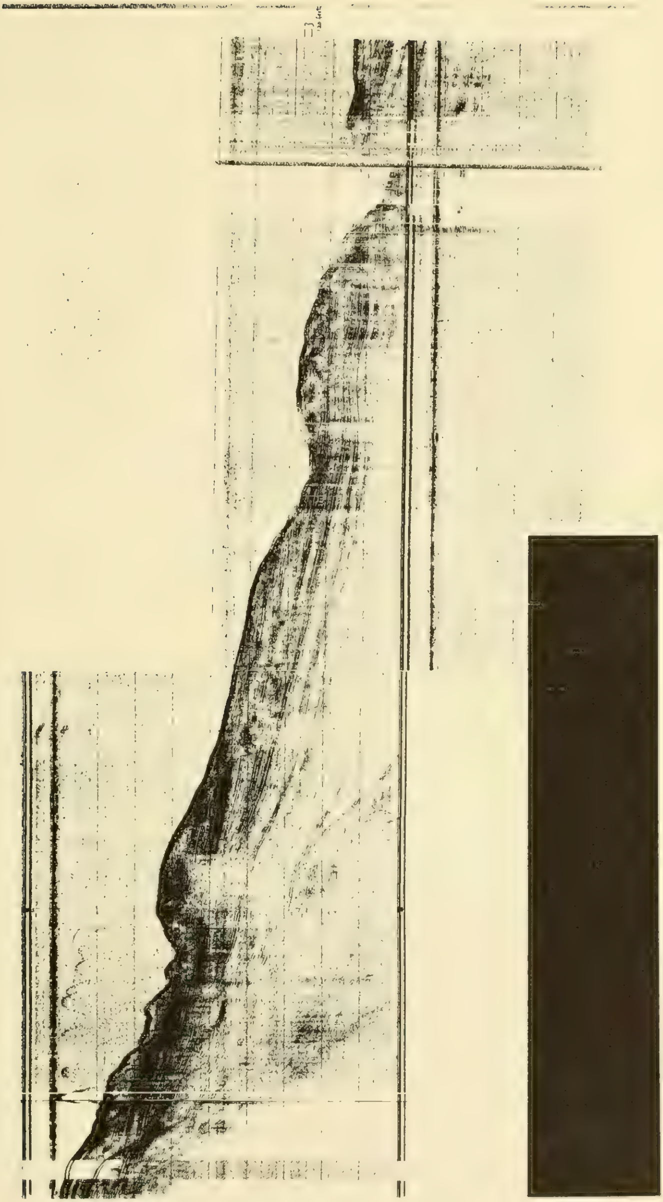


Figure T–6. Seismic profile strip charts, assembled to show continuous profile.

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INSTRUCTION MANUAL

FOR

OCEANOGRAPHIC OBSERVATIONS

Second Edition
1955

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INSTRUCTION MANUAL FOR OCEANOGRAPHIC OBSERVATIONS, Second Edition, 1955.

RECORD OF CHANGES

Change No.	Date of Change	Inserted by

Oceanographic survey ships USS *San Pablo* and USS *Rehoboth* in Monaco.

FOREWORD

The continuing necessity for naval and maritime operations throughout the world makes it increasingly important that every effort be made to collect oceanographic and related information of the various oceanic areas.

During recent years there has been an increasing demand for an instruction manual which would provide standard instructions for carrying out basic oceanographic observations. It is hoped that H. O. Pub. No. 607, Instruction Manual for Oceanographic Observations, will fill these requirements and will provide the oceanographic observer with a practical guide for use at sea.

Oceanographic surveys and expeditions are conducted by many Government agencies and private institutions. While the log sheets and forms used for recording the data may differ, the objective is the same. The methods, techniques, instruments, log sheets, and tables described in the following pages are those used at sea by oceanographers of the U. S. Navy Hydrographic Office. No claim is made for originality, nor is it proposed that these methods become universal. It is intended to add to this manual, from time to time, other methods and techniques as they are proven and to modify existing ones when improvements warrant.

Comments and suggestions concerning the use of this manual are invited.

J B Cochran

J. B. COCHRAN,
Captain, U. S. Navy,
Hydrographer.

TABLE OF CONTENTS

PART II

OCEANOGRAPHIC CODES AND TABLES

Part III [illegible]

LIST OF ILLUSTRATIONS

PART I

CHAPTER 1

INTRODUCTION TO OCEANOGRAPHIC OBSERVATIONS

1–1 OCEANOGRAPHY, A DEFINITION.—Oceanography may be defined as the science of the sea employing the principles of physics, chemistry, meteorology, biology, and geology. It originally included the world below the surface of the sea. Today, however, it has been extended to include those phenomena which occur at the sea-air interface. As the fund of knowledge expanded, it rapidly became apparent that oceanography is made up of several specialized sciences such as marine biology, marine geology, chemical oceanography, and physical (or dynamical) oceanography.

1–2 EARLY EXPLORATION.—The treatment of oceanography from the geophysical viewpoint is recent. Scientific work in oceanography has been in progress but little more than a century, however it is evident that there was lively interest throughout ancient times. The Phoenicians, Greeks, Romans, Arabs, and the nations taking part in world exploration from the time of Henry the Navigator laid the foundation for modern oceanography. The list of those ancients who showed sufficient interest to speculate about the ocean includes such famous names as Herodotus, Aristotle, Eratosthenes, Strabo, Pliny, and Seneca.

Aristotle, who lived from 384 to 322 B. C., studied the physical properties of the sea as far as possible without the aid of instruments. He thought that the water was warmer and saltier at the surface than at the bottom. He believed that evaporation due to the sun's heat would eventually dry up the sea. His opinions on oceanography are to be regarded as mere speculation, but his observations and study of marine animals were of distinct scientific value.

In about A. D. 53 Pliny in his gossipy "Natural History" presented Aristotle's investigations modified by much subsequent superstition and tradition. He placed the greatest depth of the ocean at 1,500 fathoms, a figure far too low. He conjectured that the sea was salt because of evaporation due to the sun's heat.

Very few of the theories advanced in this early period of the study of the sea have any present merit, but the necessary geographical knowledge was obtained, without which the present structure could not have been erected.

The real beginning of oceanography, with recognition of its great scope, was the British *Challenger* Expedition of 1873–76. Among the important expeditions since that time may be mentioned the German *Meteor*, of 1925–27, and the American *Carnegie*, of 1927–29. Since the end of World War II there have been around-the-world expeditions carried out by the Swedish *Albatross* and the Danish *Galathea*.

The expense of extended voyages covering large areas was no doubt the chief reason why systematic examination of even the surface of the sea was not seriously considered until the middle of the nineteenth century. The voyages of the *Lightning*, *Porcupine*, and *Challenger* brought on a rapid development of instruments which permitted investigations of the greatest depths. These techniques for sounding the contours of the sea floor; the gathering of samples of the bottom; of sampling the organisms and measuring the physical characteristics of the sea, advanced so that by the last decade of the nineteenth century scientists were in a position to use the knowledge gathered effectively. The results stimulated many subsequent expeditions in various parts of the world.

From that time forward, with every new expedition and with improvements in technical methods and instruments came a flood of new facts pouring in so rapidly that more was learned about the sea and its inhabitants during the last quarter of the 19th century than had been learned before.

Toward the end of the last century there came a pause in the regional descriptive era of oceanography. New schools arose centering their attention on mathematical analyses of the acquired data of the physical properties. This conscious alteration of the viewpoint from the descriptive to the analytic is one of the chief factors which gives oceanography its present tone.

1–3 OCEANOGRAPHIC FACILITIES.—The hydrographic and oceanographic organizations of many nations have made important contributions to the knowledge of the sea. There are a number of international oragnizations, notably the International Council for the Exploration of the Sea, which have both encouraged and initiated oceanographic investigations.

The oceanographic institutions and marine biological laboratories are organizations primarily devoted to the study of the oceans and its organisms. The Museum of Oceanography at Monaco, the Marine Biological Station at Naples, the Bergen Geophysical Institute, and the Institute of Oceanography in England are European examples of the many institutions and laboratories throughout the world.

In the United States such institutions are comparatively new. The Woods Hole Oceanographic Institution at Woods Hole, Mass., and Scripps Institution of Oceanography at La Jolla, Calif., are the principal organizations. In 1946, the Division of Oceanography was organized at the U. S. Navy Hydrographic Office, at Suitland, Md.

1–4 THE TYPES OF INFORMATION SOUGHT.—In the sense that oceanography encompasses a portion of all the physical sciences, types of information sought on oceanographic surveys and expeditions include data concerning these fields. Although man has exploited the oceans for thousands of years, there is still much to be learned from them.

Because of the high costs of maintaining the laboratory, i. e., the ship needed to obtain oceanographic information, it is important that the most profitable use be made of the time at sea. Although a particular project may concern itself primarily with a certain oceanographic feature such a study usually cannot be prosecuted effectively without supporting data from many other variables. For example, investigations of the growth of plankton becomes immediately involved with water temperature and salinities, nutrient concentrations, transparencies, and mass transport of water. Information pertaining to these variables requires, in turn, related observations of air temperatures and other meteorological data.

Variables in the sea may change with respect to both space and time. It is often important to know the periodicity and extent of these changes. In the case of the time variable, this may require repeated surveys of the same area, while in the case of the space variable, it is valuable to have simultaneous observations taken over a distance, thus necessitating the use of two or more ships or recording units.

Oceanography usually is divided into its five basic sciences: physics, chemistry, meteorology, biology, and geology. A few comments concerning the general types of information sought in each of the fields are given below.

1–5 Physical Oceanography.—The study of physical oceanography is probably the largest and most complicated of the five basic divisions. It involves information from all the other fields, especially that of chemical oceanography. It includes the studies of tides, currents, sea and swell, temperatures, densities, origin and circulation, sound propagation, transparency, sea ice, and other physical problems of sea water.

Of major importance is knowledge concerning surface and subsurface currents—whence they originate, their speed and direction, and their influence on other oceanic factors.

Determinations of subsurface currents may be made by direct measurements with current meters, described in chapter 9, or by mathematical computations utilizing the densities of the masses in question. Density is a function of the temperature and salinity of the water under a given pressure. It is therefore desirable to gain knowledge of the vertical distribution of temperatures and salinities at accurately determined depths. These two variables also provide basic information required to determine sound propagation and patterns, both vertically and horizontally, in sea water.

The studies of internal waves have concerned investigators in the field of underwater sound transmission. These waves are similar to the commonly observed surface waves, but occur at the interface of layers of water of different densities rather than at the sea-air boundary. The study of wind waves (sea) and swell is in its infancy. Until only the past few years observations of deep-water waves were limited to visual data. Recent developments of electrical wave staffs and pressure-operated wave indicators provide recorded data for analyses. The success of long- and short-range wave forecasting is dependent upon the number of observers reporting and the accuracy of the observations. Such forecasts are of utmost value for many marine operations, both military and commercial.

Observations of transparency, light penetration, scattering, and color are aided by the use of photoelectric cells which are lowered to various depths. Such studies assist in the determination of currents and provide clues to biological conditions.

1-6 Chemical Oceanography.—The field of chemical oceanography is concerned with the determination of the various constituents of sea water and their distribution. The salinity of sea water is of major importance in computing densities and dynamic currents as well as sound velocities. Analyses to determine nutrient concentration (phosphate, nitrate, silicate, etc.), the pH (acidity), and the content of dissolved gases (oxygen and carbon dioxide) provide information which aid in determining age, origin, and movement of water masses and their influences upon marine life. Some of these analyses must be made immediately after sampling. Other samples may be stored and analyzed ashore at a later date if the facilities of the ship are not adequate. In others, such as carbon-14, part of the analyses are run aboard ship and final determinations made ashore from the reduced samples.

1-7 Meteorological Oceanography.—The interaction of sea and air and the influence of one medium upon the other is a very important part of oceanographic studies. Prevailing winds in certain areas affect ocean currents while in others the air temperatures are tempered by the sea surface. Solar radiation affects the heat budget and influences biological conditions. Thus, the types of meteorological information which must accompany all oceanographic observations must include: air temperatures, humidity, wind direction and speed, atmospheric pressure, cloud types and amount, and visibility; along with the oceanographic variables of sea surface temperature, wind waves, and swell.

1-8 Biological Oceanography.—Biological oceanography is concerned with both plant and animal life in the sea. Animal life is divided into three general groups—the *benthos* (bottom living), the *nekton* (swimming), and the *plankton* (wanderers—the floating and drifting life). The plankton are further divided into *phytoplankton* (plant forms) and *zooplankton* (animal forms). Little is known of the life cycles of marine life, and we are only now beginning to realize how little is known of the pelagic populations of the sea. We are interested in the distribution of plankton populations, from both quantitative and qualitative points of view, as well as the distribution and habits of the benthos and nekton. Different types of nets are towed in the efforts to sample the marine life. It is considered that studies in this field may solve problems which are believed to be of biological origin. Among these are the influence that marine life may have on the transmission of underwater sound.

1-9 Geological Oceanography.—A most important aspect of oceanography is submarine geology. Although considerable strides have been made in the past few years with the advancement of instrumentation, less is known about it than any other field of geology. The techniques of echo sounding, seismic exploration, underwater photography, and various types of sampling and coring are gradually providing a better idea of the shape, character, and history of the ocean bottom.

1-10 SHIPBOARD EQUIPMENT AND FACILITIES.—The most basic requirement for an oceanographic vessel is to provide as stable a platform as possible from which observations at sea can be made. The more stable the platform, the greater the number of working days possible under adverse weather and sea conditions, with the resulting greater return of more accurate data. Coupled with stability is the ability to remain on station with a minimum amount of drift. Thus a deep draft vessel with a minimum amount of freeboard to give windage is desirable. Other basic requirements for an oceanographic ship include adequate deck working space and machinery, laboratory facilities, cruising range, and living accommodations for the scientists and crew. Other desirable features include control of the ship's heading at very slow speeds and while lying to on station, ability to maintain silent ship (battery) conditions for periods up to at least 12 hours, and adequate weight-handling equipment such as booms or cranes.

1-11 Deck Space and Machinery.—Open and uncluttered deck space is very important in order to handle the numerous pieces of large oceanographic equipment. Often these pieces are very heavy while others are long and awkward to handle. Deck machinery essential to the oceanographer are winches, booms, and cranes usually of special design. The largest type of winch used by oceanographic research ships is the deep-sea anchoring winch. This winch uses steel wire rope in lengths of 20,000 to 35,000 feet. Some winches use specially tapered wire, while others use wire of about ½-inch diameter. The tapered wire can be used to greater depths than the untapered wire because it has been calculated that a vertical steel wire of any diameter will not support its own weight with a safety factor of two if it is more than 30,000 feet long (Von Arx, 1954, after Stommel). Such a winch is used for deep-sea anchoring at great depths for periods ranging from a few hours to a month. Other uses to which this winch is put include bottom dredging, towing large midwater trawls, taking large bottom cores, and obtaining samples of sea water for carbon-14 (C^{14}) analysis (fig. 1–2).

The winch the oceanographer probably uses the most is the oceanographic winch. This is a medium size winch which holds 20,000- to 30,000-foot lengths of wire rope. This wire is about 5/32 inch in diameter and is usually stainless steel. The winch is a high-speed type and is the one from which the majority of oceanographic instruments are lowered. It is used for water sampling bottles, current meters, underwater cameras, small coring devices, small dredges, plankton nets, various temperature measuring instruments, and numerous other types of equipment (fig. 1–1).

One of the smallest winches used on an oceanographic ship is the bathythermograph, or BT, winch. This winch is used to lower the BT, both while underway and when lying-to on station. The BT is a recording thermometer capable of registering temperature against depth down to 900 feet. The winch uses about 2,500 feet of 3/32-inch diameter stainless steel wire. It is sometimes used in shallow water for taking small bottom samples when underway with a specially designed bottom sampler called a "scoopfish". Mechanical current meters and vertical hand plankton nets are sometimes lowered from the BT winch.

Frequently special winches are used to lower and raise specific pieces or types of equipment such as electrical current meters or special hydrophones.

1–12 LABORATORY FACILITIES.—An oceanographic ship needs several laboratory spaces. A deck laboratory is necessary in which instruments are prepared for operation and some analyses are carried out. It should be located near the oceanographic winch and

Figure 1–1. View of A-frame, platform, and oceanographic winch.

Figure 1–2. Deep-sea anchoring winch.

platform. Other laboratory spaces are needed where chemical, biological, and geological analyses are performed, where electronic recording equipment is installed, and where photographic developing and printing is done. In addition to these laboratories, office and drafting room space is needed to carry out the reduction of data and preparation of technical reports. Dry storage space for oceanographic equipment and stowage for samples obtained during a cruise are necessities. Racks to stow cases of sea water samples, cases of biological specimen jars, bottom sediment jars, and core samples are required.

1–13 OCCUPYING AN OCEANOGRAPHIC STATION.—Oceanographic observations are made from a ship under three conditions: (1) While underway, (2) while lying to on station, or (3) while at anchor. Observations taken under the first condition generally are limited to meteorological and bathythermograph observations with occasional shallow water bottom sampling with a scoopfish. For special surveys, hull-mounted recording devices for obtaining continuous data of water temperature, salinity, or conductivity are used. Certain types of current measurements are made while underway. Seismic and acoustic measurements are made with 2 ships—one lying to and the other underway. However, the greater portion of oceanographic work at sea is carried out while occupying an oceanographic station. An oceanographic station is any group of oceanographic observations made at the same, or virtually the same, geographic position at nearly the same time. Although the overall cruise planning is usually carried out well in advance of the cruise, detailed planning for the individual

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station is carried out by the senior scientist with the assistance of the other oceanographers. The decision as to what observations will be taken will depend upon local conditions as well as the requirements of the survey.

Prior to arriving on station, the instruments and equipment to be used are put in readiness. When the navigator has determined that the ship is at the desired position, the ship is maneuvered in such a position that the side on which the oceanographic winch is located is facing into the wind. The ship's engines are then stopped.

Outboard from the oceanographic winch is the platform, similar to a leadsman's chains, with an A-frame over it. From the A-frame is suspended a special block called a meter wheel. This meter wheel has a stainless steel sheave, of an exactly measured circumference, which is connected to a meter box. The oceanographic wire is passed over this meter wheel and the amount of wire that is let over the side is indicated by the meter box dials. A lead weight of about 100 pounds is attached to the end of the wire. This is lowered over the side, outboard of the platform, after the ship is dead in the water. A series of water sampling bottles with attached thermometers, one type used by the U. S. Navy is called a Nansen bottle, are attached to the wire at various depths. After these samples, with their temperatures, are taken, a series of plankton tows may be made. These might be followed with a lowering of the underwater camera or a coring device to the bottom.

The time involved in taking a series of observations as described above in water about 4,000 meters deep would be approximately 7 hours. If a large coring device, such as the half-ton Ewing piston corer, were lowered by the anchoring winch to this depth, it would take some 5 hours to lower and raise it for a single core.

Many observations can be taken simultaneously. Thus, bathythermograph lowerings, surface plankton tows, subsurface visibility measurements, wave measurements with the electric wave staff, and the associated meteorological observations, can be taken while other lowerings are in progress without adding to the time on station.

The efficiency with which the observations and measurements are obtained during the time the ship is occupying the oceanographic station naturally depends upon the number of personnel available to assist and the degree of training they have had. On the U. S. Navy survey ships, there may be anywhere from 3 to 12 men assisting the oceanographers, depending upon the requirements for a particular station. It takes about 8 men to rig and get the Ewing piston corer over the side. Nansen bottle casts take about 3 men; a winch operator, a platform man, and a bottle passer. It takes about 4 men to rig and operate the electric wave staff.

After the last piece of equipment is back aboard, the ship gets underway and heads for the next station, which may be a few miles or possibly a hundred miles away. While steaming to the next station, current measurements using the Geomagnetic Electrokinetograph (GEK) may be taken. The equipment and instruments just used are cleaned, the samples obtained are stored, and preparations for the requirements of the next station are made. In the drafting room or scientific office and in the laboratories, work is started on computing and analyzing the data recently obtained. The temperature and depth calculations are carried out, chemical titrations are run, and the data are checked. This work is more laborious and time consuming than that of occupying the station itself.

1–14 DEEP-SEA ANCHORING.—Observations taken during a deep-sea anchor station generally are similar to those described above; however, the problems of high wire angles due to the drifting of the ship are not present although wire angles due to current may be troublesome at times. In addition, current measurements with both mechanical and electrical current meters are taken. The observations taken on anchor stations usually are repeated at definite time intervals while at anchor. Current observations are carried out through one or more tidal cycles.

Deep-sea anchoring involves techniques slightly different from ordinary shallow-water anchoring. It generally is a fair-weather operation. Of necessity the anchoring equipment is light. Anchors used by U. S. Navy survey ships are 500-pound Danforth type. The anchor is attached to the half-inch wire. The scope-to-depth ratio normally used for deep-sea anchoring is less than that required by shallow anchoring. In shallow anchoring, ratios of 5 to 1 or greater are used frequently, while in deep-sea anchoring, ratios greater than 3 to 1 are rare. The reasons for this are the great depths involved compared to the length of available cable; the amount of scope lying on the bottom for deep-sea anchoring is probable far greater for a small ratio than that on a shallow bottom with a large ratio; and finally, the drag, or resistance, of the cable in the water is considerable. For example, when anchoring in 1,000 fathoms a 3-to-1 ratio will use 18,000 out of a total of 20,000 feet of cable on the winch. Of this scope, it is possible for as much as 1,500 fathoms of it to be lying on the bottom. Under such conditions, a considerably smaller anchor than that used for the bower anchor can be used. It also makes the job of weighing anchor easier, for the strain on the cable due to its own weight is considerable.

CHAPTER 2

OBTAINING SEA WATER SAMPLES AND TEMPERATURES

2–1 GENERAL REMARKS.—Sea water samples are collected from various depths of the ocean by means of specially adapted water sampling bottles. The first bottle was invented by Hooke in 1611. Since then, more than 50 types have been developed and used by different oceanographic institutions throughout the world. However, the types of bottles in general use have been reduced to a few of simple but rugged design. This is so because only a few are designed to withstand the rigorous working conditions and have specific or desirable features. The type used by the Hydrographic Office is a modification of the one developed by the Norwegian arctic explorer and oceanographer, Fridtjof Nansen, in the latter part of the 19th century. This type is known as the Nansen bottle.

Temperatures at various depths are obtained with deep-sea reversing thermometers. These special thermometers are attached to the exterior of the Nansen bottle. Reversing thermometers were first developed by the firm of Negretti and Zambra, of London, in 1874. The modern thermometers are precision instruments which are accurate to 0.01° C. They are calibrated carefully before usage and are recalibrated periodically.

Other temperature-measuring devices and sea water samplers have been developed in recent years. A few such instruments are the bathythermograph, the Spilhaus-Miller sea sampler, the salinity-temperature-depth recorder (STD), the conductivity-temperature-indicator recorder (CTI), and the microthermal depth recorder. Compared with the Nansen bottle, all of these instruments are limited to relatively shallow-depth operations. In addition, the temperature measuring elements either do not attain the degree of accuracy and reliability of the reversing thermometer or are still in the experimental stage.

The bathythermograph is an instrument used extensively for obtaining temperature versus depth observations. Its operation is explained in this chapter. Additional instructions for survey operations are given in chapter 14. Explanation and instructions for operating the Spilhaus-Miller sea sampler are given in this chapter.

2–2 INSTRUCTIONS FOR OPERATING THE NANSEN BOTTLE.—The Nansen bottle is a metal reversing water sampler with a 1.25-liter capacity. Its purpose is to bring an uncontaminated water sample from a desired depth to the surface. It is fitted with a tapered plug valve at either end and is lowered on the oceanographic wire in the open position, thus flushing itself during the lowering. When the bottle reaches any predetermined depth, a brass messenger is dropped from the deck. The messenger serves to disconnect the top of the bottle from the wire; the bottle then reverses, making a 180° arc with the wire. The plug valves close when reversal occurs, entrapping a water sample from the desired depth, and a second messenger is released which in turn effects the reversal of a lower bottle, and so on (fig. 2–1).

To keep contamination of water samples to a minimum, Nansen bottles are constructed of brass. To provide resistance to action of salt water the exterior parts are chromium plated and the interior is silver or tin plated. The exterior is painted yellow to increase visibility in the water. Should a Nansen bottle be inadvertently lowered with the plug valves closed, the pressures encountered will crush it.

Each Nansen bottle is fitted with a frame to hold deep-sea reversing thermometers. Most frames hold 2 thermometers, although frames for 3 thermometers are sometimes used. Brass tubes in the frame, into which the thermometers are inserted, are slotted to permit easy reading of the scale. One end of each tube

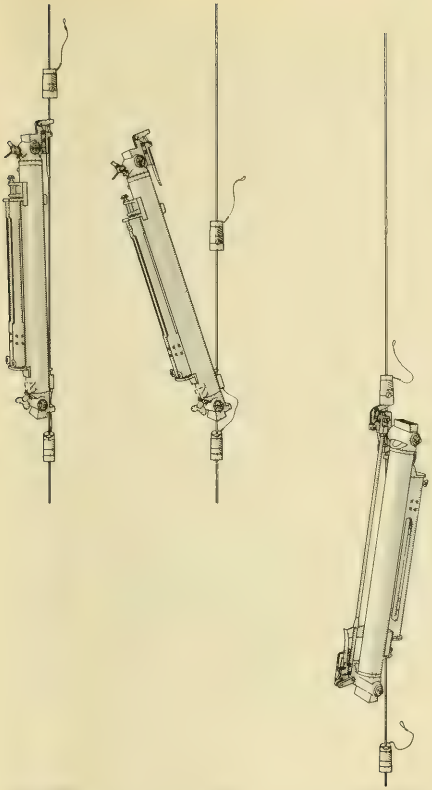

Figure 2–1. Nansen bottle in three positions—before tripping, during tripping, and after tripping.

is perforated to permit water circulation so that the thermometers may come to temperature more rapidly. The ends of the tubes contain coil springs and rubber pads to hold the thermometers securely yet provide a certain amount of protection against shock. The thermometers are always inserted into the tubes in such a manner that the large mercury reservoir is in the end of the tube having the small perforations.

2–3 Associated Equipment.—In addition to the Nansen bottle, its thermometer frame and thermometers, the following equipment is needed: oceanographic winch and wire, a meter wheel, messengers, wire angle indicator, racks for the Nansen bottles, water sample bottles, and a thermometer reader. The oceanographic winch has been described in chapter 1.

2–4 Messengers.—Messengers are essential for the operation of Nansen bottles. They are brass weights constructed in such a manner that they can be attached and detached from the wire quickly and can slide freely. A small wire, with a loop at the end, suspends them from the release mechanism of the bottle.

2–5 Wire-Angle Indicator.—The wire-angle indicator is a simple device for measuring the angle of the oceanographic wire from the vertical. It consists of a protractor with a weighted plumb arm.

2–6 Nansen Bottle Racks.—An arrangement for racking the Nansen bottles is essential for proper conduct of operations. Racks should be convenient to the platform and A-frame. They should be constructed so that the Nansen bottles are securely held in a vertical position and yet can be readily removed and replaced. The Nansen bottles should be at a height to enable easy reading of the reversing thermometers. Immediately below each Nansen bottle should be a rack to hold 2 or 4 glass water sample bottles (fig. 2–2).

2–7 Reversing Thermometer Reader.—The reversing thermometer reader, or viewer, is a magnifier used to read the thermometers to the required accuracy. It consists of a brass tube with a 6-X lens. The field end of the tube has two V notches for self-aligning the reader against the glass shell of the reversing thermometers.

2–8 Spare-Parts Kit.—Nansen bottles used by U. S. Navy survey ships are provided with a spare-parts kit containing spare clamps, springs, washers, pins, and the necessary tools to effect minor repairs and general maintenance. Generally, 1 kit is issued for every 12 bottles.

2–9 Preparing the Nansen Bottle for Operation.—Before a Nansen bottle is used on a station, it should be checked carefully for proper operation of parts. The valves should be lubricated with a silicone stopcock grease to insure smooth movement. All moving parts should be lubricated to give free action. Springs and pins of the messenger and bottle-releasing mechanisms should be tested for proper action. Should they be too weak, the bottle may trip prematurely or the messenger released while the bottle is being lowered. If they are too stiff, they will not release properly when struck by the messenger. The action of the air vent screw and the condition of the washer should be checked. The two air vent holes must not be clogged. The drain petcock valve should turn smoothly. After the bottles have been checked and are in operating condition, they are placed

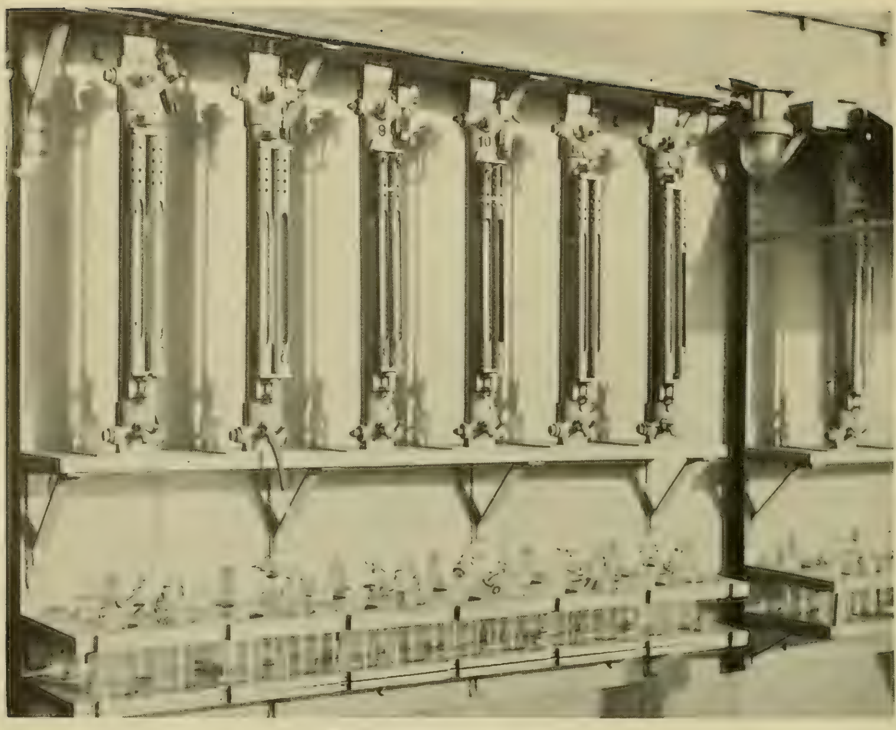

Figure 2–2. Nansen bottles in racks.

in the racks in the order in which they are going to be used on the station. Deep-sea reversing thermometers are placed in the thermometer frames as described in section 2–22 and the salinity, oxygen, and other sample bottles are placed in the racks below the Nansen bottles. The Nansen bottle, thermometer, and sample bottle numbers are recorded on oceanographic log sheet A, as shown in chapter 14.

2–10 Bottles in Series.—To expedite work at sea, Nansen bottles are used in series; several bottles are attached at intervals along the wire during a single lowering, or cast. Nearly simultaneous water samples and temperatures at different depths are obtained with one lowering. Up to 12 bottles may be used on one cast. It is not considered safe to place more than 12 bottles on $\frac{5}{32}$-inch wire. The depths to which they will be lowered is determined prior to starting a cast. Generally, the bottles are spaced at close intervals near the surface since there are greater changes of temperature, salinity, oxygen, and other variables in this region. At lower depths, the bottles usually are spaced at greater intervals because the temperature and salinity values generally change more slowly with increasing depth. Thus, with 12 to 15 bottles on the wire, the first cast may reach from the surface to only 300 or 400 meters in depth. A second or even third cast commencing at the greatest depth of the previous one is usually necessary to get adequate samples to all desired depths.

2–11 The Standard Depths.—The International Association of Physical Oceanography, in 1936, proposed the following standard depths at which observations should either be taken directly or the data adjusted by interpolation from the distribution at other levels. The standard depths, in meters below the sea surface are: 0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, 400, 500, 600, (700), 800, 1,000, 1,200, 1,500, 2,000, 2,500, 3,000, 4,000, and thence every 1,000-meter interval to the bottom. The depths in parentheses are optional. All data obtained by Nansen bottles and used at the Hydrographic Office are adjusted to the standard depths. The optional 250-meter depth is included but the 700-meter depth may be omitted.

2–12 Spacing the Nansen Bottles.—Several factors influence the spacing of Nansen bottles along the wire and vary from station to station with the types of data sought. While it is desired to obtain data at or near standard depths, this is accomplished only under conditions of zero or near zero wire angles. Such conditions are relatively rare at sea. Isoconditions of temperature, salinity, etc., may warrant wider spacing of bottles. Steep temperature, salinity, and oxygen gradients may require closer spacing in order to better delineate them.

2–13 Placing the Nansen Bottle on the Wire.—After the oceanographic winch has been tested and the lead weight shackled to the wire and lowered over the side, it usually is run down to about 10 or 15 meters below the waterline and the winch stopped. This holds the lead clear of the hull and the wire steady against the roll of the ship. After the meter dials are set at zero, the first Nansen bottle can be placed on the wire. It should be noted that the Nansen bottle to be placed first on the wire is the one that will go to greatest depth, etc. Clamp the bottle to the wire and securely tighten the wing nut on the clamp. Release the locking spring from the connecting rod and swing the bottle up. This opens the valves at each end of the bottle and reverses the thermometers. Depress the messenger trigger of the tripping assembly on the upper end of the bottle and fasten it to the wire. Make sure that the messenger trigger returns to the "up" position and the pin holding the bottle to the wire has returned completely to the closed position. Next check to insure that the drain petcock, now at the upper end, and the air vent, now at the lower end, are both closed. This is important. Check the reversing thermometers to insure that they have reversed properly and that the mercury has drained out of the bulb into the reservoir. Occasionally, the mercury will stick in the bulb and not drain readily. Tapping the glass with the fingers usually will release the mercury from the bulb and permit it to drain. In more stubborn cases, the thermometer may have to be removed and the methods given in the appendix may be applied. It is most important to see that the mercury has properly drained before lowering the Nansen bottle. To all bottles except the first bottle placed on the wire, a messenger must be attached. Each messenger has a length of wire about 6 or 8 inches long, with a small eye in the outer end. This eye is attached to the Nansen bottle by inserting it into the small slot in the under side of the clamp assembly. Depress the release arm, insert the eye, and release the arm. Make sure the messenger release pin has seated itself through the eye. Attach the messenger to the wire below the bottle. The bottle is now ready for lowering.

2–14 Lowering the Nansen Bottle.—Lower the Nansen bottle slowly until it has entered the water and the air has been expelled. After the bottle has reached a couple of meters below the surface gradually increase the speed of the winch to its normal lowering speed. If the bottle is lowered too rapidly, the messenger may be released prematurely or the bottle may trip as it enters the water. In the first instance, any bottles below will be tripped, and in the second the bottle will be crushed if any air should be trapped in it and the lowering continued. After the last bottle has been lowered to its indicated depth, plus the distance from the platform to the surface, the winch is stopped (fig. 2–3). Record this time on oceanographic log sheet A as indicated in chapter 14.

2–15 Measuring the Wire Angle and Dropping the Messenger.—Before the wire angle is measured and the messenger dropped to trip the first bottle, a certain amount of time must be allowed to permit the reversing thermometers to come to the exact temperature of the water and to let the Nansen bottles flush. The Nansen bottles, having small valve openings, tend to retain a portion of higher level water as they are lowered. They must therefore sit in the lowered position a certain time to permit this residue to flush and be replaced by water *in situ*. A *minimum* of 6 minutes is considered necessary to bring the thermometers to temperature and let the bottles properly flush.

The time required for a Nansen bottle messenger to drop may be figured at 200 meters per minute for wire angles less than 35° and at 150 meters per minute for wire angles greater than 35°.

Some time can be saved when deep casts are down by deducting messenger dropping time for the distance to the shallowest bottle from the 6 minutes required for the bottles to

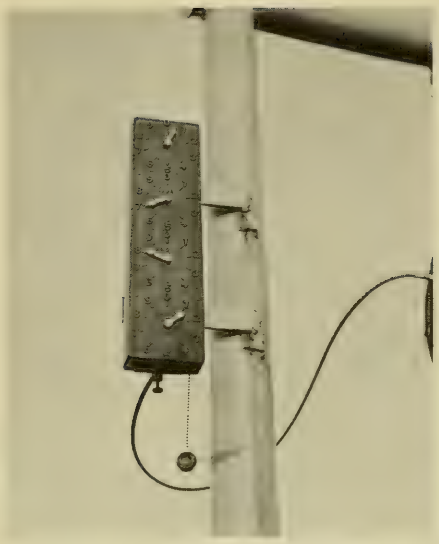

Figure 2–3. A meter wheel reading of a Nansen bottle cast.

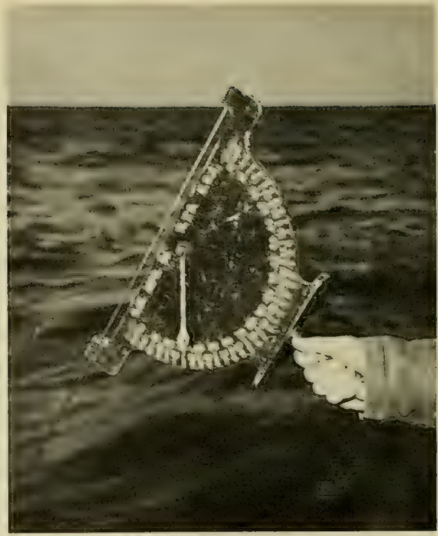

Figure 2–4. Determining the wire angle of a Nansen bottle cast.

remain *in situ*. For example, it takes 3 minutes for a messenger to reach and trip a bottle at 600 meters. Therefore, the messenger may be dropped 3 minutes after the cast is down instead of waiting the full 6 minutes before dropping it.

Measure the wire angle with the wire angle indicator. Take an average of several readings to allow for the roll of the ship. Do this before dropping the messenger (fig. 2–4).

2–16 Bringing the Nansen Bottle In.—After sufficient time has been allowed for the lowest bottle to be tripped, start the winch and commence hoisting. Keep a sharp lookout for the first bottle. Inform the winch operator when the bottle is *in sight* and again when at the *surface* of the water. Then, carefully hoist the bottle to the platform. Remove the messenger from the wire above the bottle. Unclamp the Nansen bottle from the wire and return it to the rack, being very careful to keep the bottle always in a vertical position with the clamp assembly at the top. This will prevent accidental reversing of the thermometers.

When all the Nansen bottles have been returned to the rack, the water samples are drawn. The methods used for drawing samples are given in sections 2–28 and 2–41. After all water samples have been drawn, drain the excess water from the Nansen bottles.

Time is allowed for the reversing thermometers to come to air temperature before they are read. This usually takes from 10 to 15 minutes depending upon air conditions and may be checked by observing the Auxiliary thermometers. When all Auxiliary thermometers, in both the protected and unprotected cases, read approximately the same they can be presumed to have come to air temperature. The Main and Auxiliary thermometers in each case are read and the data recorded on oceanographic log sheet A as described in chapter 14 (fig. 2–5).

2–17 USE OF DEEP-SEA REVERSING THERMOMETERS.—Deep-sea reversing thermometers are delicate, but highly accurate, mercurial thermometers specially designed for recording water temperatures *in situ* by being reversed when the Nansen bottle is tripped by the messenger. There are two types of reversing thermometers, protected and unprotected. The temperature scale is Celsius (centigrade) and is carefully etched on the glass stem. Each thermometer used by the Hydrographic Office is calibrated by the Bureau of Standards before it is used at sea. The scale is read with a ther-

Figure 2–5. Reading the reversing thermometers.

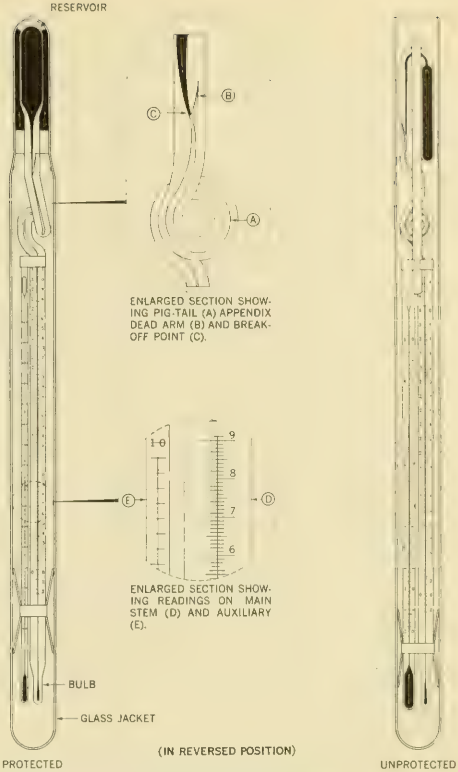

Figure 2–6. Protected and unprotected deep-sea reversing thermometers.

mometer reader, or viewer. Each thermometer actually consists of two parts: one, the reversing thermometer which is called the *main;* the other, a regular thermometer which is called the *auxiliary* (fig. 2–6).

2–18 The Main Thermometer.—The main thermometer is essentially a double ended thermometer. In the upright position, it consists of a large reservoir of mercury at the lower end connected by means of a fine capillary to a small bulb at the upper end. The capillary is constricted and branched just above the reservoir. This point is called the appendix. Above the appendix, the thermometer is bent in a 360° loop, called the pigtail, from which it continues straight and terminates with the bulb. The thermometer is so constructed that in the upright position mercury fills the reservoir, the capillary, and sometimes part of the bulb, depending upon the temperature. When the thermometer reverses, the mercury column breaks at the appendix, descends into the bulb, now at the bottom, thereby filling the bulb and part of the stem, and thus indicates the temperature at the depth of reversal. The mercury remains at this reading until the thermometer is returned to the upright position when the mercury drains from the bulb and rejoins that in the reservoir.

2–19 The Auxiliary Thermometer.—The auxiliary thermometer is a small, ordinary mercurial thermometer that is mounted alongside the main thermometer. It is used to obtain the temperature of the reversing thermometer at the time the main is read. Corrections are applied to the reading of the main for changes resulting from differences between the temperature at reversal and at the time of reading.

2–20 Protected Reversing Thermometers.—The main and auxiliary thermometers are enclosed in a heavy glass jacket. When sealed at both ends and the air within partially evacuated, it is called a protected thermometer. The area surrounding the reservoir is filled with mercury, which serves as a thermal conductor and gives greater sensitivity to temperature change. The sealed jacket protects the thermometer from hydrostatic pressure thereby giving a true reading of the water temperature *in situ*.

2–21 Unprotected Reversing Thermometers.—An unprotected reversing thermometer is similar to the protected in that the main and auxiliary thermometers are enclosed in a heavy glass jacket. However, the jacket of the unprotected thermometer is open at one end. The reversing thermometer is in direct contact with the water and is subject to hydrostatic pressure. It has no mercury surrounding the reservoir as does the protected thermometer. Since the thermometer is subject to hydrostatic pressure, it does not give a true temperature reading but gives a reading which increases approximately 1° C. for each 100 meters of depth. The unprotected thermometer, when used with a protected thermometer, is a pressure gage for determining the exact depth of the Nansen bottle at the time of reversal. By pairing a protected and an unprotected thermometer, temperature and temperature-pressure are obtained *in situ*. The water temperature is determined by correcting the readings of the protected thermometer. Corrections for the unprotected thermometer must also be applied. The difference between the two readings is used to compute the actual depth of the Nansen bottle at the time of reversal. The methods for carrying out these computations are given in chapter 3.

2–22 Arrangement of Reversing Thermometers on the Nansen Bottles.—Because the methods for computing the depths of the Nansen bottles require that the readings for the protected thermometers be corrected before those of the unprotected, it is customary to place the protected thermometers in the left-hand tube of the thermometer frame and the unprotected in the right-hand tube. This enables the reading of the thermometers and recording of the data on the log sheet in the proper order for applying the corrections. Thus, errors in computations are reduced (fig. 2–7).

It usually is not necessary to place unprotected thermometers on every Nansen bottle to be used in a cast. They should be placed strategically so that the depths of reversal of other bottles in the cast can be readily interpolated. A protected thermometer generally is substituted for the omitted unprotected. The corrected readings of the two protecteds are averaged to determine the temperature *in situ*.

On shallow casts, i. e., those commencing with bottles at the surface, it is best to group the unprotected thermometers on the lower bottles, as this type thermometer will not record accurately at shallow depths.

On deep casts, i. e., those commencing at depths below those of the shallow casts, it is important that unprotected thermometers be placed on the top and bottom bottles. The remaining unprotected thermometers should be spaced at as nearly equal distances along the wire as possible.

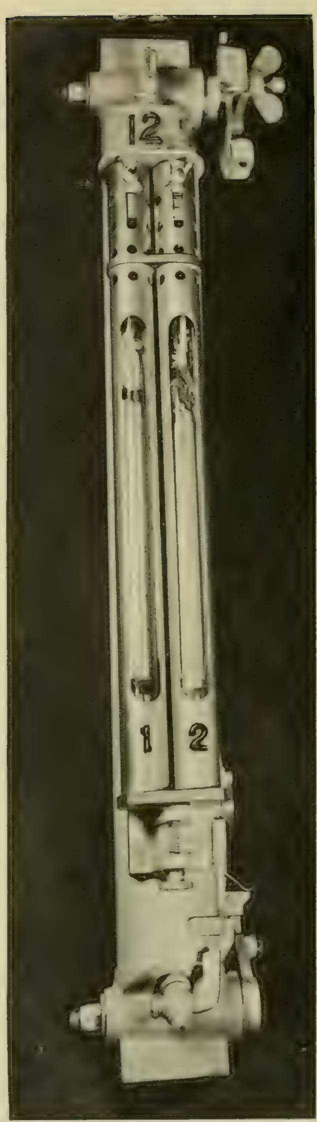

Figure 2–7. View of reversing thermometers on a Nansen bottle.

2–23 PRECAUTIONS FOR HANDLING, STORING, AND TRANSPORTING DEEP-SEA REVERSING THERMOMETERS.—Deep-sea reversing thermometers are extremely delicate precision instruments and must be handled with care. They are difficult to manufacture and calibrate and are expensive. Their construction is such that it is very easy for the mercury in the main thermometer to become separated so that gas from the bulb is trapped in the capillary, thereby making the thermometer malfunctional. To prevent this, a primary precaution in handling reversing thermometers is *never lay a reversing thermometer flat.* If a reversing thermometer has to be laid on a flat surface, it must always be placed on some object so that it is tilted slightly with the reservoir end down.

2–24 Reversing Thermometer Carrying Cases.—Special cases are provided for storing and transporting reversing thermometers. Thermometers not in use should always be stored in these cases. The cases are specially designed and are lined with foam rubber. The following precautions must be taken:

1. Wash the glass jackets of the thermometers with fresh water and dry them thoroughly before placing them in the case. Flush out the inside of the jackets of the unprotected thermometers with fresh water.

2. Always place the reversing thermometers upright in the case with the *reservoir end down* to avoid separation of the mercury in the main thermometer and subsequent malfunction. Only in the instance where the thermometers will be exposed to air temperatures lower than −10° C. (14° F.), is exception to this rule permissible. Then they are stored in the reversed position, since at such low temperatures the mercury in the auxiliary thermometer will vacate the capillary entirely and contract into the bulb. If stored in the upright position, the mercury will separate leaving gas in the bulb when warmed.

3. Always store and transport the thermometer carrying case in an upright position. *Never* lay it on the side.

4. Reversing thermometers stored in carrying cases should always be transported by courier. Unless it is absolutely unavoidable, they should never be shipped by mail, freight, or express unless packed by the manufacturer.

2–25 Reversing Thermometers Stored on Nansen Bottles.—When at sea, Nansen bottles with attached thermometers should be inverted in the rack after all thermometers have been read in order to prevent the thermometers from remaining in a reversed position. If they are not to be in use for periods greater than 2 or 3 days, it is recommended that they be removed from the frames and stored properly in the carrying cases.

2–26 DRAWING AND PRESERVING SEA WATER SAMPLES.—After the Nansen bottles have been removed from the wire they are replaced in their proper position in the rack. The water samples obtained at various depths are then drawn into respective glass bottles and the thermometers are read. These water samples are analyzed for such constituents as salinity, dissolved oxygen content, and various nutrients. As the methods of analysis for each constituent are usually quite different, the volume of sample necessary, type of glass bottle used, time permitted before analysis, and methods for drawing the samples differ. The following directions must therefore be followed carefully for each type of sea water sample desired. All glass sample bottles to be used are placed in the rack directly below each Nansen bottle. Each sample bottle must be numbered and the number recorded in the proper column on oceanographic log sheet A.

Before drawing water samples from the Nansen bottle the air vent must be opened to permit the water to drain. The vent screw is located near the top of the Nansen bottle just below the valve. The drain petcock is located just above the bottom valve.

2–27 Drawing Sea Water Samples for Dissolved Oxygen Content Analyses.—If oxygen analyses are desired, the samples for this purpose must be drawn first. Water samples to be analyzed for dissolved oxygen content are preserved in 250-ml. amber reagent bottles with ground glass stoppers. Before drawing the sample, the bottles must be thoroughly rinsed by adding a small amount of sample water and shaking vigorously. Be sure to pour the rinse water over the glass stopper. Rinse at least twice.

The addition of Nansen bottle water to the oxygen sample bottle must be performed carefully. To draw the sample from the Nansen bottle, a delivery tube must be attached to the drain petcock. A delivery tube consists of a piece of soft-wall rubber tubing about 5 inches long with a 3-inch glass tube inserted in one end. The exposed end of the glass tube is constricted slightly and is fire-polished smooth. Attach the rubber end to the drain petcock and insert the glass tip to the bottom of the sample bottle. Open the drain petcock very slowly to prevent air bubbles from entering the sample. As the bottle fills the petcock may be opened wider. Be sure that no air bubbles enter the sample. If any do, discard the sample and begin again. Fill the sample bottle until it overflows slightly and withdraw the delivery tube before turning the petcock off. Insert the end of the ground glass stopper into the mouth of the bottle in such a way that no bubbles of air are trapped, and allow it to seat. This will spill a small amount of water, but will insure the proper volume of sample for analysis.

Dissolved oxygen samples must be processed for analysis immediately after they have been drawn. Instructions for carrying out the analysis are given in chapter 13.

2–28 **Drawing Sea Water Samples for Salinity Analyses.**—Water samples to be analyzed for salinity concentration are preserved in salinity sample bottles. The type of bottle used by the Hydrographic Office has a glass or porcelain stopper with a rubber gasket which is attached to the bottle neck with a wire clamp-on device. The bottles are numbered on top of the stopper or on the side of the bottle. They are shipped and stored in compartmented wooden cases.

Before drawing the sample, the salinity bottle must be thoroughly rinsed twice with water from the Nansen bottle. To do this, fill the bottle about one-fourth full and shake vigorously. Empty the rinse water in such a manner that it washes the stopper and gasket. Be sure to do this at least twice.

Draw the water sample directly from the drain petcock and fill the bottle to within one inch of the top. A 1-inch air space must be left to prevent the bottle from breaking due to warming or freezing of the sample. The stopper is then placed in the mouth and the clamp-on device pulled securely down.

After all salinity samples are drawn and logged, they are placed in their shipping case. If they are to be analyzed aboard ship they must be placed in the laboratory for a *minimum* of 6 hours before analysis. Eight to 12 hours is preferable in order to allow them to come to the same temperature as the room, apparatus, and chemical solutions to be used in the analyses.

2–29 **Drawing Sea Water Samples for Nutrient Analyses.**—Sea water samples for various nutrient analyses are drawn in the same manner as given for salinity samples.

2–30 **Draining the Nansen Bottle.**—After all the required sea water samples have been drawn from the Nansen bottle, the remaining water must be drained before the thermometers are read. While the bottle remains in the rack, the air vent and petcock should be left open. However, be sure to close the air vent and drain petcock before lowering the bottle on a subsequent cast.

2–31 **Storing and Shipping Sea Water Samples.**—Sea water samples to be analyzed at the Hydrographic Office must be shipped in wooden cases supplied for that purpose. On the inside of the lid of each box is a label to identify the samples upon arrival. Complete this form giving all required cruise, station, and sample bottle numbers. The shipping case must be sealed in such a way that there will be no danger of its opening in transit. Give the ship's name and cruise number on the outside of the case and address the case as follows:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
(Code 5430)

2–32 **INSTRUCTIONS FOR OPERATING THE BATHYTHERMOGRAPH.**—The bathythermograph, or BT, is an instrument for obtaining a permanent, graphical record of water temperature (° F.) against depth (feet) as it is lowered and raised in the ocean (fig. 2–8 and 2–9). A depth element in the instrument drives a smoked-glass slide at right angles to a stylus which in turn is driven by a thermal element. The BT is lowered into the sea and retrieved by means of a wire rope, boom, and winch. A smoked-glass slide is inserted before lowering and removed after each submersion. The trace, or record scribed by the stylus, is read by comparing with a grid individually calibrated for each instrument, using a magnifying grid viewer. The slide is preserved by dipping in lacquer, properly draining, drying, and storing.

2–33 **The BT Assembly.**—The BT consists essentially of a thermal element; a pressure, or depth, element; a body tube; a nosepiece; a nose sleeve; tailfins; and body tube sleeve.

2–34 **How a BT Works.**—The bathythermograph is designed to obtain a record of the temperature of sea water at moderate depths. It can be operated while the ship is underway at speeds up to 18 knots. It works most satisfactorily, however, at speeds of 12 knots or less.

The thermal element, corresponding to the mercury column in a glass thermometer, consists of about 45 to 50 feet of fine copper tubing filled with xylene. The tubing is wound around inside the tailfins of the BT and comes into direct contact with the sea water. As the xylene expands or contracts with the changing water temperature, the pressure inside the tubing increases or decreases. This pressure change is transmitted to a Bourdon tube, a

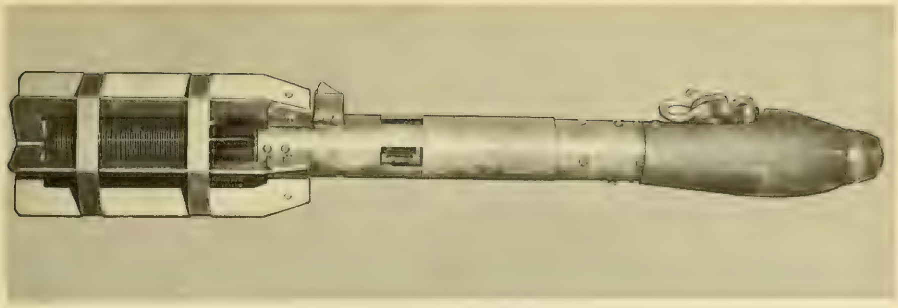

Figure 2–8. The bathythermograph.

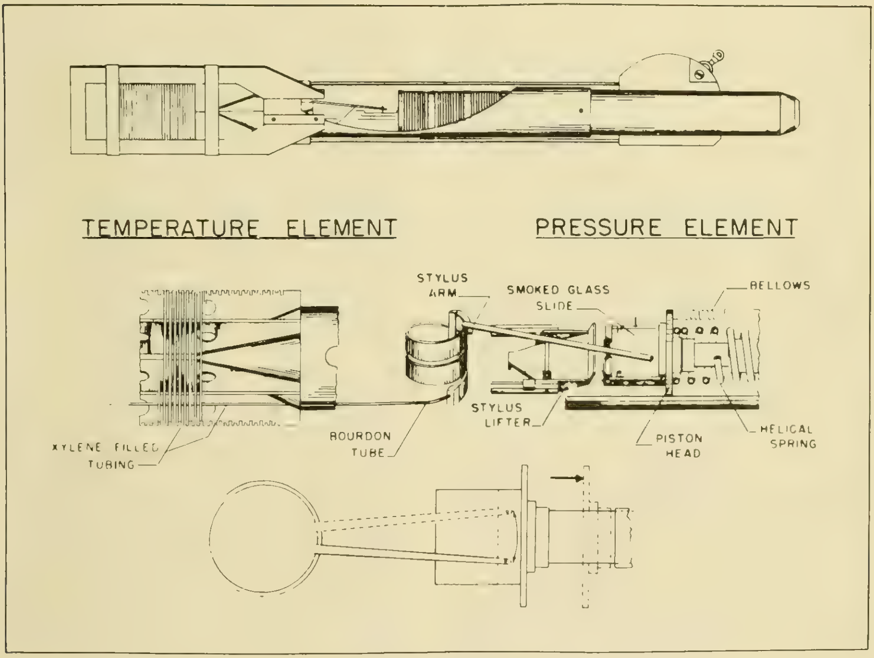

Figure 2–9. View of bathythermograph thermal and depth elements.

hollow brass coil spring which carries a stylus at its free end. The stylus records the movements of the Bourdon, as it expands or contracts with changes of temperature, on a smoked-glass slide. The temperature range is from 28° to 90° F.

The slide is held rigidly on the end of a coil spring enclosed in a copper bellows, or sylphon. Water pressure, which increases in proportion to water depth, compresses the sylphon as the BT sinks. This pulls the slide toward the nose of the BT, at right angles to the direction in which the stylus moves, to record temperature. When the BT is raised toward the surface the spring expands the sylphon to its original shape. Thus, the trace scratched on the smoked surface of the slide is a combined record of temperature and pressure, the pressure being proportionate to depth.

Since external pressure slightly affects the internal pressure of the xylene in the Bourdon, and since temperature changes also influence the movement of the sylphon, each instrument must be carefully calibrated by the manufacturer.

A special grid is supplied for each instrument for converting the stylus trace to temperature and depth readings. *These grids are not interchangeable between instruments.* From an examination of the grid, it will be noted that the temperature lines are not exactly straight and vertical, but curve slightly to the left with increasing depth. Likewise the depth lines are not exactly arcs of circles with radius equal to the length of the stylus, but also allow for thermal expansion of the sylphon.

At temperatures of 105° F., the recording stylus moves up against a stop pin; *if this temperature is exceeded, permanent deformation of the brass coil of the Bourdon will occur,* and the calibration of the instrument will be ruined. For this reason, the BT must always be kept out of the sun and away from the vicinity of fire rooms, steam pipes, and other sources of heat. An instrument that has been overheated often may have the stylus arm jammed by the pen-lifter bar in the high temperature position. If another BT is aboard, use it, and turn in the damaged instrument for adjustment. If a spare is not available, gently lift the stylus arm from the pen-lifter bar and let the arm swing back toward the low temperature side.

The temperature calibration will henceforth be in error as a result of deformation of the Bourdon.

Record on oceanographic log sheet B that the calibration is uncertain beginning with the next slide, and turn in the instrument at the first opportunity. Complete instructions for filling in the log sheet are given in chapter 14.

2–35 Equipment Needed to Operate the BT.—In addition to the BT itself, the following list of equipment is required to operate the instrument.

1. A BT winch. BuShips E6/S Hoist, or equivalent, with spares as provided.
2. A BT Boom. BuShips Drawing 56800–668234.
3. A BT towing block, counterbalanced, Navy stock No. N16–600 821–101.
4. Wire rope. $\frac{3}{32}$-inch diameter 7 x 7 stainless steel, aircraft control category, in 2,000-foot lengths per reel.
5. Two grid mount assemblies.
6. A box of accessories containing:
    a. Four boxes of 50 smoked slides each.
    b. One-half pint can of slide lacquer.
    c. One-half pint can of lacquer thinner.
    d. Two glass dipping jars with tops—one for fresh water, the other for lacquer.
    e. One pair of dipping tongs.
    f. One slide viewer.
    g. One thermometer in a metal case.
7. One-gallon can of Grade III Rust Preventive Compound—Navy Dept. Spec. 52–C–18 (Standard Navy Stock No. G52–C–3257–60).

2–36 Spare Parts Needed for the BT.—No spares are provided. Those possibly required would be extra smoked slides, lacquer, lacquer thinner, spare reels of wire, and spare towing blocks.

2–37 Tools Needed To Operate the BT.—The following tools are needed to operate and maintain the BT.

1. Pliers, 8-inch combination.
2. Screwdriver, medium.
3. Adjustable end wrench.
4. Fifteen-inch round wooden stick.
5. Rags for cleaning and cooling.

2–38 Making a BT Lowering.—The BT is designed for lowering from a ship underway at speeds up to 18 knots. Best results, however, are obtained when the speed is not in excess of 12 knots. At higher speeds, unless the sea is very smooth, only an experienced operator should attempt to operate the winch. New operators should practice lowerings and recoveries with a dummy BT before undertaking the operation of an actual instrument. Operation of the BT winch cannot be learned from reading a description only, any more readily than one can learn to pitch a baseball or bowl 300 by reading a manual. Nevertheless, the essential steps together with some useful hints are outlined below.

2–39 Examine the Wire and Connection to the BT.—Be sure that the wire is hitched to the winch reel in such a manner that it cannot pull loose if all wire should pay off the drum. As an additional precaution, do not pay out the last layer of wire when lowering the BT. The wire should be wound on the drum so that it pays out and reels in at the top of the drum. For survey work, it is recommended that bare wire and not plastic-coated wire be used. If 900-foot-depth BTs are to be used at least 2,000 feet of $\frac{3}{32}$-inch, 7 x 7 stainless steel wire should be used. As the plastic-coated wire usually comes in 1,200-foot lengths and cannot be spliced, it is not long enough for use with 900-foot BTs. Run the free end of the wire through the towing block at the end of the boom. This block is of a special counter-balanced design for BT use.

The type of cable hitch used to connect the BT to the wire differs slightly with different models. The instruction book accompanying each BT shows the method of attachment for that model. If the connection is frayed, rusted, kinked, or in any way doubtful, cut off the faulty part of the wire and make a new connection. Check the swivel carefully. On those models that use a Fiege-type swivel connector make sure the Fiege sleeve is screwed into the socket as tightly as possible. More BTs are lost by poor connections than from any other cause.

2–40 Check the Winch.—The hand lever on the winch serves as both brake and clutch. It has three positions: (1) When it is vertical, the winch is in neutral and the drum can be turned in either direction; (2) when it is pushed outboard to the engaged, or hoist, position, the motor turns the drum and spools on the wire; (3) when the lever is pulled inboard, or toward the operator, to the brake position, the drum is locked and cannot be rotated.

With the winch lever in neutral, turn on the motor to make sure the power is available. The shaft bearings should be kept well lubricated according to the instructions provided with each model winch. The drum should turn freely.

The winch installation should be such that the wire comes across the top of the drum. The hand lever should move away from the operator to engage the motor and toward the operator to set the brake. On some earlier model winches, the hand-lever operation is just the reverse; i. e., the brake is away and the clutch is toward the operator. Check these operating positions to make sure that the installation is correct and that the drum revolves freely in neutral.

2–41 Put the Slide in the BT.—Remove the waterproof cover from the box of smoked-glass slides and take out one slide at a time, holding the slide by the edges to avoid removing the smoke film. Do not remove the waterproof cover from the box until actually ready to use the slides. This will prevent the oil from drying out. When the slides get too dry, the smoke tends to wash off more readily.

Insert the slide into the hole on the side of the BT and push it into its bracket. The edge of the slide with the bevelled corners goes in first, the longer bevel toward the nose of the BT, making certain that the smoked surface of the slide is toward the stylus. Push the slide *all the way* in against the stop pin. It is important that the slide is fully in, otherwise the temperature will be recorded fictitiously low. Occasionally check the grooves of the slide holder to make sure they are clean, free of glass chips, and that the spring holds the slide firmly against the opposite groove. With the slide fully in, the stylus will be brought against the smoked surface when the sleeve is moved back to cover the opening. To reduce extraneous scratches on the slide, do not move the sleeve back until the BT is ready to be put over the side.

2–42 Put the BT over the Side.—After permission has been obtained from the officer of the deck to make a lowering, and the depth of the water has been determined, pick up the BT, pull the sleeve down over the slide holder, and set the winch lever in neutral. With one hand hold the BT at the rail and with the other take up the slack in the wire by rotating the drum. When all slack is in, set the brake.

Turn on the winch motor so that power is instantly available for the rest of the operation. Lower the BT into the water to such a depth that it tows smoothly just below the surface. Put on the brake and hold the BT there for one minute to enable the thermal element to come to the temperature of the surface water. Set the winch counter at zero.

2–43 Take the Bucket Temperature.—While the BT is being towed at the surface, take the bucket temperature of the surface water and record it on oceanographic log sheet B as shown in chapter 14. Special bucket thermometers are supplied for U. S. Navy surveys by the Hydrographic Office. These are more accurate than the thermometers issued with the BT kits and are to be used in place of the latter. These thermometers are read to the nearest 0.1° F.

A bucket can be made by obtaining a half-gallon can from the galley and attaching a line to it. Attach the bitter end of the line to the lifeline or rail. Throw the can over the side and let it fill and empty several times before hauling a surface sample aboard. As soon as it is aboard, set it on deck and insert the thermometer into the bucket so that at least 3 inches of the bulb end is immersed in sea water. Stir the thermometer with a circular motion for 15 to 20 seconds and then read it *with the stem still immersed* in the water. Stir it once or twice more and check the reading (fig. 2–10).

Figure 2–10. Taking the bucket temperature.

It is important that the bucket sample be taken at the time the BT is being towed and that the temperature reading be made as soon as possible after the sample is on deck. If the sample is allowed to stand for more than 45 seconds the temperature reading will be no longer valid. It is also important to stir the thermometer to bring it to temperature more rapidly and accurately.

2–44 Lower the BT.—Move the winch lever to the neutral position and allow the wire to pay out freely. Success in reaching the maximum desired depth depends primarily on two factors; (1) having the winch drum and towing block bearings well lubricated to minimize friction and (2) getting the BT down below the ship's screw wash as soon as possible. With practice, it is possible to raise the BT slightly after the 30 seconds of towing at the surface is completed. Skip it off the crest of a wave so that it swings forward, and then lower rapidly. This enables the BT to plunge into the water and its momentum will carry it more rapidly past the turbulence of the wash and will enable it to reach a greater depth. This technique is especially useful with the 900-foot instrument. It takes practice, but to the experienced operator is easier to use and more effective than the diving lug assembly attached to some models (fig. 2–11).

When the ship is making more than 12 knots, there usually is enough drag on the wire while the BT is diving to insure that it will not slacken and backlash. At lower speeds, and during heavy rolling, the wire may slack between the winch and the towing block. This may cause backlash on the winch drum or a kink at the towing block. The operator should provide himself with a round stick about 15 inches long to be used to gently slow the drum when excessive slack appears. Do not apply too much pressure to the drum with the stick because once the diving motion of the BT is arrested it will not dive further regardless of the amount of wire payed out. Do not touch the wire with your hands when the drum is in motion; you may be seriously injured.

2–45 Stop at the Proper Depth.—To reach a given depth, the amount of cable to be payed out will depend upon the speed of the ship, the type of BT, and whether or not the nose sleeve is attached. The table below provides a rough estimate of speeds at which full depth may be expected to be reached when using 1,000 feet of wire.

BT depth (feet)	Maximum speed without nose sleeve (knots)	Maximum speed with nose sleeve (knots)
200	15	22
450	10	13
900	3	6

The observer should take data on the length of wire payed out and the actual depths re-

Figure 2–11. Lowering the bathythermograph.

corded by the BT, and plot a graph showing counter reading against depth for various ship's speeds.

When the counter indicates that the proper length of wire has been payed out, or when the last layer of wire on the drum has been reached, the brake should be applied smoothly allowing the drum to stop without a sudden jerk. An excessive jerk will part the wire. The BT will now swim back up to near the surface far astern. Check to see that the wire leads properly for hauling in. If it does not lead from the towing block to the center of the drum adjust the boom guys until it does.

2–46 **Haul in the BT.**—Move the hand lever smartly from the brake position to the hoist position. Do not pause while going through neutral or more wire will pay out. Guide the wire back and forth in even layers on the drum using the 15-inch stick. The end of an old swab handle will do. Do not use a metal guide. If kelp or gulfweed fouls the wire, ease on the brake and clear the wire with a boathook. Haul in at full speed until it is seen from the counter and by rapid decrease in the wire angle that the BT is close astern but still a safe distance from the ship's screws.

2–47 **Bring the BT Aboard.**—When only about 100 feet of wire is out, the BT should be readily visible at the surface. As the wire is hauled in, the BT will reach a position nearly under the boom where it will begin to porpoise, breaking clear of the surface and swinging forward as the ship rolls or as wave crests pass. This is the most critical point in the operation. To bring the BT alongside and raise it without too much swing requires practice. If the BT is brought in too fast, it may skip or swing forward of the boom, perhaps hitting the side of the ship or swinging completely over the boom. If the BT skips or swings forward of the boom, it is advisable to shift at once to neutral and allow the BT to sink freely until it has passed clear

350676 O—56——3

astern and is safe to try again. The operator must learn the feel of his own winch.

With a little patience the BT can be brought safely to within 2 or 3 feet of the towing block. The winch motor should be turned off at this point, eliminating the possibility of accidentally jamming the BT against the towing block.

The BT can then be brought aboard in various ways, depending on how the boom is rigged. With the standard gate boom, the use of a retrieving line and ring is recommended. This consists of a metal ring of an inch to an inch and a half in diameter through which the wire is passed between the towing block and the BT. To the ring is attached a retrieving line which is secured to the lifeline or rail. With the proper amount of slack, the ring will ride freely when the BT is being lowered and hoisted. By hauling in on the retrieving line while easing the brake the BT can be easily brought to hand (fig. 2–12). If a retrieving line is not used, then it will be necessary to rig in the boom by casting off the after guy and swinging the boom in with the forward guy. Two men can pull it in with a boathook—one man on the hook and the other to slack the wire with the winch. If the boom tops up, the BT can be brought aboard by one man hauling in on the topping lift.

Figure 2-12. Bringing in the BT with a retrieving line.

2–48 Remove the Slide and Secure the Equipment.—As soon as the BT is in hand move the sleeve forward toward the nose to lift the stylus off the slide. This prevents the upper portion of the trace from being affected by air temperature and becoming obscured as the instrument is handled.

Slack off the wire, place the BT in its deck rack, and set the brake. Notify the bridge that the BT is on deck. Partially eject the slide by pushing against its edge with the forefinger, the wire slide remover, or a pencil through the slide-ejecting port. Grip the slide carefully by the thumb and forefinger. Hold the slide only by the edges, being careful not to obscure the trace with smudges or fingerprints.

If another lowering is to be made soon and there is no danger of overheating the BT, it may be left in the deck rack connected to the wire; otherwise unshackle it and stow in a cool place.

CAUTION

Never let the temperature of the BT exceed 105°F. (40.8°C). If the temperature is exceeded, the calibration of the instrument will be damaged. Never leave the BT on deck without protection from hot sun. Suitable protection to the thermal element can be afforded by keeping it covered with wet cloths.

2–49 Label the BT Slide.—As soon as the slide is removed from the BT, examine it to be sure that a suitable trace has been obtained. Sometimes the smoked surface washes away on contact with sea water. If this has occurred, lower the BT again with a fresh slide. If it recurs, follow instructions given in section 2–58. With a sharp pencil, write the following information on the slide, being careful not to obscure or touch the temperature-depth trace (fig. 2–13).

(1) *Cruise and slide serial number.*—Give the ship and cruise number followed by the consecutive serial number of each slide. Thus the first slide taken on the fifteenth cruise of USS *Rehoboth* would be RE–15–1. The last figure is the serial number recorded in the first column of the B-sheet.

(2) *Time group.*—The second line contains the 4-digit time group. Use Greenwich mean time (0001 to 2400), giving the hour and minute at which the BT enters the water.

Figure 2–13. Labeling the BT slide.

(3) *Date.*—The third line is the day, month, and year in numerals. Use Roman numerals for the month. Thus 13 August 1955 is written 13–VIII–55.

(4) *BT number.*—Each BT has its own number. The BT number is stamped near the nose of the instrument and also is recorded on the grids for the slides. This number is very important since the laboratory that will process the slides has hundreds of grids, only one of which is a duplicate of yours. Without the proper grid, the information on the slide is worthless. Prefix the number with BT, thus BT 1591. If there is a letter immediately following the number always include it, thus BT 780A. Always enter the above information in the order given.

Avoid the temptation to improve an apparently faint trace by enlarging or tracing over it at the time you enter the data. The processing laboratory can copy an actual trace, however faint, by the delicate photographic processes it uses, but will invariably detect a retouched trace and reject it as spurious.

2–50 Lacquer and Store the BT Slide.—After the BT slide has been labeled, hold the slide with the dipping tongs provided and rinse it by dipping in a jar of fresh water. Let the slide dry and then gently dip it in thin lacquer. Let the excess lacquer drain against the lip of the jar or by standing on end on absorbent paper for several seconds. The slide may be dried by holding it near a light bulb or some other source of dry heat. On survey ships where BT observations are taken very frequently a drying box containing a light bulb is used. The slide is left in the dipping tongs and the tongs are suspended from a hook near the bulb until thoroughly dry. The slide is then placed in the storage box.

If the slide is left to dry in damp moving air the lacquer often fogs, or turns white, and the slide is difficult to read. A fogged slide may be cleared, however, by redipping it in lacquer after it has dried.

If a source of drying such as described above is not available, it is best to place the slide in the storage box, immediately after draining the lacquer, and close the lid. To prevent the slides from sticking to the box it is good practice to put a length of string, wire, broom straw, or a strip of waxed paper lengthwise under the slides in the bottom of the box. After about an hour, open the box and move each slide before the lacquer is fully dry and hard. If the slides are permitted to stick solidly to the box, the chances are that many of them will be broken when the time comes to remove them.

CAUTION

BT lacquer is inflammable; it should not be used in the presence of lighted cigarettes or other open flames. The jar of lacquer should be closed immediately after using since it evaporates rapidly and is highly flammable.

After drying, the lacquer on the slide should be perfectly transparent, hard, even, and just thick enough to protect the smoked surface from being scratched during ordinary handling. If evaporation has occurred, the coating on the slide will be thick and uneven, and thinner must be added to the lacquer. The lacquer should be kept at a consistency only a little thicker than water.

Acrylic spray (Krylon), applied from a spray-bomb-type container, has been used successfully to coat slides.

2–51 Viewing the Slide.—Place the long edge of the slide having the smaller bevel against the spring at the bottom of the grid, with the smoked surface toward the grid and the edge with the beveled corners just clearing the eccentric stop screw of the viewer. Gently push the slide against the spring down into place so the smoked surface lies flat against the grid. Then push the slide snugly against the stop.

To remove the slide from the grid depress the spring with the fingernail to loosen the slide from the grid mount.

This method prevents excessive scratching or rubbing of the smoked surface against the grid. When the holder and the slide are placed in the viewer care must be taken to keep the slide always tight against the stop and against the groove opposite the spring. Otherwise incorrect temperature and depth readings will result.

2-52 **Reading the Slide.**—The trace scratched by the stylus is a temperature-depth record. Each point on the trace represents a value of temperature and depth which can be read off the appropriate line of the grid. The lines on the grid are established by actual test of the instrument. Each BT has its own grid. Serial numbers of both grid and BT must agree. Temperatures should be read to tenths of a degree and depth to within 10 feet or better for the 900-foot type, 5 feet or better for the 450-foot type, and 2 feet for the 200-foot type.

2-53 **Checking for Malfunctions.**—The stylus scratches its trace both while the BT is diving and as it rises to the surface. The water conditions where it dives may be slightly different from where it rises. These conditions are usually negligible. However, the instrument may have hysteresis; that is, there may be a slight lag in the movement of the element. If the up and down traces are essentially similar, a slight divergence of the traces is usually immaterial. *If the traces differ widely, change to another BT.* The temperature reading at the given depth (if the water conditions are not changing) would be a point midway between the two traces.

The BT, when on deck, usually has a different temperature than when in the water. The thermal element assembly will move the stylus assembly along the zero depth line to the surface water position during the period it is being towed at the surface. Thus, the top of the trace is almost always a horizontal line which should fall on the zero depth line of the grid when the slide is viewed. If the trace appears more than 3 feet above or below the zero line, the depth readings must be corrected by the amount of this error for accurate results.

The surface temperature is read from the BT slide by noting the temperature of the point at which the trace starts downward from the surface trace.

It is advisable to make frequent comparisons between the BT surface temperatures and those obtained by the bucket thermometer. For a series of slides taken with the same BT, the slide and thermometer surface temperature readings should be approximately the same, or if they differ slightly, the difference should remain constant over a long period of time. If this difference changes and if the amount of the difference then found continues for subsequent lowerings, it is an indication that the calibration has shifted. A shift in calibration, sometimes called a "shift in the zero points", should not affect the shape of any given trace. The operator should make a note on the log sheet showing the slide number or time at which this shift in calibration was detected.

If the zero shift is more than 4° F., or if it shifts from one lowering to another, the BT needs adjustment and should be turned in for repair.

If the BT strikes bottom or an underwater object, the depth at which it struck usually can be determined by reading the depth of the horizontal lines across the trace, made where the stylus arm vibrated with the shock. *Always check the depth just before making each lowering.* Shocks which occur to the instrument during the handling and lowering may cause hysteresis, temperature error, and depth error. Nothing can be done aboard ship for hysteresis. In order to determine the amount of correction to apply to temperature or depth errors for accurate work the following procedures can be used—in an emergency.

2-54 **Temperature Error.**—Load the BT with a smoked slide and leave the brass sleeve up so the stylus does not rest on the slide. Immerse the tailfins, thermal element, and the sleeve in a bucket of water for several minutes. Then push the sleeve down to bring the stylus in contact with the slide. At that instant obtain the water temperature in the bucket with the bucket thermometer. Then raise the sleeve and trip the automatic stylus lifter without taking the BT out of the bucket. Add hot water to raise the temperature a few degrees. Stir the water and allow time for the BT to come to temperature and then make another mark as before and read the thermometer. Repeat the process several times to establish a series of temperature points across the slide, along the zero depth line. The values of the points are read with the viewer and may be plotted on a graph against the temperatures obtained by the bucket thermometer. A shift in surface temperature values may be corrected by adjusting the eccentric stop screw, on the slide holder of the viewer, to line up the grid values correctly with the recorded values.

2-55 **Depth Error.**—With the sleeve all the way back, immerse the thermal element in cold and then in warm (less than 105° F.) bucket of water. This will cause a long zero depth line to be drawn across the slide. The slide is then placed in the viewer and the difference, in feet, of the trace above or below the zero depth line on the grid is the error for which corrections must be made at all depth readings.

2–56 Disassembly of the BT.—Do not disassemble the BT. It is a precision instrument with delicate internal mechanisms, and even with the greatest care possible it is difficult to avoid damage if disassembling is attempted aboard ship. If for any reason the BT fails to operate satisfactorily, it should be turned in for repair with a report indicating the symptoms to aid the repair facility in correcting the trouble. Standard failure reports should also be submitted in accordance with current directives. Those BTs issued by the Hydrographic Office for Navy surveys should be returned to that office.

2–57 Maintenance of the BT.—The BT is an accurate measuring instrument and while the construction is reasonably rugged, the internal mechanisms are delicate. Careful handling is essential to maintain the accuracy of the measuring elements.

After each period of use, the BT should be rinsed with fresh water. Never store a BT that is being withdrawn from use without thoroughly rinsing it.

The interior of the BT should be rinsed with one-half cupful of grade III rust preventive compound each week. Place the BT in a clean bucket with the tail fins down. Slide the sleeve forward toward the nose, pour in the compound and close the sleeve. Then cover the four ports or openings in the body tube, shake the BT and turn it over on its nose and back several times so that every part is thoroughly covered. Let the compound drain out. The compound can be reused several times. Do not oil the BT—fresh water or rust-preventive compound is all the lubrication necessary.

2–58 Inspection of New Slides.—Do not remove the water and airtight cover from around the box of slides until ready to use the slides from that box. This cover is to keep the oil that retains the smoke on the slides from drying out. Samples of slides in a new box should be inspected before using. If the smoked surface of a new slide is in bad condition, or if the smoked surface shows spots after lowering the BT, *all the slides* in the box should be tested by holding each slide under a moderate stream of water. Do not use those slides on which spotting or flaking of the smoked surface appears. If more than 25 percent of the slides are unusable as a result of spotting or flaking, report the failure in accordance with current Bureau of Ships instructions.

2–59 Packaging the Slides.—Whenever a full box of slides is accumulated during the course of a survey, it should be packed securely and shipped to the Hydrographer. Be sure that all slides are properly lacquered and are easily removable from the box. Indicate clearly the cruises contained in each box. Pad the corners of each box and wrap securely with heavy wrapping paper. Seal the wrapper and label "BREAKABLE—HANDLE WITH CARE." Slides should always be kept in the special boxes in which they are provided and should not be shipped in any other type of container.

2–60 Forwarding Completed Slides and Log Sheets.—At times special instructions may be given for forwarding completed slides and log sheets. When such special instructions have not been received and when a box of slides has accumulated, send in the slides, log sheets, BT position charts (see sec. 14–59), and any special notes to:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430

2–61 Forwarding Grids from BTs Lost During Operations.—All grids from BTs lost during operations at sea shall be forwarded to the Hydrographer upon return to port or at the end of a survey cruise.

2–62 INSTRUCTIONS FOR OPERATING THE SPILHAUS-MILLER SEA SAMPLER.—The Spilhaus-Miller sea sampler is an instrument resembling the bathythermograph and operating in a similar fashion, with the additional ability of obtaining water samples at discrete depths within the limit of operation (fig. 2–14). Basically a bathythermograph to which 12 small sea water sampling bottles are

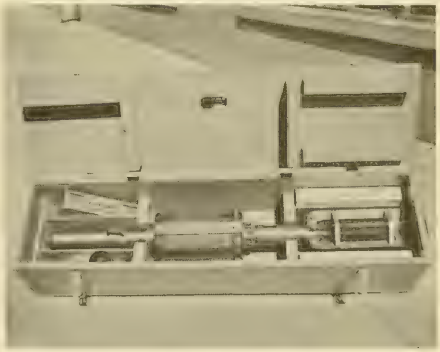

Figure 2–14. The Spilhaus-Miller sea sampler.

attached, it performs the same functions as a cast of Nansen bottles and reversing thermometers to limited depths, but with less accuracy. It is useful for studies of shallow water areas, bays, and estuaries, where rapidity of sampling is of greater importance than the degree of accuracy of temperatures.

The sea sampler is operated in much the same manner as the bathythermograph, and is lowered from a bathythermograph winch. The temperature is recorded both during lowering and hoisting on a smoked-glass slide. The water sampling bottles have valves at each end and are sent down open. They are closed at predetermined depths while the sampler is rising to the surface.

2–63 Equipment Needed to Operate the Spilhaus-Miller Sea Sampler.—In addition to a standard bathythermograph winch, with associated wire and boom, the following equipment is needed. This equipment is provided in the wooden shipping case for the sampler.

1. 100 smoked-glass slides, in two boxes.
2. Two calibrated grids for temperature-depth, in mounts.
3. One slide viewer.
4. One bucket thermometer and case.
5. One can of dipping lacquer.
6. One can of lacquer thinner.
7. Slide forceps.
8. One dipping jar.
9. One tube of stopcock grease.
10. Two bathythermograph swivels and shackles.
11. One small plastic funnel.
12. One Instruction Book for Bathythermographs.

2–64 Assembling the Sea Sampler for Operation.—Remove the sea sampler from the box and shackle the swivel on the bathythermograph wire to the eye on the nose of the sampler. Remove the sample bottles from the frame, open the valves of the bottles and replace them in the frame. Insert a smoked slide in the slide holder. The sea sampler is now ready to be lowered. Detailed instructions for each operation are given below.

2–65 To Remove the Sample Bottle.—Each sample bottle is made of brass, holds about 125 ml. of water, and has a valve at each end. To remove the sample bottle from the frame, pull out the plunger on the aft bottle retaining ring, lift the bottle up, forward and out as shown in figure 2–15.

2–66 To Open the Sample Bottle.—After the bottle has been removed, turn the valve knob on the aft end of the bottle clockwise until the bottle is open. Hold it in the open position and lift the tripping mechanism on the narrow side into a vertical position as shown in figure 2–16. The arrow indicates the tripping mechanism. When the tripping mechanism is vertical, both valves are locked open and the bottle is ready to be replaced on the sea sampler.

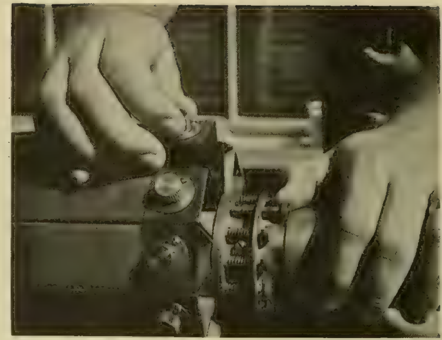

Figure 2–15. Removing the bottle.

2–67 To Replace the Sample Bottle.—To replace the sample bottle in the frame, place the spacing plugs shown in figure 2–17 on the forward end of the bottle in the holes provided on the forward retaining ring. Pull out the plunger on the aft bottle retaining ring, lower the bottle into position and release the plunger. Make sure the plunger reseats itself properly to hold the bottle. There is a number on the aft end of each bottle and a corresponding number on the retaining ring. Always replace

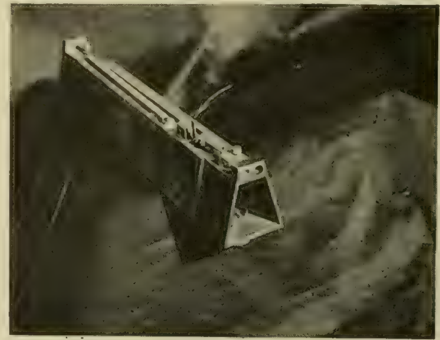

Figure 2–16. Bottle opened.

Figure 2–17. View of spacing plugs.

the bottles in the rings so the bottle and ring numbers match.

2–68 To Insert the Smoked-Glass Slide.—Insert a smoked-glass slide in the slide holder aft of the bottle frame, as shown in figure 2–18,

Figure 2–18. View of smoked-slide holder with stylus raised.

and rotate the sleeve about a quarter turn to let the stylus rest on the slide. The sea sampler is now ready to be lowered.

2–69 Lowering the Sea Sampler.—The procedures for lowering the sea sampler and bathythermograph are essentially the same. The sea sampler, however, is much heavier than a bathythermograph, weighing approximately 70 pounds. It is recommended that lowerings be made when the ship is stopped or steaming at very slow speed.

Lower the sea sampler into the water and tow it at the surface while taking a bucket sample and temperature of surface water. Check the depth of the water with the echo sounder. The best results are obtained by stopping the ship and lowering the sea sampler approximately 50 feet below the maximum depth of a 400-foot sampler and 25 feet below the maximum depth of a 150-foot sampler to insure cocking of the deepest sampling bottles. Then get underway at slow speed and bring in the sampler.

2–70 Marking the Slide and Recording the Data.—Immediately after the sea sampler is brought back on deck, rotate the sleeve so the slide holder is exposed and the stylus raised from the slide. Remove the slide and process it in the same manner as for a bathythermograph slide. Mark on the slide, the serial number of the lowering; the Greenwich mean time; and the date, in the order following: Day, month in Roman numerals, and last two digits of the year. On the bottom of the slide, record the letters SS followed by the sea sampler serial number. Dip the slide in lacquer and dry.

Record the lowering on oceanographic log sheet B together with the associated meteorological observations in the same manner as for bathythermograph observations. Instructions for recording these data are given in chapter 14.

2–71 Sample Depths.—As with the bathythermograph, the sea sampler records depth (feet) and temperature (°F.). The sample bottles of the sea sampler are tripped and closed as the sampler is raised to the surface. The tripping mechanism of each sample bottle is actuated by the pressure (depth) element. Because of its construction it is impossible to have each sea sampler trip its bottles at exactly the same depths. Each sea sampler is individually calibrated and supplied with a grid to interpret temperature and depth, as is each bathythermograph, and in addition, each sea sampler must be calibrated for the depth at which the individual sample bottles operate. A calibration sheet giving these sample depths is supplied with each instrument.

2–72 Drawing the Sea Water Samples from the Bottles.—In general, the procedure for drawing the water samples is the same as given in section 2–28. Because the bottles have no drain petcocks as Nansen bottles do, it is necessary to use a small plastic or glass funnel when draining the water into salinity sample bottles. To rinse the salinity bottles place the funnel in the mouth of the bottle, and by turning the valve knob in one end of the sea sampler bottle very carefully, let a small amount, about 15 ml., of water drain into the funnel (fig. 2–19). Remove the funnel, close the salinity bottle, and shake vigorously. Drain the rinse water out so it washes over the glass stopper and gasket and through the funnel. Repeat this rinsing procedure a second time. Replace the funnel in the salinity bottle and pour in the remaining water. Remove the funnel and fasten the stopper tightly. Great caution must be taken not to use too much water in rinsing as the sea-sampler bottle contains only about 125 ml. of water.

2–73 Maintenance of the Sea Sampler.—The sea sampler is a delicate instrument and must be handled accordingly. The routine maintenance procedures given in the bathythermograph instruction manual should be followed carefully. The tripping mechanisms on the sampling bottles are delicate and must be protected from damage. After each day's sampling has been completed, remove the sampling bottles, wash them in warm fresh water, and store them in SAE 20 oil until the instrument is to be used again.

Figure 2–19. Drawing the sample.

CHAPTER 3

TEMPERATURE AND DEPTH CALCULATIONS

3–1 GENERAL REMARKS.—The determination of true sea water temperatures and the depths at which they are obtained by means of Nansen bottles and deep-sea reversing thermometers are relatively complex. This entire chapter explains the methods and calculations involved in computing these values. The formulas given herein have been reduced to their simplest forms to enable rapid processing of data by observers in the field. For the person desiring more detailed information as to the derivation of these formulas, reference is made to H. O. Pub. No. 614, Processing Oceanographic Data.

The calculations involved in determining the temperatures and depths of Nansen bottle samples are recorded on the A-sheet, which is described in chapter 14, and on related graphs. Although these calculations can be made with an ordinary slide rule, the use of a special reversing thermometer slide rule, or a calculator, makes the process easier. The Hydrographic Office uses a small, inexpensive, plastic slide rule made for this purpose.

3–2 Deep-Sea Reversing Thermometer Calibration Corrections.—Before each deep-sea reversing thermometer can be used it must be tested and precisely calibrated to determine small errors in graduations of the scales of the main and auxiliary thermometers; the volume of mercury in the bulb of the main thermometer; the glass constant; and for unprotected thermometers, the pressure coefficients. Each thermometer used by the Hydrographic Office is tested and calibrated by the Bureau of Standards which issues a calibration sheet for it before use at sea.

When the thermometers are used at sea, either a copy of the calibration sheet or a card as shown in figure 3–1, giving the necessary information, is provided for each thermometer. Select the calibration sheet or card with the thermometer manufacturer's serial number corresponding to that of the reversing thermometer being used, and obtain the volume of mercury in the bulb of the main thermometer, called the V_0; the correction for the main thermometer scale, called the index correction; and the index correction for the auxiliary thermometer. These walues are to be recorded in the proper columns of the A-sheet. The glass constant of each main thermometer, called K, and the pressure coefficient of each unprotected thermometer, called Q, are also given on this sheet.

3–3 THERMOMETER CORRECTIONS.—To determine the true temperatures of the water samples, the protected thermometer readings must be corrected to allow for expansion of the glass and mercury after reversal and for the errors in the index scale. To determine the true depths at which the samples were actually taken, similar corrections must be applied to the unprotected thermometers, and also using the corrected temperatures of the protected thermometers. Thus, slightly different formulas are required to correct the protected and unprotected thermometers. As the formula to correct the unprotected thermometers requires the use of the corrected temperatures of the protected thermometers, the calculations for the latter must be completed first. It is mainly for this reason that when protected and unprotected thermometers are paired on a Nansen bottle, the protected thermometer is always placed in the left-hand tube and the unprotected in the right-hand tube of the thermometer frame. The data are then recorded and the calculations carried out on the A-sheet in the order in which they are used.

3–4 Correcting the PROTECTED Thermometer.—The protected thermometer is corrected to give the true temperature of the water by the following formula:

$$T_w = T' + C + I$$

T_w=The corrected value of the protected reversing thermometer. This is the true water temperature.

NUMBER	MAKE	TYPE	RANGE	V_0	"K" VALUE
4720	R&W	☐ PROTECTED ☑ UN-PROTECTED	-2° to +30°C	= 99°C	= 6100

DEEP SEA REVERSING THERMOMETER CORRECTIONS

MAIN THERMOMETER		AUXILIARY THERMOMETER	
TEMPERATURE	CORRECTION	TEMPERATURE	CORRECTION
0 °C	-.01	0 °C	-.1
5 °C	-.01	10 °C	.0
10 °C	-.01	20 °C	.0
15 °C	-.01	30 °C	-.1
20 °C	-.01	40 °C	
25 °C	-.01	50 °C	
30 °C	-.02		
°C			
°C			

T°		T°		T°		T°		T°		T°	
0.0											
	-.01										
27.5											
	-.02										
30.0											

"Q" FACTOR	
1000 M =	.01275
2000 M =	.01272
3000 M =	
4000 M =	

CORRECTIONS TAKEN FROM BUSTDS/W.H.O.I. CALIBRATION SHEET

NUMBER

DATED 17 June 1954

COPIED BY BSR

DATE 3 Nov. 1954

1. Apply thermometer corrections algebraically.
2. Keep a complete history of this thermometer on the back of card. Indicate condition and action of thermometer by checks (✓) in applicable columns, where possible. Explain condition accurately where checks are not applicable.
3. Reverse the thermometer at least once every day.
4. Always store thermometer in the carrying case with the large reservoir DOWN, unless the stored thermometer will be subjected to temperatures colder than -10 °C.
5. ALWAYS TRANSFER THIS CARD WITH THE THERMOMETER.

DEEP SEA REVERSING THERMOMETER CORRECTIONS AND HISTORY RECORD PRNC-NHO-1463 (NEW 8-54) NAVY-DPPO PRNC, WASH., D.C.

NUMBER	MAKE	TYPE	RANGE
4720	R&W	☐ PROTECTED ☑ UN-PROTECTED	-2° to +30°C

THERMOMETER HISTORY RECORD

CRUISE	DATE	REPRODUCIBILITY: GOOD ±.02	FAIR ±.05	POOR ±.08	ERRATIC >±.10	*If malfunctional, check action of mercury.* SEPARATES	DOESN'T BREAK	BREAKS IMPROPERLY	FLOODS	OTHER (*Explain*)	OBSERVER'S NAME
	2 Jan. 54									Received at Hydro.	JEB.
	17 June 54									Calibrated	C.B.
SP-14	15 Nov. 54	✓									BSR.
RE-15	2 Aug. 55	✓									BSR.

Figure 3–1. Deep-sea reversing thermometer corrections and history card.

T'=The uncorrected temperature reading of the main protected reversing thermometer.

I=The index correction for errors in the main protected thermometer scale. This is given on the calibration sheet or card and must be interpolated for the temperature reading (T') as closely as the calibration sheet will permit.

$C=\frac{(T'+V_0)\ (T'-t)}{K-100}$ This is the correction for the thermal expansion of the thermometer system, where

V_0=The volume of mercury below the 0° C. mark determined at 0° C. in the reversed main thermometer, expressed in degrees Celsius. It is given on the calibration sheet.

t=The temperature reading of the auxiliary thermometer corrected for index errors. The corrections are given on the calibration sheet. It is the temperature at which the protected reversing thermometer is read.

K=The reciprocal thermal coefficient of expansion of the thermometer system. It is a constant dependent upon the type of glass of which the thermometer is made. The K-value is given on the calibration sheet. Since most reversing thermometers are read to hundredths °C., the correction is desired to the same accuracy. This accuracy can be obtained when the denominator of the fraction is taken to be K-100.

An example of correcting a *protected thermometer* is shown as follows:

Given:

9.33° C. (uncorrected main thermometer as shown on the A-sheet).

20.2° C. (uncorrected auxiliary thermometer as shown on the A-sheet).

From the calibration sheet for this thermometer we find:

$V_0=96°$.

t=20.2° C.± the auxiliary thermometer index correction (in this case +0.7° C.)=20.9° C.

K=6100.

I=−0.01° C. (index correction for the main thermometer at 9.33° C.).

Find:

$$C=\frac{(9.33+96)\ (9.33-20.9)}{6100-100}.$$

$$C=\frac{(105.33)\ (11.57)}{6000}.$$

$$C=-0.20°.$$

Find:

$T_w=T'+C+I.$

$T_w=9.33°+(-0.20°)+(-0.01°).$

$T_w=9.12°.$

3–5 Correcting the UNPROTECTED Thermometer.—The unprotected thermometer is corrected by the following formula:

$$T_u=T'_u+C+I$$

where the symbols are defined as:

T_u=The corrected reading of the unprotected reversing thermometer, a function of both temperature and pressure.

T'_u=The uncorrected temperature reading of the main unprotected reversing thermometer.

I=The index correction for errors in the main unprotected thermometer scale. This is given on the calibration sheet or card and must be interpolated for the temperature reading (T'_u) as close as the calibration sheet will permit.

$C=\frac{(T'_u+V_0)\ (T_w-t_u)}{K}$ This is the correction for the thermal expansion of the thermometer system, where

V_0=The volume of mercury below the 0° C. mark determined at 0° C. in the reversed main thermometer, expressed in degrees Celsius. It is given on the calibration sheet.

T_w=The corrected value of the *protected* reversing thermometer reading, (the true water temperature at depth of reversal).

t_u=The temperature reading of the unprotected auxiliary thermometer corrected for index errors. The corrections are given on the calibration sheet. It is the temperature at which the unprotected reversing thermometer is read.

K=The reciprocal thermal coefficient of expansion of the thermometer system. It is a constant which is dependent upon the type of glass with which the thermometer is made. The K-value is given on the calibration sheet.

An example of correcting an *unprotected thermometer* is shown as follows:

Given:

$T'_u = 16.40°$ C. (Uncorrected main thermometer as shown on the A-sheet.

$t'_u = 20.7°$ C. (Uncorrected auxiliary thermometer as shown on the A-sheet.

From the calibration sheet for this thermometer we find:

$V_0 = 99°$.

$t_u = 20.7°$ C. $\pm$ the auxiliary thermometer index correction (in this case 0.0° C.) $= 20.7$ C.

$K = 6100$.

$I = -0.01°$ C. (index correction for the main thermometer at 16.4° C.).

From the paired *protected* thermometer we find:

$T_w = 9.12°$ C.

Find:

$$C = \frac{(16.40+99)\ (9.12-20.7)}{6100}.$$

$$C = \frac{(115.40)\ (11.58)}{6100}.$$

$$C = -0.22°.$$

Find:

$$T_u = T'_u + C + I.$$
$$T_u = 16.40° + (-0.22°) + (-0.01°).$$
$$T_u = 16.17°.$$

3–6 REVERSING THERMOMETER CALCULATIONS WITH THE SLIDE RULE.—To simplify the calculations of reversing thermometer corrections, a special oceanographic slide rule was developed. The type used by the Hydrographic Office is shown in figure 3–2. Printed on the face of the slide rule are four scales marked A, B, C, and D. The A-scale gives the values of $V_0 + T'$ or $V_0 + T'_u$. The B-scale denotes the K—value for each thermometer. The C-scale gives the $T'-t$ or $T_w - t_u$. The D-scale gives the value C.

The reverse side of the slide has a three-place table of cosines for wire angles of 1° to 60°. On the back of the slide rule is a depth conversion table for fathoms to meters.

3–7 Correcting the PROTECTED Thermometer with the Slide Rule.—Corrections for the protected thermometer are made with the slide rule as follows:

Step 1: $V_0 + T'$. Determine this value and locate it on the A-scale.

Step 2: K. Determine K and set its value on the B-scale under the value for $V_0 + T'$ on the A-scale.

Step 3: $T' - t$. Determine this value and locate it on the C-scale.

Step 4: C. The answer (C) is read from the D-scale directly below the value $T' - t$ on the C-scale.

The sign of C is *plus* when T' is *greater* than t.

The sign of C is *minus* when T' is *less* than t.

3–8 Correcting the UNPROTECTED Thermometer with the Slide Rule.—Corrections for the unprotected thermometer are made with the slide rule as follows:

Step 1: $V_0 + T'_u$. Determine this value and locate it on the A-scale.

Step 2: K. Determine K and set its value on the B-scale under the value for $V_0 + T'_u$.

Step 3: $T_w - t_u$. Determine this value and locate it on the C-scale.

Step 4: C. The answer (C) is read from the D-scale directly below the value $T_w - t_u$ on the C-scale.

The sign of C is *plus* when T_w is *greater* than t_u.

The sign of C is *minus* when T_w is *less* than t_u.

3–9 THERMOMETRIC DEPTH DETERMINATION.—After the reversing thermometer readings have been corrected, the thermometric depth for each Nansen bottle equipped with an unprotected thermometer, e. g., the depth at which the thermometers reversed, can be calculated. Such calculations are possible only when protected and unprotected reversing thermometers are paired on a Nansen bottle. Usually protected and unprotected thermometers are not paired on every bottle but only at selected depths.

There are two methods in general use for determining thermometric depth. Although similar, one involves direct use of a formula, while the other uses preconstructed graphs based on the formula. Each unprotected reversing thermometer has a unique graph called a depth anomaly (ΔZ) graph from which the depth correction is read directly.

3–10 Determining Thermometric Depth by Formula.—The thermometric depth may be determined directly by the following formula:

$$Z = \frac{T_u - T_w}{\rho_m Q}$$

where:

Z = The thermometric depth in meters.

T_u = The corrected reading of the *unprotected* reversing thermometer.

T_w = The corrected reading of the *protected* reversing thermometer.

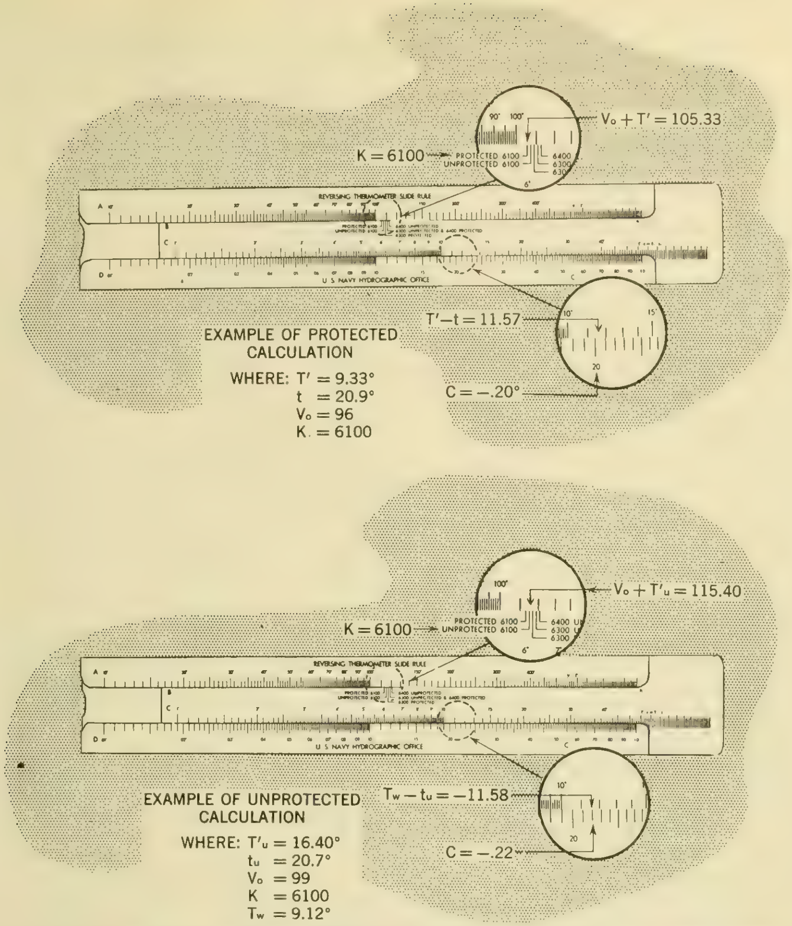

Figure 3–2. Two drawings of reversing thermometer slide rule with protected and unprotected sample calculations.

ρ_m= The mean density of the water column above the level of reversal. This may be obtained from graphs, tables, or the computed densities of the station. Graphs of these values for several areas are shown in figure 3–3 and in table 17.

Q= The pressure coefficient of the unprotected thermometer, expressed in degrees Celsius increase in the reading per 0.1 kg/cm^2 increase in pressure. As so defined, Q has a magnitude of roughly 0.01. Q is given on the thermometer calibration certificate.

An example of the calculation of thermometric depth is shown as follows:

Given:

T_u=16.17°.

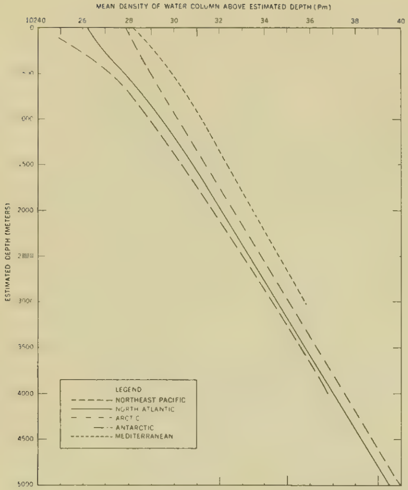

Figure 3–3. Mean density (ρ_m) of sea water.

$T_w = 9.12°$.
$\rho_m = 1.0281$ at 600 m.
$Q = 0.01275$.

Find:

$$Z = \frac{(16.17)-(9.12)}{(1.0281)\ (0.01275)}.$$

$$Z = \frac{7.05}{0.01311}.$$

$Z = 538$ meters.

This figure is entered in the "Thermometric Depth" column of the A-sheet.

3–11 Determining Thermometric Depth by Depth Anomaly (ΔZ) Graphs.—The depth anomaly (ΔZ) graph permits more rapid application of the above formula inasmuch as certain values of the formula may be precalculated and graphed. Thus, to find the thermometric depth of reversal of a given unprotected thermometer, ΔZ is read from its graph and added algebraically to $100(T_u - T_w)$ corresponding to the given $T_u - T_w$. ΔZ is defined as the meters depth by which Z differs from $100(T_u - T_w)$. In other words, since ρ_m is approximately 1.0 and Q is roughly 0.01, $Z = 100(T_u - T_w) + \Delta Z$.

Each unprotected thermometer should have its own depth anomaly (ΔZ) graph. A sample one is shown in figure 3–4. Enter the graph with T_u-T_w from the Difference column of the A-sheet (7.05°) and determine the ΔZ (−167m). Enter this value in the Correction column. Be sure to indicate if the correction is to be added or subtracted. Add this correction algebraically to the difference times 100 and enter this value (538m) in the Thermometric Depth (Z) column of the A Sheet.

3–12 Constructing a Depth Anomaly (ΔZ) Graph.—If it is assumed that an ideal unprotected thermometer will register an increase of 0.01° C. per meter of depth in sea water, then 100 times the difference between the protected and unprotected thermometer readings would equal the depth in meters. Actually, this is not exactly the case due to minute variations in the glass and other slight imperfections that are impossible to avoid in manufacture. Thus, the unprotected thermometer will have Q-factors that are somewhat greater or less than the ideal (0.01). Therefore, correction graphs can be constructed using the values of Q and ρ_m, assuming values of T_u-T_w, and then solving the formula, in section 3–10 above, for depth (Z). The difference between the computed or thermometric depth and the ideal or assumed depth is the depth anomaly (ΔZ). For example, the values used to construct the ΔZ graph shown in figure 3–4 are given below:

Assumed depth in meters	Assumed T_u-T_w	ρ_m	Q	Z	ΔZ
100	1. 00°	1. 0264	0. 01275	76	24
500	5. 00°	1. 0277	. 01275	382	118
1,000	10. 00°	1. 0294	. 01275	762	238
1,500	15. 00°	1. 0308	. 01274	1141	359
2,000	20. 00°	1. 0321	. 01272	1521	479
2,500	25. 00°	1. 0333	. 01272	1902	598

The values of ΔZ are plotted at the values of T_u-T_w and a curve drawn through the points. It should be noted that in the sample these are *negative* errors, that is the thermometric depth is less than the assumed or ideal depth, and that the corrections obtained from this graph must be *subtracted* from $100(T_u$-$T_w)$ to obtain the correct thermometric depth.

3–13 ACCEPTED DEPTH DETERMINATIONS.—There are two methods in general use for determining the accepted depth; e. g., the best possible determination of the true depth of each Nansen bottle at the time of reversal. These are the depth-difference method (wire length, L, minus thermometric depth, Z) and the depth-ratio method (thermometric depth, Z, divided by wire length, L). In the first, a reasonably accurate picture of the true wire shape during cast is reproduced graphically, and in the second the ratio of the thermo-

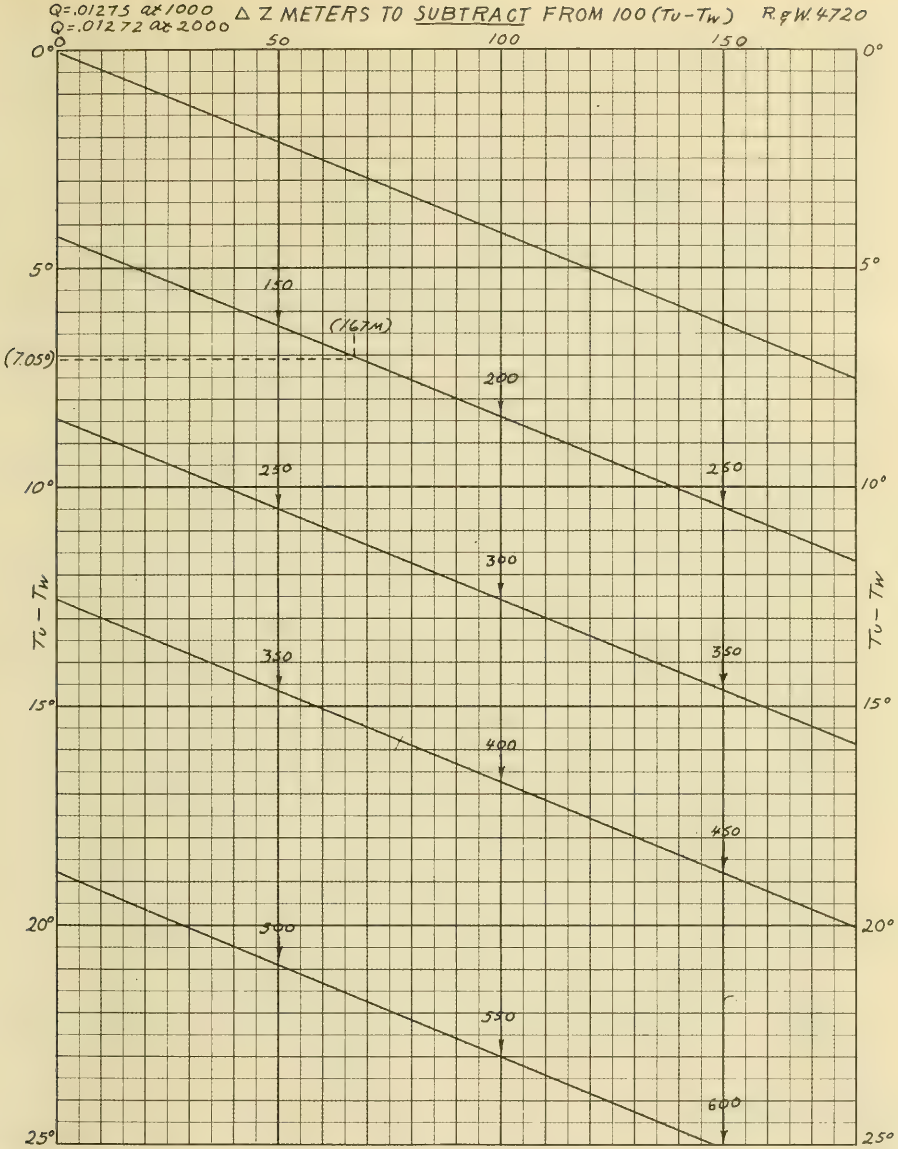

Figure 3–4. Depth anomaly (ΔZ) graph.

metric depths obtained to the wire length is utilized. Each of these methods is described below.

3–14 The Depth Difference (L–Z) Method for Determining Accepted Depth.—The L–Z method of determining accepted depth from a given wire depth, L, thermometric depth, Z, and surface wire angle affords a simplified method for evaluating the validity of each thermometric depth and interpolating for the samples taken between these depths. The curve used in the evaluation and interpolation closely approximates the actual pattern assumed by the wire during the cast. Each cast taken must be graphed separately. Graph paper of 10 x 10 to the ½ inch or millimeter may be used. The Hydrographic Office uses millimeter graph paper with the values for L and L–Z printed thereon (fig. 3–5). The procedure used in constructing the L–Z graph is as follows:

1. On the vertical side of the graph, lay off the wire depth, L, starting with zero at the upper left corner for the shallow cast and the upper right corner for the deep cast. Use a convenient depth increment for each cast which will allow sufficient space for the maximum wire depth sampled.

2. Across the top of the graph lay off the depth difference, L–Z, for each cast. The increments need not be less than one per millimeter and must not be greater than four per millimeter to maintain accuracy. It is better to use larger graph paper than to reduce the scale if conditions of high wire angle give large L–Z values.

3. From the origin (upper left or right corner) construct a line making an angle from the vertical which represents one minus the cosine (1-cosine) of the wire angle. This is done as follows:

   a. From a table of trigonometric functions, find the cosine of the measured wire angle. For example, the cosine of the wire angle 27° is 0.891.

   b. From 1.000 take the cosine. 1.000—0.891=0.109.

   c. Multiply the remainder by 100. 0.109×100=10.9

   d. At wire depth of 100 meters plot the value 10.9 as L–Z and construct a line passing through the origin and this point. This line represents a wire angle of 27° for the scale used.

4. From the A-sheet tabulate the wire depth, L, for each thermometric depth, Z, and compute the depth difference, L–Z. The values shown on the sample log sheet, figure 14–2, are:

Wire depth (L)	*Thermometric depth* (Z)	*Depth difference* (L–Z)
Cast I:		
200	190	10
300	283	17
400	385	15
Cast II:		
600	538	62
1200	1086	114
2000	1853	147
2300	2153	147

5. At the wire depths, plot the depth difference values for each cast. Select the best points and draw a smooth curve through them to the origin so that it becomes tangent with the wire angle line. Owing to inaccuracies of wire angle measurement (±5°) the curve may not fair into the wire angle precisely. In such case, plot lines representing angles 5° greater and less than the one measured. The curve must fall between these limits to be valid. The L–Z curve must be studied for errors. From the nature of the plotted curve certain errors should be apparent; for example, no value of L–Z can be negative, nor can the curve have a negative slope because the wire reaches a limiting shape at any depth when it becomes vertical (Pollak, 1950). The curve should be reasonably smooth. If the instrument fails to give a correct thermometric depth, the error will be evident and the value should not be used when constructing the curve. This situation appears with the 300-meter-depth bottle in figure 3–5 where, if used, would make a negative curve between 300 and 400 meters depth.

6. From the curve, a new set of L–Z values are taken to determine the accepted depths for every Nansen bottle of the cast. These are taken by interpolation along the arc of the curve. At the wire depth for each sample, take the L–Z from the curve and record this in the Used column of the A-sheet, thus indicating on the log sheet the values actually used to determine the accepted depths. Next subtract the Used L–Z from L to get the accepted depth for each sample. Example:

   $(L)-(L\text{–}Z)=$Accepted depth.
   1500−131=1,369 meters.

3–15 The Depth-Ratio (Z/L) Method of Determining Accepted Depths.—Another method of determining accepted depths consists of plotting the ratio of the thermometric depth to wire depth, Z/L, against wire depth, L, and drawing a smooth curve through these points to the cosine of the wire angle at the surface. This depth-ratio method is sometimes referred to as the cosine method. The pro-

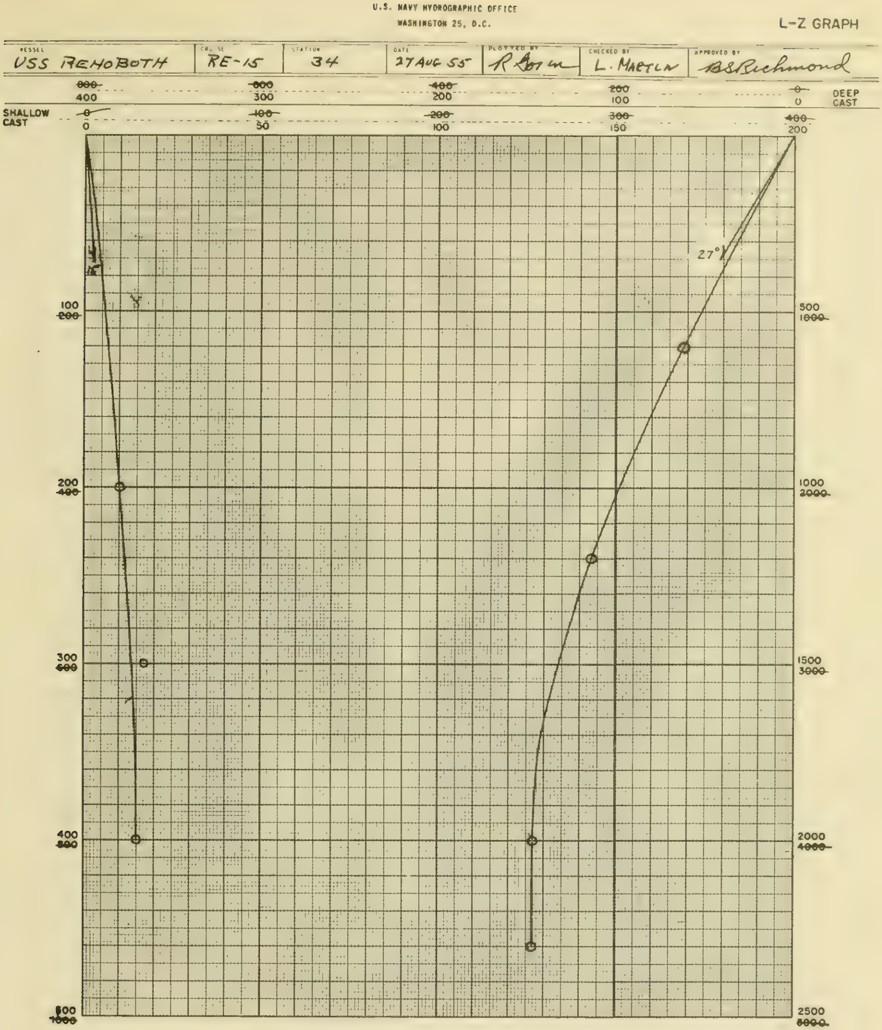

Figure 3–5. The L–Z graph.

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cedure for constructing the Z/L graph is as follows:

1. On the vertical side of the graph, lay off the wire depth starting with zero at the upper left for the shallow cast and the upper right for the deep cast (fig. 3–6). Use a convenient depth increment for each cast which will allow space for the maximum wire depth sampled.

2. Compute the depth ratio for each thermometric depth by dividing the thermometric depth by the wire depth and record these values in the Obs. (Observed) column of the A-sheet. The values used for the sample in figure 3–6 are:

Wire depth (L)	*Thermometric depth* (Z)	*Depth ratio* (Z/L)
Cast I:		
0	0	0.961 (cos 16°)
200	190	.950
300	283	.943
400	365	.962
Cast II:		
0	0	0.891 (cos 27°)
600	538	.897
1200	1068	.905
2000	1853	.927
2300	2153	.936

3. Across the top of the graph lay off the depth ratio, Z/L, commencing with highest cosine value at the left decreasing to the right in convenient increments.

4. Plot on the graph the depth ratio at wire depth and construct curves through the best combination of usable points. If the wire angle is small, the ratio is nearly constant and approaches unity. However, if the wire angle is large the ratio usually increases with depth, indicating that the wire becomes more vertical with depth. If the ratio curve is not reasonably smooth it should be studied for errors. Erroneous values can be caused by improper tripping of the bottles, malfunction of the thermometers or meter wheel, etc. Values that appear to be in error will fall out of the smooth-curve pattern and should be disregarded when drawing the curve.

5. After drawing the curve, pick off the new ratio values for every bottle at the wire depth and enter them in the Used column of the A-sheet. To obtain the accepted depth for each sample multiply the wire depth by the new depth ratio. Example:

$(L)\times(Z/L)=$Accepted depth.
$1{,}500\times0.913=1{,}369$ meters.

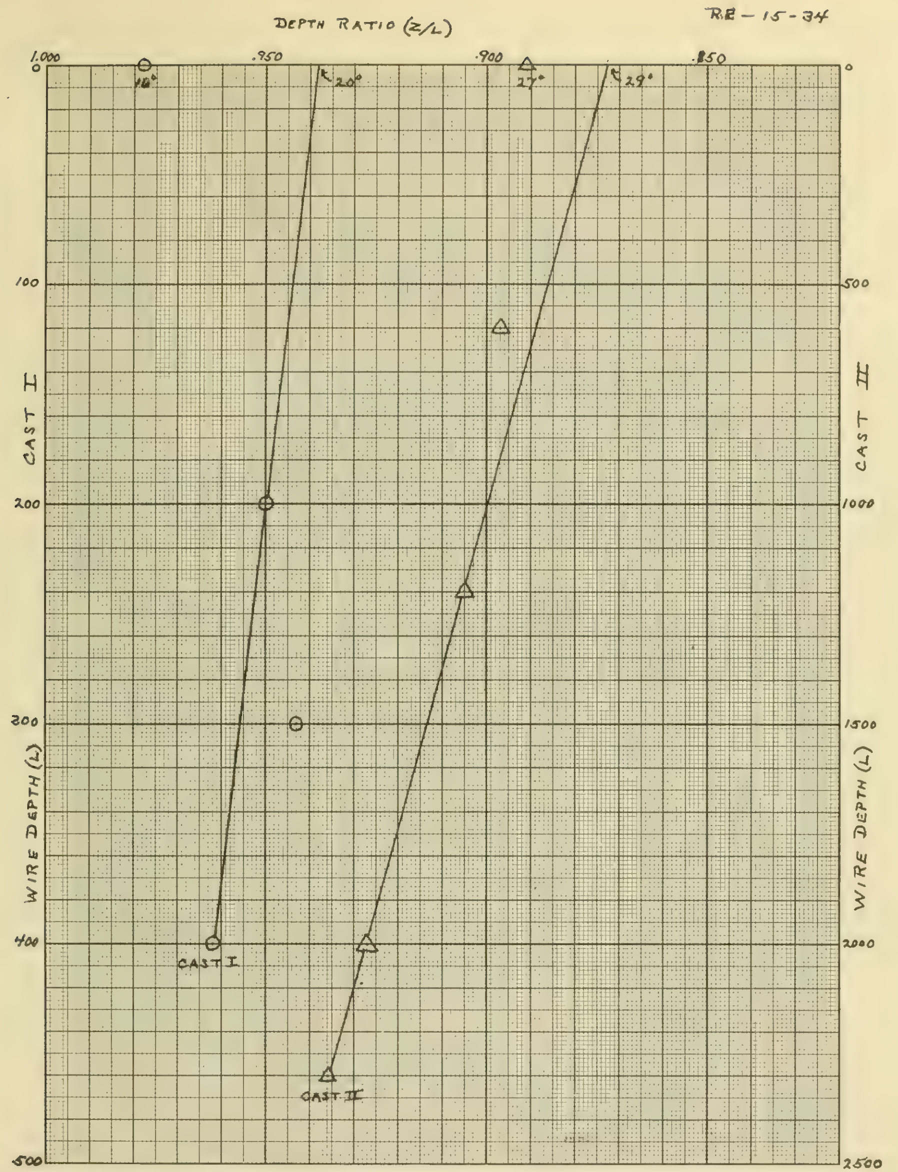

Figure 3–6. The Z/L graph.

CHAPTER 4

DRAWING OCEANOGRAPHIC GRAPHS AND PROFILES

4–1 GENERAL REMARKS.—Graphs and profiles of oceanographic data serve many uses in studies and interpretations of these data. Some of the immediate important shipboard applications include checking for possible errors in computations, chemical analyses, spacing the Nansen bottles, and obtaining the standard depth values from the plotted observed values.

All graphs and profiles should be drawn with great care. Use a pencil no softer than a number 3 drawing pencil. Keep the point sharp and draw fine clear lines. Plot all data accurately. Use french and ship curves to construct lines. Draw the curves through the plotted points in such a manner that the points appear to lie on the curve rather than being connected by curved lines. This can be done easily with a little practice.

4–2 PLOTTING OBSERVED OCEANOGRAPHIC VALUES.—Observed values for temperature, salinity, dissolved oxygen, and density, as well as any other determined values, are plotted against depth. For this purpose, Navy survey ships use a special graph printed by the Hydrographic Office and known as an Oceanographic Station Plotting Sheet (H. O. Misc. 15,252–1). A sample sheet is shown in figure 4–1. If these sheets are not available aboard ship, any good quality graph paper scaled 10 x 10 to the ½ inch may be used.

4–3 Standard Symbols and Scales.—To aid in interpretation of data and eliminate unnecessary replotting ashore, the Hydrographic Office uses a standard set of symbols and scales for temperature, salinity, oxygen, and density, as shown below. These symbols and scales are given on the Oceanographic Station Plotting Sheet. The point in the symbol indicates the value and the symbol indicates the type of observation.

Type of observation	Symbol	Scale
1. Temperature (° C.)	-·-	½ inch = 1° C.
2. Salinity (°/₀₀)	△	½ inch = 0.2 °/₀₀.
3. Oxygen (ml./l.)	⊙	½ inch = 0.25 ml./l.
4. Density (σ_t)	▽	½ inch = 0.2.

On the vertical scale, ½ inch equals 100 meters of depth. If the station depth exceeds the length of the graph paper extend the graph by attaching part of another sheet to the bottom with rubber cement.

4–4 OBTAINING INTERPOLATED VALUES.—Temperature, salinity, oxygen, and density values for standard depths are interpolated from the plotted observed value curves and are recorded on oceanographic log sheet E. To find an interpolated value, simply locate the intersection of the curve and the horizontal line which represents the desired standard depth and read the corresponding value at the top of the graph. The standard depths are printed on the E-sheet.

Interpolated standard depth values obtained for temperature, salinity, and density may be checked by entering a Nomograph for the Determination of Density from Salinity and Temperature of Sea Water (tables 1 to 6, identified as H. O. Misc. 15530–1 to 6) with the values for temperature and salinity. The resulting density value must agree with the interpolated value. In like manner, the density values of the temperature-salinity (T–S) curve can be checked. In the event the values do not agree then at least one of observed values is not valid and must be reviewed.

4–5 TEMPERATURE-SALINITY (T–S) CURVES.—To plot temperature-salinity relationships, referred to as T–S curves, Navy survey ships use special graph paper printed by the Hydrographic Office called a Temperature-Salinity Plot (H. O. Misc. 12,252–B). A sample sheet is shown in figure 4–2. This graph indicates density values for the range of temperature and salinity it covers. If these sheets are not available aboard ship, any good quality graph paper scaled 10 x 10 to the ½ inch may be used. The same temperature and salinity scales as given in section 4–3 are used. Temperature is represented on the vertical scale and salinity on the horizontal scale.

Using the data for temperature and salinity from the E-sheet, plot the observed T–S values for each depth. Circle each point and draw a smooth curve through the plotted points. Now

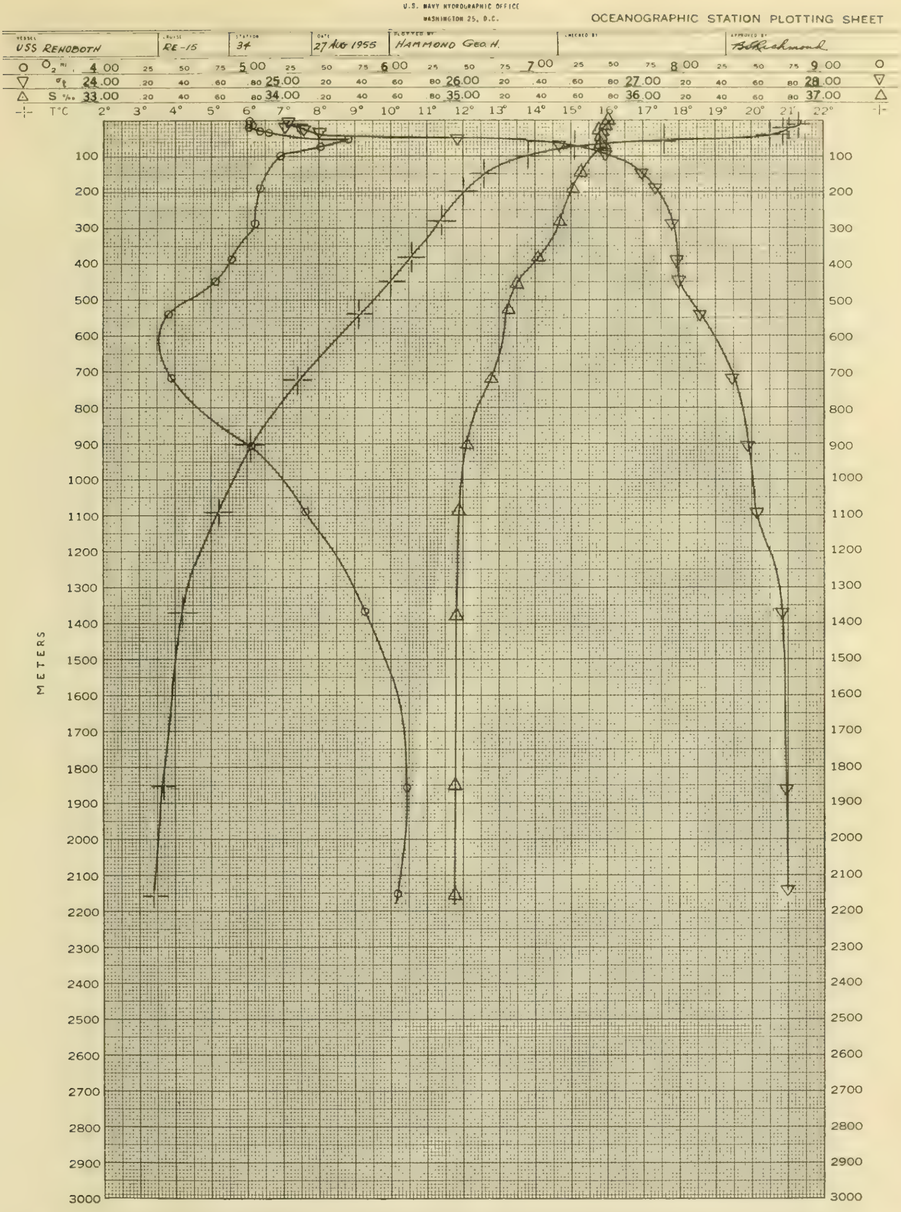

Figure 4–1. Oceanographic Station plotting sheet.

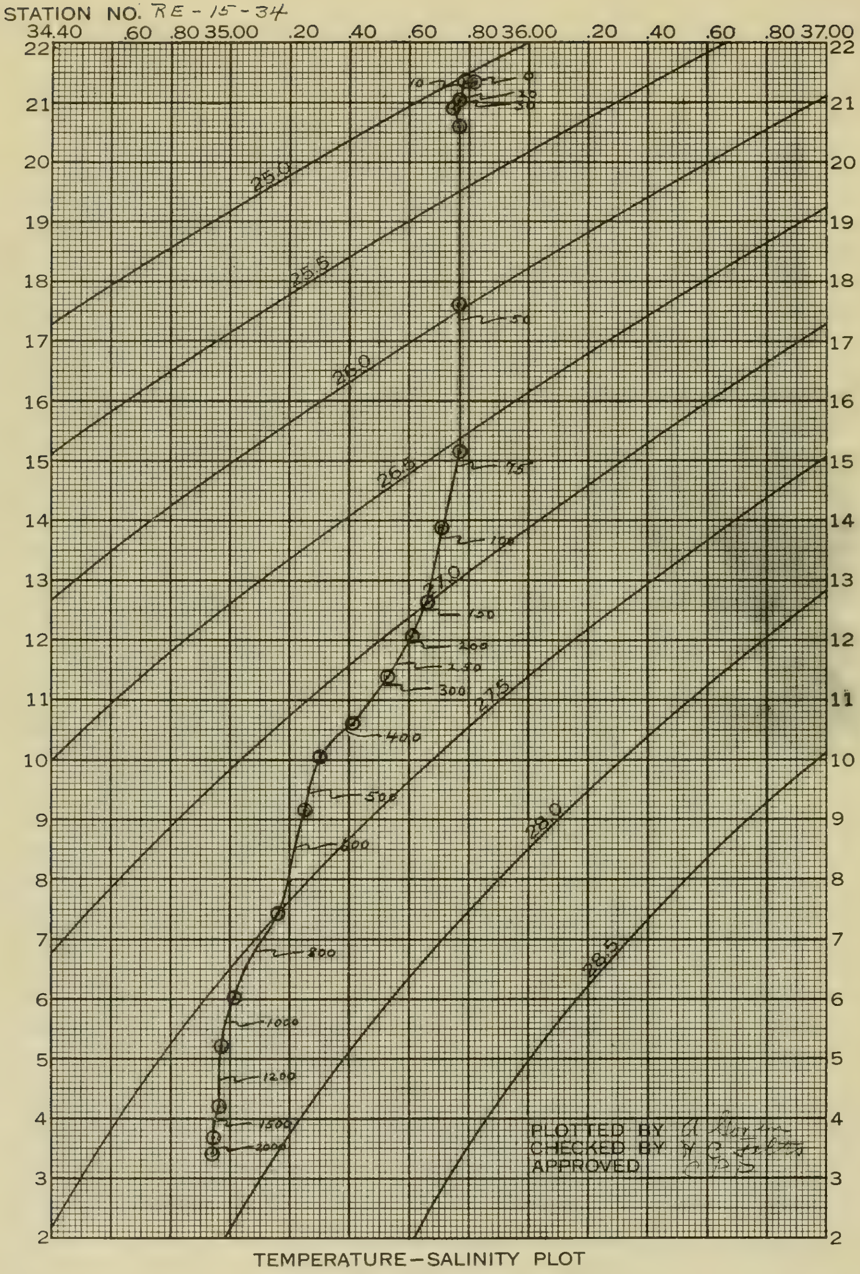

Figure 4-2. Temperature-Salinity (T-S) curve.

determine the positions on the curve which represent the interpolated values at standard depths, and enter the standard depth to the right of the curve, indicating the position with an arrow.

4–6 BATHYTHERMOGRAPH TEMPERATURE—DEPTH PROFILE.—A continuous temperature against depth profile is plotted as the bathythermograph observations are made. The most convenient paper to use is 50-yard rolls of graph paper scaled 10 x 10 to the inch. Depth is represented on the vertical scale using 50 feet per inch. For routine observations where speeds and courses are relatively constant, the horizontal scale may be in units of time, using one inch per hour. However, in special cases and where frequent course and speed changes are involved, as in current studies, it is recommended that the horizontal scale be in miles, using 10 miles per inch.

The treated bathythermograph slide is viewed against the proper grid. The slide number, Greenwich mean time, and surface temperature read to the nearest 0.1° F., are entered at the top of the graph. Whenever more than one bathythermograph is being used, record the instrument serial number over the slide number. A sample profile section is shown in figure 4–3. The slide is then read; the depth of each one-degree change is noted and plotted. As subsequent observations are entered on the graph, points of equal temperature are connected. Five-degree intervals are connected with solid lines; other isotherms are dashed. The ship, cruise number, and data should be noted every 24 hours at the top of the graph. Speed and course changes also are recorded so that distortions causing apparent anomalies will be recognized.

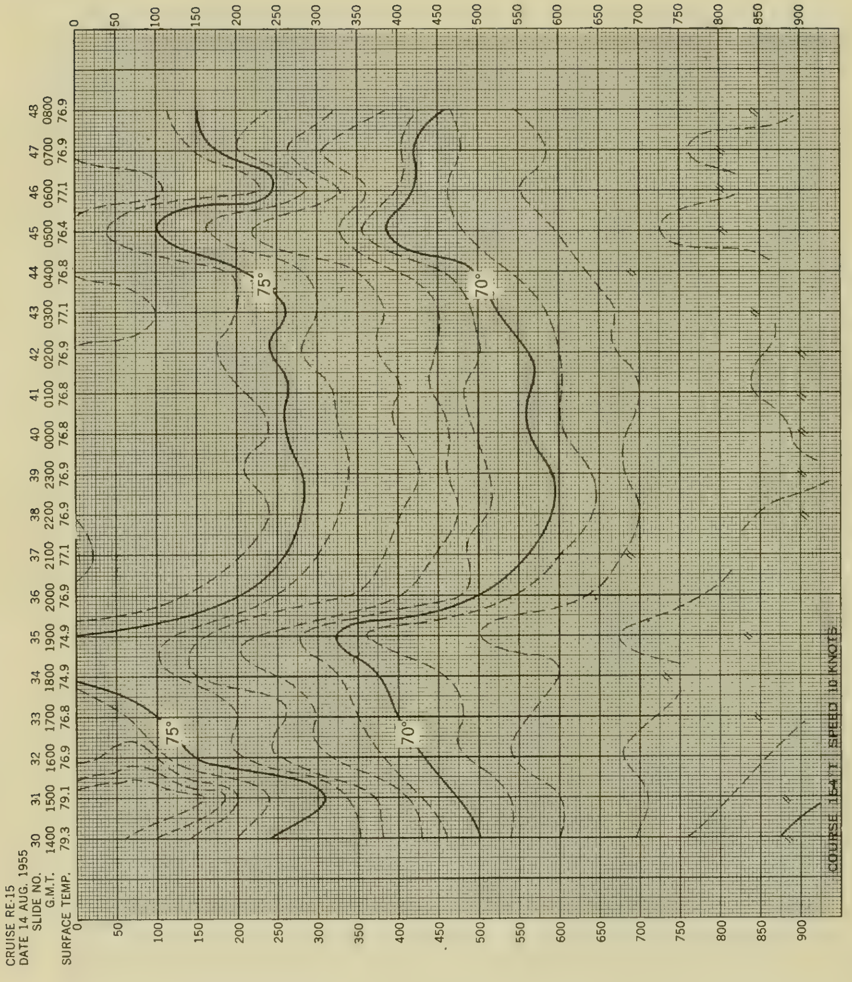

Figure 4–3. **Bathythermograph temperature-depth profile.**

CHAPTER 5

NAVIGATION AND SONIC SOUNDINGS

5–1 GENERAL REMARKS.—Obtaining detailed and accurate sounding data for immediate and future use is of prime importance to the fleet and merchant marine. Navy survey ships are required to take continuous soundings while underway and frequently take intensive soundings over selected areas. Careful attention to navigation, plotting corrected ship's tracks, recording soundings, and correctly marking the echogram is of utmost importance.

It is not within the scope of this manual to attempt to cover the various aspects of hydrographic surveys. However, in view of the importance of accurate navigation and sounding information to oceanographic observations, the following general instructions are given. These instructions apply to Navy ships conducting oceanographic surveys. They may be added to or modified by specifications for a particular cruise when circumstances so demand.

5–2 NAVIGATION.—Navigation of the ship is not expected to present any more than the usual problems. The value of the data collected will be much greater if the ship's position is determined so accurately as to leave no questions for the future.

Whenever two or more ships are conducting a survey and proceeding in company, it is desired that they maintain a range between ships of at least five miles. This will give a better spread of soundings and prevent overlapping track lines on the final compilation sheets.

5–3 Plotting Sheets.—For each survey cruise, two sets of contoured position plotting sheets (H. O. Series 3000) will be furnished the ship. These sheets cover all areas of the survey and are numbered and coded by the Hydrographic Office. On one set are plotted the positions of the proposed oceanographic stations, any special sounding grids, and the recommended ship's track for the cruise. This set is the navigator's worksheets, or rough plots. The other set is used for plotting the corrected ship's track, soundings, stations, and other observations. It is the smooth track plot.

5–4 Information to be Furnished by the Navigator.—The following information is to be furnished by the navigator: All fixes, celestial, Loran, sun lines, geographic bearings; a DRT position for each fix for the purpose of computing set and drift; and all changes of course and speed, with times noted. Local zone time shall be used and time zone changes noted. At each fix, especially the morning, local apparent noon, and evening fixes, the navigator shall give his evaluation of the fix with comments about weather conditions; i. e., poor horizon, good horizon, hazy, clear, cloudy, etc. Time of arrival at and departure from stations shall be given, with proper allowances for maneuvering the ship.

The navigator shall indicate the corrected, or actual, ship's track between the best available fixes. This track shall be shown in blue pencil and shall be used to construct the smooth plot track. Any notes or changes made on the navigator's worksheet by any person other than the navigator or his assigned personnel shall be made with colored pencil (other than blue). A sample sheet is shown in figure 5–1.

5–5 Preparation of the Smooth Track Plots.—The smooth track plots shall be constructed from the corrected ship's track, indicated in blue on the navigator's worksheet. Times plotted on the smooth sheets shall be underlined so as not to be confused with soundings. Local zone times shall be noted every hour, for every change of course and speed, and for time of arrival at and departure from stations. The soundings shall be plotted at 10-minute intervals, except that where more detail is needed the interval shall be closer. All soundings shall be taken from the echograms and shall be checked against those recorded in the sounding logbooks. The bathythermograph slide number shall be plotted for each observation made. A sample sheet is shown in figure 5–2.

5–6 SONIC SOUNDER INSTRUCTIONS.—The sonic sounders shall be operated continu-

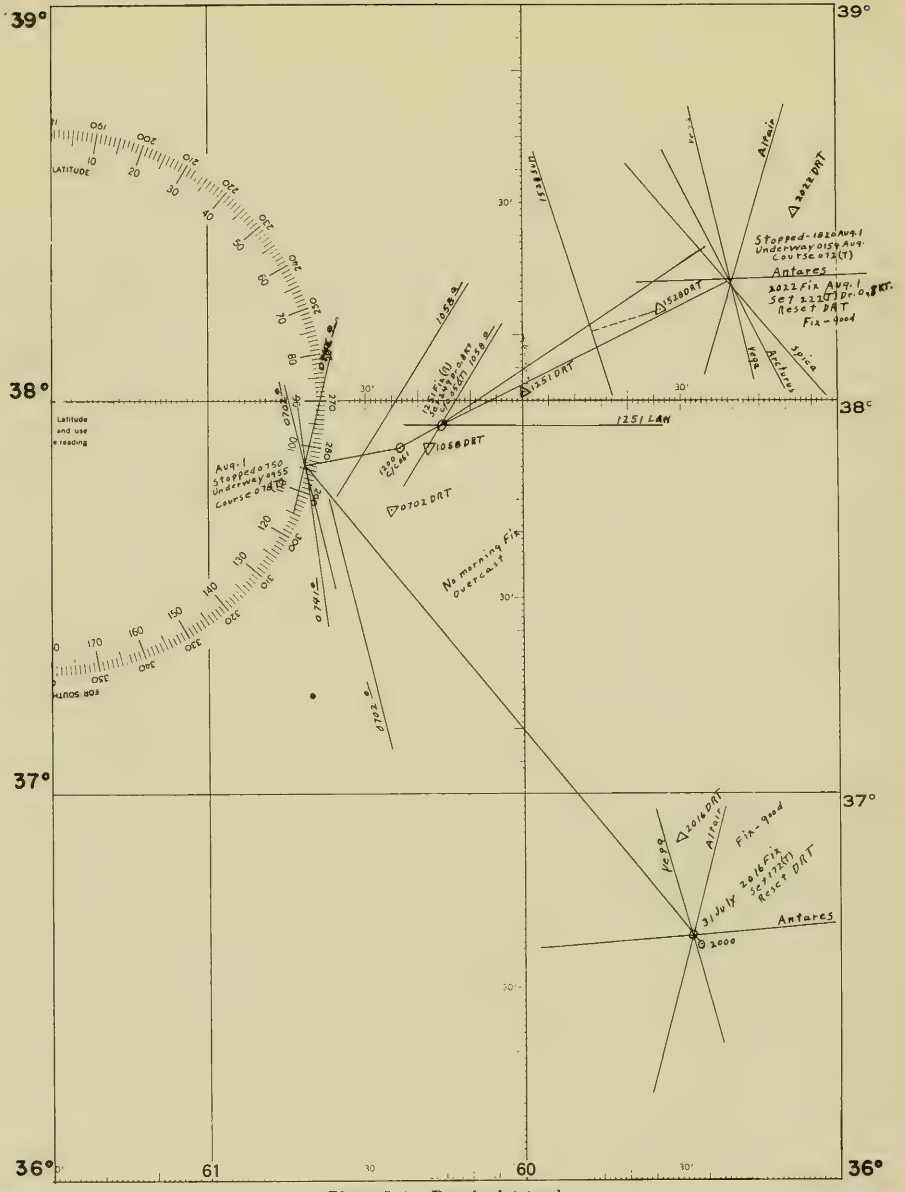

Figure 5–1. Rough plot track.

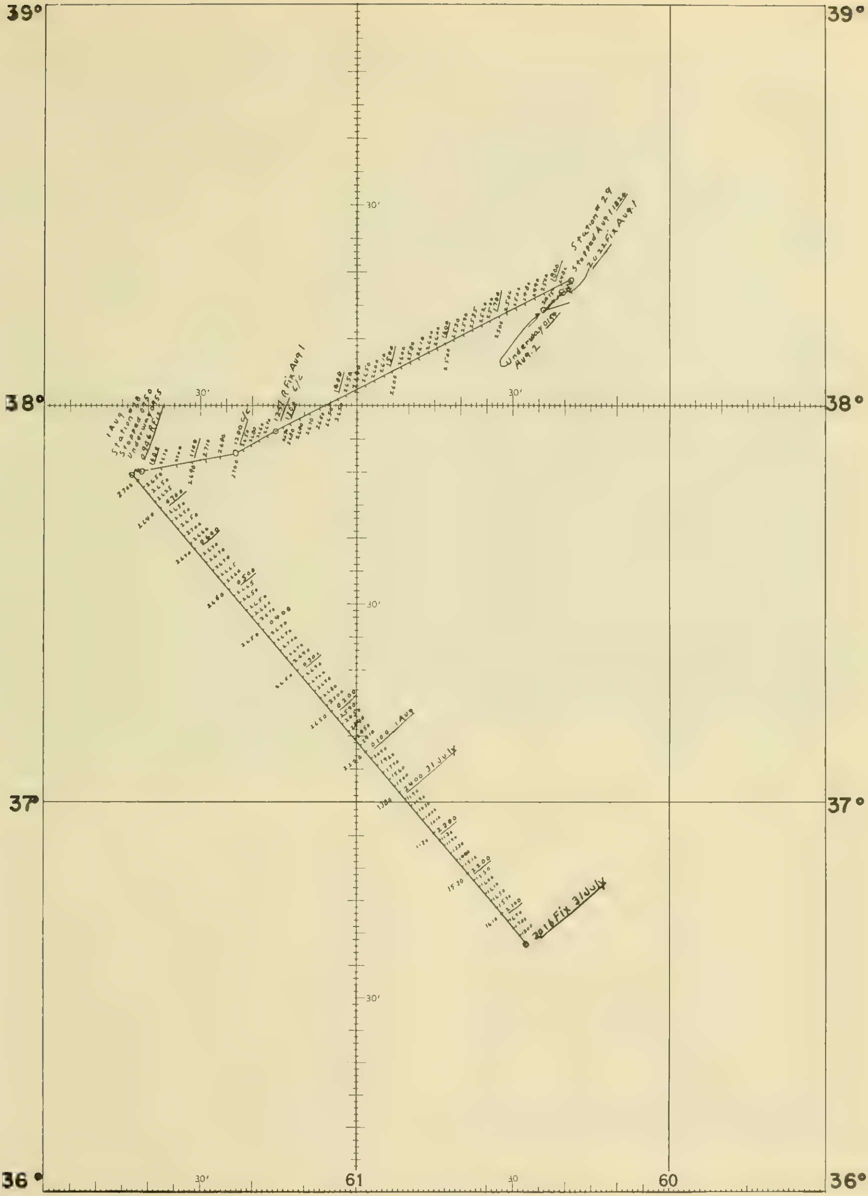

Figure 5–2. Smooth plot track.

ously while underway and every effort made to record a continuous profile of the bottom. (fig. 5–3).

Figure 5–3. Recording the sounding.

5–7 **Marking the Echogram.**—When a new roll of recorder paper is installed in the echo sounder, the data must be written on it with a colored pencil. Time must be recorded on the echogram every hour when the recorder is operated at slow paper speed and every 30 minutes when operated on fast paper speed. In addition to the time, the date must be written at 0000, 0400, 0800, 1200, 1600, and 2000 hours. Upon removing the roll from the machine, the date must be written at the end of the echogram. Any notations made on the echogram must be made with a dark-red pencil, as the ordinary graphite pencil blends too well with the finish on the paper. A sample echogram is shown in figure 5–4.

5–8 **Maintaining the Sounding Logs.**—Sounding logbooks are furnished by the Hydrographic Office for Navy surveys. Two sounding logs shall be kept, one for the *odd* numbered days and the other for the *even* numbered days. Unless otherwise specified, soundings shall be recorded in the log every 5 minutes. These soundings shall be read from the echogram, whenever possible, as recordings of soundings by audible or visual (dial light) means are subject to many personal errors. Whenever a change of depth scale is made or the recording shifted to another machine, it shall be noted in the log; e. g., "Changed to 0–600 fathom scale," or, "Shifted to recorder No. 2." All changes of course and speed shall be entered in the log. When two or more ships are operating together, hourly pelorus bearings and radar ranges of the other ships shall be recorded. Proper time notations must accompany all entries in the sounding log. Local zone times shall be used and time zone changes noted. A sample logbook page is shown in figure 5–5.

5–9 **DEVELOPING SPECIAL SOUNDING GRIDS.**—Cruise instructions often call for development of special sounding grids in specified areas. These grids may be run to collect detailed sounding data over a little-known area or to verify the existence or extent of some doubtful feature, such as a reported shoal or bank. Sounding grids are run with the major number of sounding lines parallel and at least two lines normal (perpendicular) to the major development. The latter are needed to verify the main-line soundings. Wherever possible, the main sounding lines are run normal to the general bottom contours. If sea conditions are unfavorable, the track pattern may be modified to avoid excessive pounding, provided the same area is covered with lines of the specified distance apart. Unless otherwise specified, sounding grids in oceanic areas are usually run with lines five miles apart. Soundings are entered every minute in a separate log used only for the grids. Echograms are time marked every 30 minutes.

5–10 **Using Two or More Ships on Sounding Grids.**—When 2 or more ships are employed in developing a special sounding grid, the following method is used. One ship maintains navigational control. All ships record radar ranges and pelorus bearings every 30 minutes. Soundings are entered in separate logs used only for the grids. Navigational fixes are obtained as often as feasible. DRT tracks are maintained with half-hourly time notations; all changes of courses and speeds, and information pertaining to resetting shall be noted. A typical 2-ship sounding grid pattern is shown in figure 5–6.

5–11 **Discovering Uncharted Features.**—During the course of oceanographic cruises, uncharted bottom features such as seamounts,

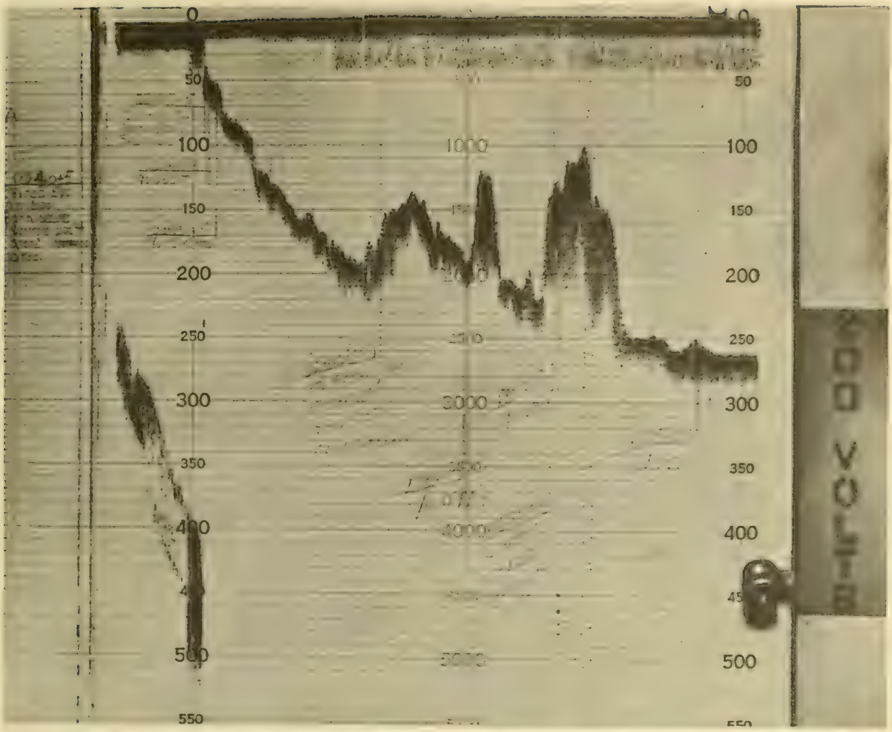

Figure 5–4. **Sample echogram from AN/UQN–1 echo sounder.**

Page No. ____

Time h (1)	m (2)	s (3)	s (4)	Pos. No. (5)	Final Sdg. (6)	Obs. Sdg. (7)	Scaled Sdg. (8)	Corrections in Feet: Total (9)	Zero (10)	Obs. Tide (11)	Freq. (12)	Draft (13)	Pred. Tide (14)	Field Red. Sdg. (15)	Course ~~and Speed~~ °T (16)	Readings and Signals (17)	(18)	(19)	Notes (20)
07	55	00	00			2785									085				S 12 KTS
08	00	15	20			2780													0800 POSIT.
08	05	30	40			2775													ϕ45-20.4N-λ15°56.0W
08	10	45	00			2770													
08	15	00	20			2760													0815 OPERATING #2
08	20	15	40			2740													RECORDER
08	25	30	00			2720													
08	30	45	20			2700													0830 STOPPED
08	35	00	40			2690													OPERATING #1 RECORDER
08	40	15	00			2690													
08	45	30	20			2685													
08	50	45	40			2650													
08	55	00	00			2600													
09	00	15	20			2575									080				C/C 080(T) 0900
09	05	30	40			2590													
09	10	45	00			2600													
09	15	00	20			2605													C/S 14 KNTS 0915
09	20	15	40			2620													
09	25	30	00			2635													
09	30	45	20			2645													BROWN RELIEVED
09	35	00	40			2670													WATCH 0930
09	40	15	00			2685													
09	45	30	20			2690													
09	50	45	40			2695													
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Figure 5–5. Sounding logbook page.

ridges, trenches, etc., occasionally are discovered. Whenever such unusual phenomena are encountered, it is highly desirable that sounding grids be run to further develop the immediate region.

5–12 Preparation and Shipping of Sounding Data.—Upon completion of a cruise, all smooth track plotting sheets, DRT tracks, and the navigator's work sheets must be sent to the Hydrographic Office for final inspection and incorporation onto compilation sheets. Under no circumstances are these sheets to be folded. They must be rolled or kept flat. These sheets, along with all sounding logs and echograms, must be packed in suitable shipping cases. The ship's name and number, and the cruise name and number, must be marked on the case. The case should be marked "HANDLE WITH CARE" and addressed to:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5670

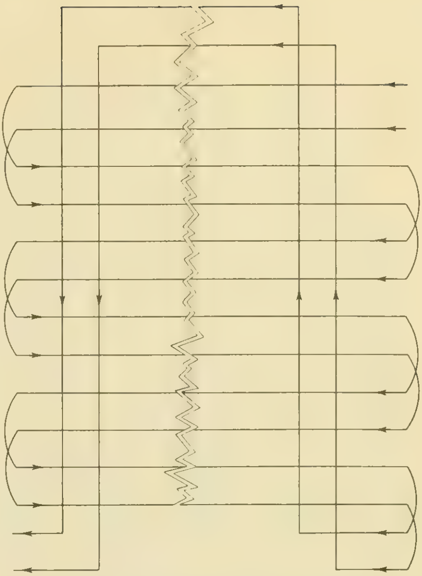


Figure 5–6. A two-ship oceanic sounding grid.

CHAPTER 6

OBTAINING BOTTOM SEDIMENT SAMPLES

6–1 GENERAL REMARKS.—Marine sedimentation embraces that phase of oceanography which is related to the deposition, composition, and classification of organic and inorganic material found on the ocean floor. Various sampling devices are utilized to obtain bottom sediments from a particular locality under investigation. Once obtained, samples are packed and shipped to a sedimentation laboratory to be analyzed and classified.

6–2 Analysis.—Analysis of marine sediments generally includes the determination of size, shape, and percentage of component particles; identification of minerals and ratio of light to heavy minerals; wet density; pH; and calcium carbonate content. Biological and ecological studies emphasize the animal population as well as the environmental factors determined by temperature, depth, type of sediment, and geographic location.

6–3 Classification.—Classification of bottom sediments is based on composition. Hence, one may have samples composed of terrigenous material, subaerial or submarine volcanic material, organic matter, inorganic material, and extraterrestrial matter. Size of the component materials may range in extremes and is used as a further, more detailed classification criteria. Bottom samples composed of volcanic materials for example, may range in size from very fine ash to pebble and cobbles. Very often bottom samples contain an aggregation of sizes so that a combination of volcanic ash and other material of pebble size is possible.

6–4 Charts.—Bottom sediment charts are prepared from thousands of reported classifications and collected samples. These charts illustrate the nature of the sea bottom in coastal and oceanic areas.

6–5 Collecting Samples.—Collecting marine sediments involves the use of a variety of bottom samplers which fall into three basic categories: Coring tubes, snappers, and dredges. Selection and use of the proper instrument is a function of the nature of the investigation, the character of the bottom, the depth of the water, and the availability of the proper wire, winch, boom, crane, or A-frame required for the operation.

6–6 GENERAL PROCEDURES FOR CORING OPERATIONS.—Coring activities aboard Navy survey ships are guided by procedures intended to facilitate operations, insure a maximum degree of efficiency, and allow for a proper distribution of working time. Survey instructions provide for a coring program as part of the oceanographic survey and take into account the nature of the investigation, type of corer to be used, location of the desired cores, time allowed for coring, and disposition of the core samples (fig. 6–1).

Upon reaching the station area, prior to lowering any coring gear over the side, determine the sonic depth of the ship's position and note these on oceanographic log sheet M. This log sheet is described in chapter 14. Duration of a coring operation is largely dependent on the depth of the bottom and the speed at which the wire is payed out. Deep-sea cores taken with a Phleger corer and an oceanographic winch of the type used aboard Navy survey ships, take about 1 to 2 hours. Those made with a Ewing piston corer and a deep-sea anchoring winch may take 3 to 5 hours to complete. It must be noted that these are average times; each coring operation will differ.

6–7 HOW TO DETERMINE THE AMOUNT OF WIRE TO PAY OUT FROM THE WIRE ANGLE.—Frequently during bottom sampling operations, high wire angles occur as a result of the ship's drift. It is necessary to know how much wire to pay out so that the instrument will reach the bottom without laying an excessive amount of wire. When wire is layed on the bottom, it usually kinks so badly that the kinked portion has to be cut off before the wire can be used again. By using the cosine of the surface wire angle and the sonic or charted depth of the area, the approximate amount of wire needed can be estimated. Figure 6–2 illustrates the problem. This method of estimating the amount of wire to

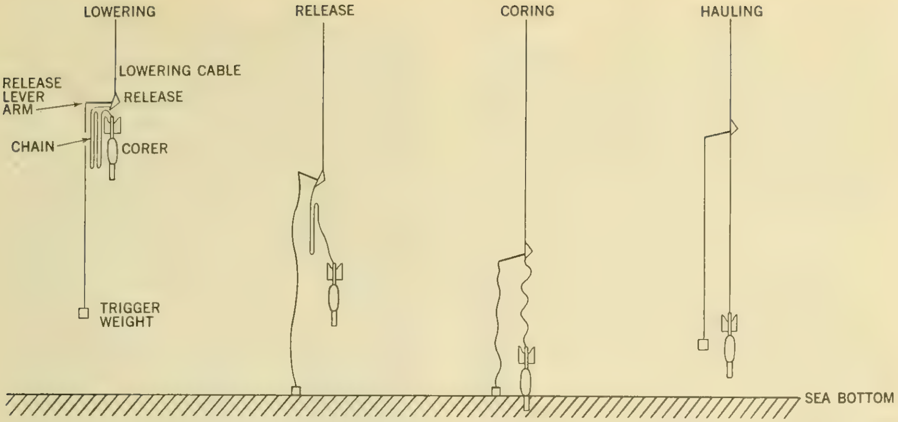
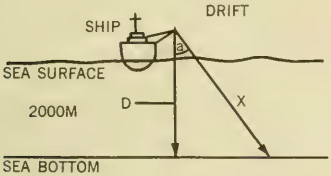


Figure 6–1. Principle of operation of free-fall corers.



2000M = D = DEPTH OF WATER
30° = a = SURFACE WIRE ANGLE
.866 = COSINE OF SURFACE WIRE ANGLE a
X = ESTIMATED AMOUNT OF WIRE TO PAY OUT

$$\cos a = \frac{D}{X};\ \cos 30° = \frac{2000}{X};\ .866 = \frac{2000}{X};\ X = 2309\text{M}$$

Figure 6–2. Determining the amount of wire to pay out from known wire angle.

be payed out is, at best, an approximation. It does not tell exactly how much wire is required to reach bottom but affords a minimum and maximum working range. The working range is the difference between the least and greatest amount of wire to be payed out. The larger the wire angle the larger the difference will be; conversely, the smaller the angle the smaller the difference. In the example above, the working range is 309 meters. Proper use of this method requires close attention as the apparatus nears the sonic or charted depth. Erroneous estimates may result from incorrectly charted depths, errors in position, or drift of the ship to shallower water while on station. Hence, caution must be exercised before, during, and after the estimated wire extent is reached. In practice, the bottom generally is contacted after the minimum estimate is reached.

6–8 CORING DEVICES.—Coring devices are essentially steel tubes that are driven into the ocean floor by gravity penetration. A typical coring device consists of interchangeable core tubes, a main body of streamlined lead weights, and a tailfin assembly. The latter is instrumental in directing the corer in a vertical line normal to the bottom. The main body, lead weights, and tailfin assembly are referred to as the mainweight.

6–9 Length of Cores.—The amount of sediment collected by coring devices is dependent upon the length of the corer, size of mainweight, and penetrability of the bottom. The minimum length of a core will be governed by the general conditions of a given area. In areas of predominantly rocky or hard bottoms, it will not be possible to obtain a core of any great length at any lowering. In such instances it is well to make sure that failure to obtain a core is due to the impenetrability of the bottom rather than accidental blocking of the corer by stray shell or stone. In other areas the bottom may consist of such loose sand or volcanic ash that the core catcher will not retain the sample. When these conditions exist it is best to use some other type of bot-

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tom sampling instrument such as a snapper or dredge.

6–10 Corers Used by the Navy.—Aboard the survey ships and associated vessels of the U. S. Navy Hydrographic Office, three types of coring devices are currently in use: The Phleger corer, the Kullenberg piston corer, and the Ewing piston corer. Detailed descriptions of these coring devices are given in the following pages (fig. 6–3).

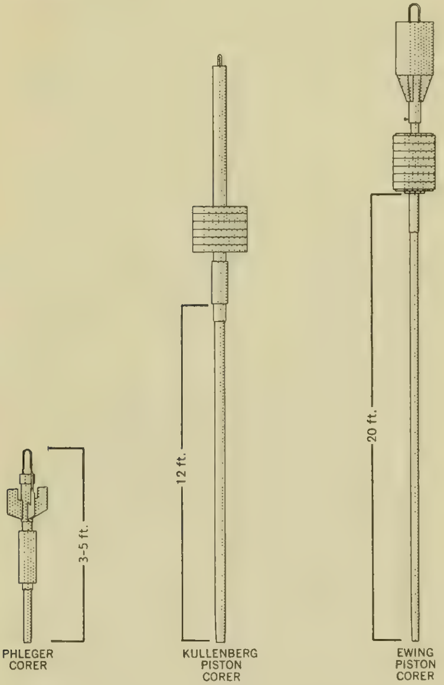


Figure 6–3. Coring devices - Phleger, Kullenberg, and Ewing.

6–11 INSTRUCTIONS FOR OPERATING THE PHLEGER CORER.—Designed to obtain cores up to about 4 feet in length, the Phleger corer is utilized in cases where only the upper layers of the sea bottom are to be analyzed. Because of its small size and weight, the Phleger corer is widely used. It may be operated from an oceanographic winch, and has been used successfully from a bathythermograph winch in depths of less than 100 fathoms. Coring tubes 12 and 36 inches in length, a main body weight, an upper tube, check valve, and tailfin assembly account for an overall length of 3 to 5 feet for the corer (fig. 6–4). The upper tube, main body weight, check valve, and tailfin assembly comprise the mainweight. The check valve, located at the tailfin, is to prevent the flow of water into the upper section and consequent washing out of the core sample while hoisting the corer.

6–12 Equipment Needed to Operate the Phleger Corer.—In addition to the mainweight and coring tube mentioned above, the following components are needed to operate the Phleger corer:

1. A plastic liner, which runs the entire length of the inside of the corer. The liner is used to retain and store the core.
2. A core catcher, whose interleaved springs fit inside the lower end of the liner. The core catcher springs will allow sediment material to enter but not leave the coring tube.
3. A cutting edge, which holds the core catcher and liner in the coring tube and has a sharpened rim for penetrating the bottom. It is attached to the coring tube with a bayonet-type fitting.
4. A release mechanism, from which the corer is suspended and released for free fall to the bottom.
5. A trigger line, used to suspend the trigger weight from the arm of the release mechanism. This line has a suspended length of 15 feet. Any light line, such as cotton heaving line or 9-thread manila, may be used.
6. A trigger weight, which is suspended from the end of the trigger line. It prevents the release mechanism from dropping the corer until the weight hits the bottom. The trigger weight is usually a 14-pound sounding lead.
7. A 20-foot length of galvanized steel chain, which is attached to the release mechanism and corer to retrieve the corer after the free fall. Chain size: 3/16-inch BBB type. Two shackles are needed to attach the chain.

6–13 Spare Parts Needed for the Phleger Corer.—The following spare parts are needed to operate the Phleger corer:

1. Coring tube. One extra.
2. Core catcher. Four extra.
3. Cutting edge. Four extra.
4. Plastic liner. Enough lengths of 1½-inch (outside diameter) plastic liner as needed to conduct the coring program for a survey cruise. One liner is needed for each sample.
5. Rubber stoppers or plastic caps (enough rubber stoppers, size No. 7, as needed to conduct the coring program for a survey cruise).

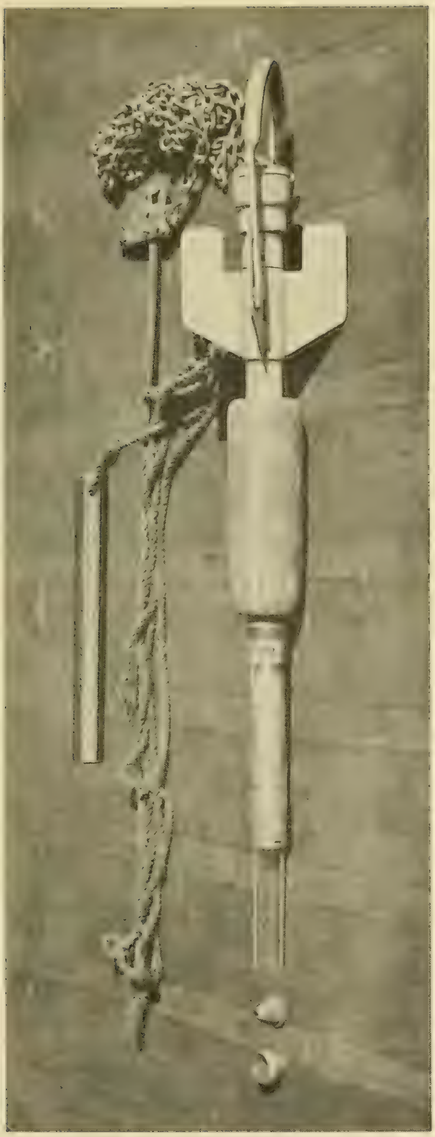


Figure 6–4. Phleger corer assembly.

Two stoppers or plastic caps are used for each sample.

6. Bottom sample jars (enough sample jars, 4- to 8-ounce ointment jars are satisfactory, as needed to conduct the coring program for a survey cruise). One jar is needed for each sample. The sediment retained by the core catcher and nosepiece is stored in a sample jar.

7. Glass wool, used to pack the unfilled portion of the plastic liners above the core samples.

6–14 Tools Needed to Operate the Phleger Corer.—The Phleger corer is easy to assemble and operate and usually requires few tools. A pair of eight-inch combination pliers, a pipe wrench, and a small saw or sharp knife to cut the plastic liner is all that is needed for most operations.

6–15 Assembling the Phleger Corer for Operation.—The first step in assembling the Phleger corer for operation is to screw the threaded end of the coring tube into the mainweight. Make sure that the check valve is operating properly as improper operation may be the cause of short samples or the washing out of the entire core. Measure the length of the core-catcher ring and that part of the cutting edge which fits into the coring tube. Next insert a length of plastic liner into the corer as far as it will go and scratch a mark on it flush with the end of the coring tube. Pull the liner out a distance exactly equal to the length measured (probably about one-half inch) and cut or saw the plastic liner flush with the end of the coring tube. If the liner is too long, it will not be possible to seat the cutting edge in the bayonet grooves. If it is too short, there will be play in the liner with resultant loss of the bottom sample when the liner is removed after lowering. Now, reinsert the liner and insert the core catcher and cutting edge. Make sure that there is a tight fit of the bayonet to prevent loss of the cutting edge. If it is loose, it is advisable to wedge the groove with a small chip of wood to prevent turning. The corer is now ready to be attached to the release mechanism.

6–16 Rigging the Release Mechanism.—Secure the trigger line and weight to the end of the releasing arm. Next shackle the free fall chain to the bottom shackle on the release mechanism and to the bail on the mainweight of the corer. Shackle the top of the release mechanism to the lowering wire. Insert the bail of the corer into the slot in the release mechanism so the release arm is able to support the full weight of the corer. As soon as this is done it is *important to insert the safety pin* in the release arm before putting the gear over the side. Gather the chain in several small coils and fasten lightly with sail thread to the bail. This will prevent the chain from fouling the corer during the free fall. The fastening should be light enough to break readily when the release mechanism is tripped at the bottom but strong enough not to part while lowering.

6–17 Rigging for Lowering.—Suspend the coring assembly over the side. Check to see that the trigger weight and line is hanging properly and not fouled, that the corer is hanging properly from the release mechanism, and that the chain is not fouled on the fins. The assembly is now ready for lowering. *Important—now remove the safety pin* from the release arm. Lower the assembly to the water's edge and set the meter wheel to zero. Commence lowering.

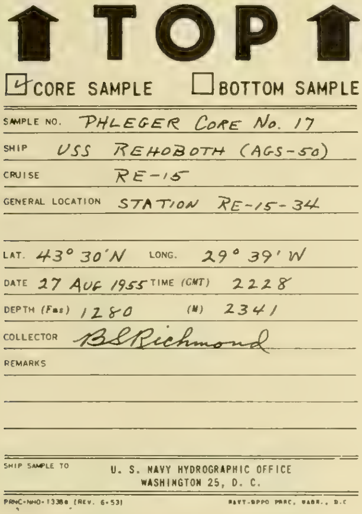
6–18 Obtaining the Core.—Lowering should be accomplished as quickly as possible since greatest penetration will occur when free fall conditions are approximated. In order to ascertain when the corer has reached bottom, a deep-water bottom-signaling device, the ball breaker, may be used. This device is described in detail in section 6–56. In shallow waters, a simple spring scale and block may be used, as shown in figure 6–5. The block is placed on the winch wire; the spring end is secured to a rigid part of the ship, such as a rail stanchion. As the corer is lowered the wire exerts a steady pressure on the block and spring. An indication that the bottom has been reached, or the release mechanism tripped, will be observed when tension on the spring is relaxed owing to wire slack. This method is satisfactory in shallow coastal waters and has been used successfully in depths as great as 3,000 meters. In very deep waters, the weight of the corer is often a small fraction of the total weight of the lowering wire and of variable loads caused by the roll of the ship; hence, no apparent release in tension may be observed when bottom is reached. The instant that the scale indicates the corer is on the bottom the winch must be stopped. Failure to do so will result in laying wire on the bottom, thereby kinking it badly.

6–19 Retrieving the Core.—When the winch has stopped, note the amount of wire out. Commence hauling in immediately. Do not increase the winch speed until the coring gear is well clear of the bottom. Caution should be exercised when the corer approaches the surface. When bringing the corer aboard, it is important to always keep it in a vertical or near vertical position. Never allow the corer to be inverted as this will damage the sample.

Figure 6–5. A spring scale dynamometer.

6–20 Removing the Core Sample and Recording the Core Data.—As soon as the corer is brought aboard, measure the length of sediment visible on the outside of the instrument and record this in the Penetration column of the M-sheet. Next, carefully remove the cutting edge and core catcher and insert a rubber stopper into the bottom of the liner or cover the end with a plastic cap. Put any sediment retained by the cutting edge and core catcher in a sample jar. Now, holding the corer in a vertical position, remove the liner. If the liner is too tight to slip out easily, unscrew the core tube from the mainweight and remove both tube and liner from the mainweight. Then slip the liner free of the core tube. If the liner is not completely filled with sediment, fill the empty portion with glass wool. This material does not have absorbent qualities nor will it react chemically with the sample. Packing will prevent disturbance of the sample during storing and shipping. Insert a rubber stopper in the top of the liner or cover with a pastic cap, tape both ends securely, and seal with melted wax. The latter will insure retention of the original water content. Measure the length of the core sample and record this on the M-sheet, along with a description of the core.

6–21 The Core Label.—A core label, shown in figure 6–6, is attached to the core sample. The label lists all pertinent information relating to the core and is to be filled out immediately after obtaining the core. A feature of the label is that when it is properly attached the top of the core is indicated by the word "top" and two flanking arrows. Proper identification will prevent loss of cores, effort, and time. Tape the label securely to the liner and make sure that the sample jar is properly marked with the same identifying serial number as the core.



TOP

☑ CORE SAMPLE ☐ BOTTOM SAMPLE

SAMPLE NO. PHLEGER CORE No. 17

SHIP USS REHOBOTH (AGS-50)

CRUISE RE-15

GENERAL LOCATION STATION RE-15-34

LAT. 43° 30′N LONG. 29° 39′ W

DATE 27 AUG 1955 TIME (GMT) 2228

DEPTH (Fms) 1280 (M) 2341

COLLECTOR B L Richmond

REMARKS

SHIP SAMPLE TO U. S. NAVY HYDROGRAPHIC OFFICE WASHINGTON 25, D. C.

PRNC-NHO-13380 (REV. 6-53) NAVY-DPPO PRNC, WASH., D.C.

Figure 6–6. Sample core label.

6–22 Securing the Corer.—All parts of the Phleger corer must be washed after each lowering. This cannot be too strongly emphasized. The cutting edge, core catcher, coring tube, and mainweight must be well rinsed to remove all evidence of bottom material from a previous coring operation. After all coring activities are completed, the corer is prepared for packing. This involves washing down the corer to remove all sediment. After drying, a light coat of machine oil is applied to all parts. A wooden shipping case is furnished as part of the core assembly and accommodates the corer, release mechanism, trigger line, trigger weight, and free fall chain. Smaller parts, such as core catchers and cutting edges, are also stored in the case.

6–23 Maintenance of the Phleger Corer.—In general, the corer requires very little maintenance. However, the cutting edge may be dented should the corer hit hard or rocky bottom. If not badly deformed the cutting edge may be hammered and filed back into shape and used again. Core-catcher springs must be watched for free play of action. Inasmuch as the spring leaves are delicate, care should be taken in the handling and packing of core catchers. Needless to say, any damage to this important unit of the corer will result in unwarranted loss of samples. Most corers used by the Hydrographic Office are made of stainless steel. However, some corers are made of ordinary steel and must be wire brushed and painted periodically to minimize corrosion effects. The interior must be wire brushed and coated with a thin film of oil to prevent the pitting and rusting which obstructs entrance of the plastic liners.

6–24 Packing, Storing, and Shipping of Phleger Cores.—To prevent disturbance and damage of the core, the sealed liner should be stored in an upright position. For this purpose a special shipping case should be provided. This case should be wooden, compartmented to hold a number of cores in an upright position, and provided with a screw-fastened top. The case must be plainly marked *HANDLE WITH CARE* and *THIS END UP* and is to be packed, stored, and shipped in an upright position at all times. It should be marked with the ship's name and number and the cruise name and number. Cases to be shipped to the Hydrographic Office are to be addressed as follows:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430

6–25 PRINCIPLE OF OPERATION OF PISTON CORERS.—Interest in obtaining undisturbed cores has resulted in a number of developments directed toward improving ocean bottom coring samplers. Most notable and successful has been the piston corer, of which the Kullenberg and Ewing corers are representative. Inasmuch as the principle of operation is identical for both types the following paragraph applies to both. However, detailed descriptions for each instrument will be treated separately.

6–26 The Piston.—A closely fitting piston attached to the end of the lowering cable is installed inside the coring tube just above the core catcher, as shown in figure 6–7. When the coring tube is driven into the ocean floor, friction will exercise a downward pull on the core sample which is opposed by the hydrostatic pressure on the ocean bottom. The hydrostatic pressure will not allow a vacuum to be created between the piston and the top of the core so long as the frictional forces do not exceed the hydrostatic pressure. As the coring tube penetrates the sea floor, the friction created will always cause the pressure immediately below the piston to be diminished as compared with the hydrostatic pressure. The difference in pressure between the mouth of the coring

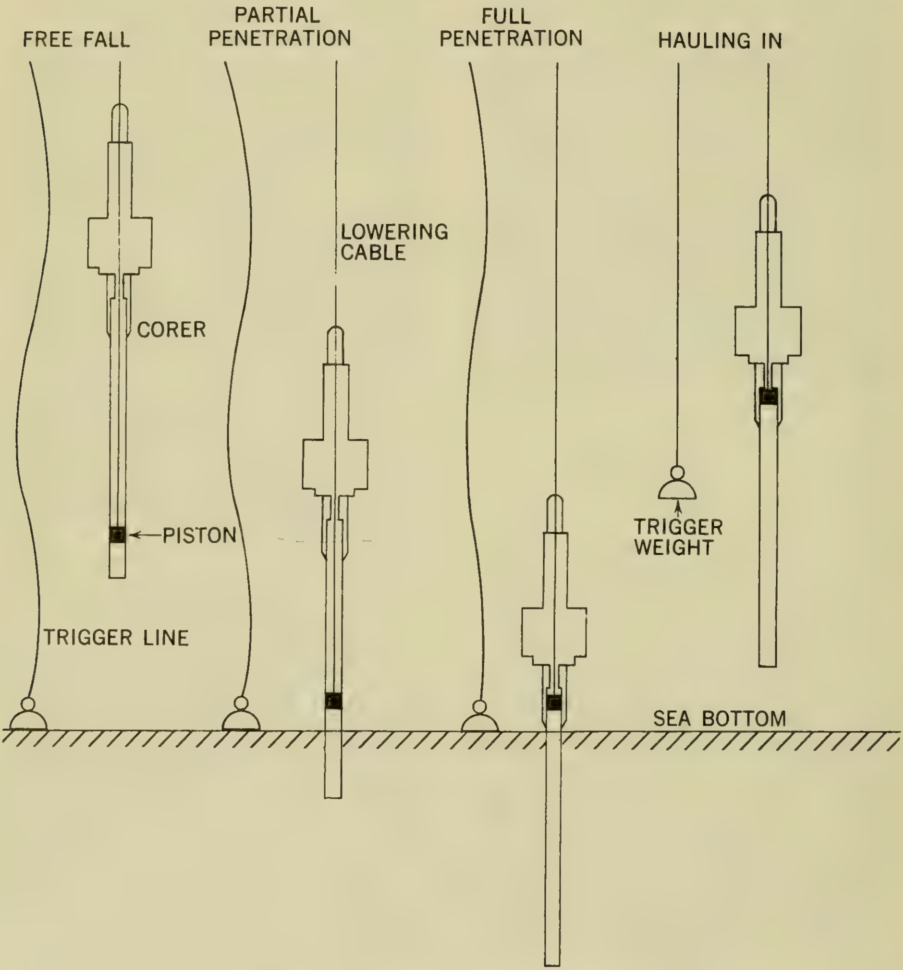


Figure 6–7. Principle of operation of piston corers.

tube and the top of the core will automatically balance the frictional resistance to the core resulting in a true representation of the bottom sediment column *in situ*. The piston, in effect, provides a suction which overcomes the frictional forces acting between the sediment sample and the inside wall of the coring tube.

6–27 INSTRUCTIONS FOR OPERATING THE KULLENBERG PISTON CORER.—Originally developed to obtain deep sea cores of 65 feet or more, the Kullenberg piston core is currently employed by the Hydrographic Office in obtaining cores in shallow coastal areas. The modified Hydrographic Office model of the Kullenberg piston corer differs from the original not only in the assembly of the corer but also in the manner in which it is employed. Throughout the remainder of the chapter, all references to the Kullenberg piston corer will be understood to mean the model developed by the Hydrographic Office and not the original. Like the Phleger corer, the Kullenberg uses a plastic liner, but unlike the Phleger and Ewing corers, it does not have a tailfin assembly.

6–28 Operational Limitations.—Owing to its size and weight the Kullenberg corer has operational limitations which best suit it to vessels equipped with a boom, heavy winch, and wire. The complete assembly of corer and release gear weighs about 400 pounds. While this equipment can be operated from an oceanographic winch using ⁵⁄₃₂-inch wire, its use is not recommended in depths greater than 1,000 fathoms nor is the free-fall release mechanism recommended for use with wire this light. When operated aboard a ship equipped with an A-frame, certain precautionary steps must be taken which are discussed in section 6–34.

6–29 Equipment Needed to Operate the Kullenberg Piston Corer.—Three wooden cases are supplied with each corer. The cases in each kit contain the following:

Case No. 1:
- 8 coring tubes, 4 cutting edges, and 4 core catchers.

Case No. 2:
- 4 50-pound cast lead weights.

Case No. 3:
- 2 50-pound cast lead weights.
- 1 main body tube and collar.
- 1 piston with Fiege and swivel fittings.
- 2 trigger weights.
- 1 release mechanism.

The corer itself consists of the following parts:

1. The mainweight, consisting of a main body tube and several cast lead drive weights, usually 4 to 6 in number. These leads weigh 50 pounds each and are removable.
2. The coring tube, which comes in 2 sizes: 5½ and 11½ feet in length.

In addition to the above, the following components are needed to operate the corer:

1. A plastic liner, with a 2-inch outside diameter. The length of the liner is 5 feet 9¾ inches when a 5½-foot coring tube is used, and 11 feet 9¾ inches when an 11½-foot coring tube is used.
2. A piston, with swivel fitting that attaches to the end of the lowering wire. The piston is equipped with a single leather cup washer.
3. A core catcher, whose interleaved springs fit inside the lower end of the liner. The core-catcher springs will allow sediment to enter but not leave the coring tube.
4. A cutting edge, which holds the core catcher and liner in the coring tube and has a sharpened cutting edge for penetrating the bottom. It is attached to the coring tube with one-fourth-inch Allen head setscrews.
5. A release mechanism, from which the corer is suspended and which releases it for free fall to the bottom.
6. A trigger line, used to suspend the trigger weight from the arm of the release mechanism. It should have a suspended length of 17 feet for the 5½-foot coring tube and 23 feet for the 11½-foot tube.
7. A trigger weight, suspended from the end of the trigger line, which prevents the release mechanism from dropping the corer until the weight hits the bottom. The trigger weight is usually a 25-pound sound lead.

6–30 Spare Parts Needed for the Kullenberg Piston Corer.—The following spare parts are needed to operate the Kullenberg piston corer:

1. Piston and swivel. One extra.
2. Piston leather cup washers. Four extra.
3. Allen-head setscrews, one-fourth inch. Two dozen extra.
4. Core catcher. Four extra.
5. Cutting edge. Four extra.
6. Plastic liner, 2-inch outside diameter. Enough lengths of liners as needed to conduct the coring program for a survey cruise. One liner is needed for each sample.
7. Rubber stoppers or plastic caps (enough rubber stoppers, size No. 10, or plastic caps as needed to conduct the coring program for a survey cruise). Two stoppers or caps are needed for each sample.
8. Bottom sample jars (enough sample jars, such as ointment or pint mason jars, as

needed to conduct the coring program for a survey cruise). One jar is needed for each sample. The sediment retained by the core catcher and cutting edge is stored in a sample jar.

9. Glass wool, used to pack the unfilled portion of the plastic liner above the core sample.

10. Shackles, used to attach the trigger line to the release arm.

6–31 Tools Needed to Operate the Kullenberg Piston Corer.—In order to assemble and operate the Kullenberg piston corer, the following tools are needed:

1. Pliers, 8-inch combination.
2. Pipe wrench.
3. Adjustable end wrench.
4. Allen wrench, one-fourth inch.
5. Screwdriver.
6. Small saw or sharp knife, for cutting liners.
7. Wire brush, circular, with long handle. A boiler-tube-type wire brush, with a metal handle, for cleaning the inside of the coring tube is recommended.
8. Steel wool.
9. Oil can.
10. Cleaning rags.

6–32 Assembling the Kullenberg Piston Corer for Operation.—The mainweight consists of 4 to 6 cast lead drive weights which are placed in position on the upper end of the main body tube. These weights weigh 50 pounds each and are held in place by a cap or cable sling. A coring tube is attached to the mainweight by means of three Allen-head setscrews. The plastic liner is next inserted into the coring tube until it is flush with the piston stop collar in the mainweight. Scratch a mark on the liner, flush with the end of the coring tube, and pull the liner out a distance of one-fourth inch to allow for the seating of the core catcher and cutting edge. Cut the liner to this length. If the liner is too long, it will not be possible to seat the core catcher and cutting edge. If it is too short, there may be vertical play between the liner and coring tube resulting in possible loss of some of the bottom sample when removing the liner. The length of the liner is 5 feet 9¾ inches when a 5½-foot coring tube is used and 11 feet 9¾ inches when an 11½-foot coring tube is used.

Now feed the lowering cable through the upper end of the mainweight and the liner until it extends out the lower end of the coring tube. Attach the cable to the swivel fitting on the piston. Insert the piston into the coring tube about 3 inches above the end of the tube. It must just clear the core catcher. Insert the core catcher and cutting edge and secure the latter with Allen-head setscrews.

6–33 Rigging the Release Mechanism.—Insert the bail of the corer into the slot in the release mechanism so the release arm is able to support the full weight of the corer. As soon as this is done, it is *important to insert the safety pin.* Clamp the lowering wire on the side of the releasing mechanism, leaving from 4 to 6 feet of slack in the wire depending on the amount of free fall desired. This bight of wire between the top of the corer and the clamp of the release mechanism is taped in order to prevent kinking. Fasten the trigger weight line to the end of the release arm with an overall length equal to the total length of the coring device plus the amount of slack in the wire between the release mechanism and the top of the corer. For a free fall drop of 4 to 6 feet, the length of the trigger line and weight will be 17 feet if using a 5½-foot coring tube, and 23 feet if an 11½-foot coring tube is used.

6–34 Rigging for Lowering.—The methods for suspending the Kullenberg piston corer over the side will vary with the type of ship being used for the operation. On a ship equipped with a large enough boom, the corer may be hoisted until it is entirely supported by the lowering cable before swinging the gear outboard. If an A-frame is used, it is suggested that a cradle be suspended outside the lifelines in which the corer can be secured and rigged while at sea. From such a cradle the corer can be lowered to a vertical position from the A-frame with handling lines. After the corer is suspended over the side in a vertical position from the lowering wire, check to see that the trigger weight and line is hanging properly and the corer is hanging correctly from the release mechanism. *Important—now remove the safety pin* from the release arm. Lower the assembly to the water's edge and set the meter wheel to zero. Commence lowering.

6–35 Obtaining the Core.—The method for obtaining the core is similar to that outlined in section 6–18 for the Phleger corer. However, a heavier spring scale must be used than that used for the Phleger. In shallow waters and without a spring scale, contact with the bottom may be detected fairly reliably by a slack in the wire and a jerk in the meter wheel. For deep-water operations the use of a dynamometer is recommended. The type of dynamometer used on Navy survey ships is a device with two fixed sheaves at a given distance; between them is a movable sheave upon which the lowering wire exerts a pressure. The movable sheave is attached to a coil spring and variations in wire tension are registered on a gage. A metering sheave and counter are also attached to the dynamometer as shown in figure 6–8.

Figure 6–8. Deep-sea dynamometer on a U. S. Navy oceanographic survey ship.

6–36 Retrieving the Core.—The instant the tripping weight hits the bottom the winch must be stopped to immobilize the piston in the coring tube. The upward movement of the release arm, caused by the trigger weight striking the bottom, frees the corer from the release mechanism allowing it to penetrate the sea bottom. The falling corer will take up the slack in the wire and stop the downward movement of the piston just above the bottom. The corer itself will continue on past the piston into the bottom. To haul the corer free of the bottom, the same method is used as given in section 6–19 for the Phleger corer. During hoisting, the piston supports the entire weight of the corer.

When the release mechanism is at deck working level bring in the trigger weight and remove the release mechanism from the wire. Now hoist the corer to the deck and bring aboard. The Kullenberg will usually have to be laid on deck or in a cradle to remove the sample. Care must be taken not to allow the nose end of the coring tube to be raised higher than the upper end. Keep the nose down at all times.

6–37 Removing the Core Sample and Recording the Core Data.—As soon as the corer is on deck, measure the length of sediment visible on the outside of the instrument and record this in the Penetration column of the M-sheet. This log sheet is described in chapter 14. Next, carefully remove the cutting edge and core catcher and insert a rubber stopper into the bottom of the liner or cover with a plastic cap. Put any sediment retained by the cutting edge and core catcher in a sample jar. Remove the setscrews from the upper end of the coring tube, and carefully withdraw the tube and liner from the mainweight. Extract the liner from the coring tube. If the liner is not completely filled to the top with sediment, fill the empty portion with glass wool and insert a rubber stopper firmly into the top or cover with a plastic cap. Tape both ends and seal with wax. Measure the length of the core sample and record this on the M-sheet, along with a description of the core. Fill out and attach a core label in the same manner as given in section 6–21 for the Phleger corer.

6–38 Securing the Corer.—After each lowering, all parts of the Kullenberg piston corer must be washed. The cutting edge, core catcher, coring tube, piston, and mainweight must be well rinsed to remove all evidence of bottom material from a previous coring operation. All parts are then dried and a light coating of machine oil is applied to them with particular emphasis to the inner walls of the mainweight and coring tube.

6–39 Maintenance of the Kullenberg Piston Corer.—Because of its sturdy construction, the Kullenberg piston corer generally requires little maintenance. However, the cutting edge may chip or be dented should the corer hit hard or rocky bottom. If not too badly damaged, the cutting edge may be hammered and filed back into shape. Core catcher springs must be watched for free play of action. Usually these springs can be reshaped quite easily. As these springs are delicate, care in the handling and packing of core catchers must be taken. Needless to say, damage to this important unit of the corer will result in unwarranted loss of samples. The interior of the coring tube and mainweight should be wire brushed, wiped clean with rags, and oiled after each lowering. Rusting and pitting will prevent entrance of the liner. When necessary, the exterior of the corer should be wire brushed and a protective coat of red lead applied.

6–40 Packing, Storing, and Shipping of Kullenberg Cores.—To prevent disturbance and damage of the Kullenberg core the sealed liner should be stored in an upright position. For this purpose a special shipping case should be provided. This case should be wooden, compartmented to hold a number of short cores in an upright position, and provided with a screw-fastened top. The case must be plainly marked "Handle With Care" and "This End Up" and must be packed, stored, and shipped in an upright position at all times. It should be marked with the ship's name and number and the cruise name and number. Cases to be shipped to the Hydrographic Office should be addressed as follows:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430

6–41 INSTRUCTIONS FOR OPERATING THE EWING PISTON CORER.—The Ewing piston corer is designed for use where bigger and longer cores are desired than those obtainable by either the Phleger or Kullenberg corers. It is employed when a detailed study of sediments below the surface of the ocean floor is desired. It is the largest corer currently in use by the Hydrographic Office, weighing about 1,200 pounds. The coring tubes are approximately 20 feet in length and 1, 2, or 3 lengths may be coupled together by connecting sleeves to obtain cores up to about 60 feet in length. Unlike the Phleger and Kullenberg corers, the Ewing does not use a plastic liner. Core samples are stored in the coring tubes in which they were obtained, or they are extruded onto a heavy waxed paper provided for wrapping, and stored in a wooden core box.

6–42 Operational Limitations.—Due to its size and weight, the Ewing piston corer is operationally limited to ships equipped with a large winch carrying wire of at least ½-inch diameter, a dynamometer, a boom or crane capable of supporting about 5 tons, and enough deck space to assemble the corer.

6–43 Equipment Needed to Operate the Ewing Piston Corer.—The corer itself consists of the following parts:

1. The mainweight, which is made up of a main body tube, a tailfin assembly, and several cast lead drive weights, usually 8 or 10 in number. These leads weigh about 100 pounds each and are secured above and below by heavy steel disks which are bolted to the main body tube. There is a bail and ring at the top of the tailfin assembly for hooking into the release mechanism. The overall length of the mainweight is about 5 feet.
2. The coring tube, which is a seamless steel tubing of 2¾-inch outside diameter and 2½-inch inside diameter, and 20 feet long. Each end of the tube is drilled and tapped to take about 15 stainless steel bolts. Each end is covered with a protective sheet-metal cap which is used to retain the samples when stored in the tube.

In addition to the above, the following components are needed to operate the corer:

1. A piston, with a Fiege fitting for attaching to the ½-inch lowering wire. It is made of brass and has four leather washers and a check valve. The latter permits flow of water upward through the tube during free fall of the corer.
2. A piston stop collar, which is movable and is attached to the wire just back of the piston. This U-slotted stainless steel collar consists of two disks that are held together with screws. It prevents the piston from passing through the main body tube and supports the weight of the corer after free fall.
3. A core catcher, whose interleaved springs fit inside the lower end of the coring tube. The collar of the core catcher fits flush with the end of the tube and inside the cutting edge.
4. A cutting edge, which holds the core catcher in place and has a sharpened rim for penetrating the bottom. It fits over the end of the coring tube and is attached with several stainless steel bolts.
5. A connector sleeve, which fits over the end of the coring tube and is used when attaching the coring tube to the mainweight and when two lengths of tube are fastened together. It is bolted to the tubing with stainless steel bolts.
6. Stainless-steel bolts, which are used to attach the coring tubes, connector sleeves, and nosepiece. These small bolts are specially made and have shanks whose lengths are equal to the thickness of the coring tube wall. They must not protrude into the inside of the tube so as to obstruct passage of the piston or disturb the sediment structure. To assemble the corer with a single length of tube, about 30 bolts are needed.
7. A wire-clamp release mechanism, from which the corer is suspended and which releases it for free fall to the bottom.
8. A trigger line, used to suspend the trigger weight from the arm of the release mechanism. Manila line strong enough to carry an 80-pound trigger weight is needed. It must be long enough to suspend the trigger weight 12 to 14 feet below the nosepiece on the coring tube.
9. A trigger weight, suspended from the end of the trigger line, which prevents the release mechanism from dropping the corer until the weight hits the bottom. As the piston action of the big corer frequently disturbs the surface layers of sediment, it is necessary to obtain a small undisturbed sample. To do this the trigger weight is made like a small Phleger corer without a tailfin assembly. It consists of a main tube with a cast lead drive weight of approximately 50 pounds, a short coring tube, plastic liner, core catcher, and cutting edge. The liner, core catcher, and cutting edge are the

same as used for the Phleger corer. They are assembled in the same manner as given in section 6–15 for the Phleger corer.

6–44 Spare Parts Needed for the Ewing Piston Corer.—The following spare parts are needed to operate the Ewing piston corer:

1. Coring tubes. Enough coring tubes, drilled and tapped for bolts and with caps on each end, to conduct the coring program for a survey cruise.
2. Piston and Fiege fitting. One extra. The Fiege fitting must be for the size of wire to be used.
3. Piston leather washers. Eight extra.
4. Piston-stop collar, with screws. One extra.
5. Connector sleeves. Four extra.
6. Metal spacers. Five extra.
7. Stainless steel bolts. One gross.
8. Core catcher. Four extra.
9. Cutting edge. Four extra.
10. Trigger weight and coring tube assembly. One extra.
11. Phleger parts for trigger weight corer:
    a. Plastic liner (enough for coring program). One liner is used for each sample.
    b. Rubber stoppers, size No. 7 (enough for coring program). Two are used for each sample.
    c. Core catcher. Four extra.
    d. Cutting edge. Four extra.
12. Bottom sample jars. Enough ½-pint sample jars, as needed to conduct the coring program for a survey cruise. One jar is needed for each Ewing core sample. The sediment retained by the core catcher and cutting edge is stored in a sample jar. It is not necessary to do this for the trigger weight core.
13. Rags. These are needed to pack the unfilled portion of the coring tube to prevent disturbance of the sediment. They are also needed for cleaning purposes and general maintenance of the corer.
14. Waterproof tape, which is used to secure the metal caps onto the ends of the coring tubes. The caps must be sealed to retain the moisture in the sample.

6–45 Tools Needed to Operate the Ewing Piston Corer.—In order to assemble and operate the Ewing piston corer, the following tools are needed:

1. Pliers, 8-inch combination.
2. Screwdriver, medium size.
3. Screwdriver, large size.
4. Socket wrench set with ratchet handle.
5. Adjustable end wrench.
6. Small saw or sharp knife for cutting trigger core plastic liners.
7. Oil can.
8. Steel wool.

6–46 Assembling the Ewing Piston Corer for Operation.—To assemble the mainweight, first place a heavy steel disk, 8 to 10 cast lead drive weights, and another heavy steel disk over the main body tube up to the tailfin assembly. Secure the disks and weights by placing a connector sleeve over the end of the main body tube and bolting it in place. When less than ten weights are used, it is necessary to use spacers in place of the missing weights. These spacers are placed between the lower disk and the connector sleeve. Next, insert a 20-foot length of coring tube into the connector sleeve attached to the bottom of the mainweight and secure it with bolts. It is very important to bolt *every* hole in the connector sleeve to insure suction for the piston. If more than one length of coring tube is to be used, bolt another connector sleeve at the end of the tube, and insert and bolt the next length to it.

Attach the Fiege fitting securely to the end of the lowering wire and insert the wire into the end of the main body tube at the tailfin assembly. Push the wire through the coring tube until it extends out the end of the tube. Attach the piston stop collar onto the cable above the Fiege fitting. Attach the piston to the Fiege fitting. Insert the piston into the coring tube until it is just above and clear of the core catcher. Insert the core catcher into the end of the coring tube and secure by fitting the nose piece over it and the end of the tube. Bolt the cutting edge in place. Some cutting edges do not cover all holes in the end of the tube. When using this type of cutting edge be sure to fill all exposed holes with bolts to insure suction for the piston and prevent disturbance of the sediment layers.

6–47 Rigging the Release Mechanism.—Attach the wire clamp of the release mechanism onto the wire 15 feet beyond the end of the tailfin assembly. The wire clamp is a modified wire rope stopper, or come-along. Shackle the wire clamp to the top ring of the release mechanism. Now insert the ring attached to the bail of the tailfin assembly into the slot of the release mechanism so that the release arm is able to support the full weight of the corer. As soon as this is done, it is important to *insert the safety pin* into the release arm. There are now about 12 feet of slack wire between the corer and the release mechanism for free fall.

Assemble the trigger weight corer in the same manner as described in section 6–15. Attach the trigger line to the trigger weight and the end of the release arm. Adjust the length of the trigger line so that the trigger weight will be suspended 14 feet below the cutting edge of the Ewing corer nosepiece. This length may have to be adjusted slightly one way or the other. The proper length of trigger line depends upon the speed at which the winch can be stopped, the rate at which the wire is payed out, and the amount of "recoil" in the wire when the corer is released. If the trigger line is too short, sediment will get into the piston. If the line is too long, then several feet of water will be cored before the tube enters the sediment. For proper operation, the piston must take up the slack in the wire and stop one foot above the ocean bottom.

6–48 Rigging for Lowering.—The methods for suspending the Ewing piston corer over the side will vary depending upon the equipment available aboard ship. Because of the size and weight of the corer, the operation requires the use of a cargo boom or boat crane equipped with a swivel hook. It is recommended that a wire rope sling be spliced just above and below the lead drive weights. The boom or crane hook can be hooked into the sling and the corer hoisted up and over the side in a horizontal position. The coring tube is then lowered into the water with handling lines and the hook lowered until the entire assembly is suspended vertically from the lowering wire. The hook then can be released from the sling and hoisted clear of the gear. Lower the trigger weight over the side. Check to see that the trigger weight and line is tending properly and the corer is suspended correctly from the release mechanism. It is important now to *remove the safety pin* from the release arm. Rig out the boom or crane until the corer is in the lowering position and lower the corer to the water's edge. Set the meter wheel or dynamometer counter to zero. Commence lowering.

6–49 Obtaining the Core.—When lowering, it is important to keep a careful check on the depth at all times, especially as the corer nears the bottom. Close attention must be paid to the amount of wire out and to the dynamometer reading for indication of striking bottom (fig. 6–8). Contact is indicated by a sudden momentary drop in wire tension. When this drop in tension is noted, the winch must be stopped *immediately* to insure proper operation of the piston and to prevent the wire from piling up on the bottom. Piled up wire will kink, causing damage to the wire and possible loss of equipment. Upon reaching the bottom, the trigger weight will strike first, producing a slack in the trigger line and activating the release mechanism. This allows the Ewing corer to fall and penetrate the sea bottom. As soon as the winch is stopped, reverse controls and commence hoisting.

6–50 Retrieving the Core.—During the pull-out, that period while the corer is being freed from the bottom, watch the dynamometer closely. Have all hands stand clear of the wire. Be ready to stop the winch the instant tension appears excessive. Normally, the pull-out tension is in the order of two to four thousand pounds greater than the tension just prior to free fall. When free of the bottom, the tension usually will drop to approximately one thousand pounds greater than that just prior to free fall. It is advisable to cease hoisting should the tension become excessive. When tension has decreased, hoisting may be started again. During hoisting, the piston stop collar supports the entire weight of the corer.

When the release mechanism has surfaced, rig in the boom or crane and bring the gear to deck working level. Hoist aboard the trigger weight and detach the release mechanism from the wire. Next bring the mainweight to deck working level and insert the swivel hook into the sling on the mainweight. Take a strain with the hook and slack the lowering cable in order to raise the coring tube to a horizontal position. The tube is raised with handling lines. When level, bring the corer inboard and lower it to the deck. It is recommended that the mainweight be placed in a cradle to prevent it from rolling on the deck. Release the hook and secure the boom or crane (fig. 6–9).

6–51 Removing the Core Sample and Recording the Data.—The trigger-weight coring tube takes a core which is of greatest importance in determining the surface sediment of the ocean floor. This cannot be determined from the top of the main core because that part usually is unconsolidated and becomes badly distorted when the core is laid on its side. The contents of the cutting edge and core catcher of the main coring tube also are of great importance; they represent the material found at the deepest penetration. In many cases, full-length penetration of the coring tube is stopped short by striking firmer sediment or hard rock. In such an instance the harder sediment is likely to be much older than that which overlies it and, therefore, will furnish information of greatest value for marine geology and sound propagation studies. Since such material is often penetrated but a few inches, all evidence of it may be lost if

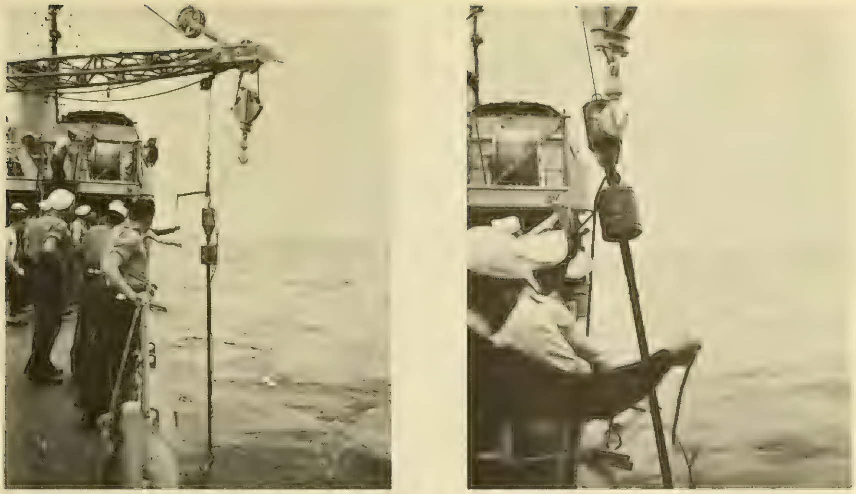


Figure 6–9. Lowering and retrieving the Ewing piston corer.

the contents of the cutting edge and core catcher are not retained.

Remove the cutting edge and core catcher from the trigger-weight corer. Insert a rubber stopper into the bottom of the liner and remove the liner from the tube. If the liner is not completely filled with sediment, fill the empty portion with glass wool. Insert a rubber stopper in the top of the liner, tape both ends, and seal with wax. Label the liner and store in an upright position.

Measure the length of sediment visible on the outside of the Ewing coring tube and record this in the Penetration column of the M-sheet. Next, unbolt the cutting edge and remove it and the core catcher. Carefully remove any sediment retained by these pieces and place in a sample jar. Label the sample. Place a metal cap over the end of the coring tube and secure it tightly with waterproof tape. Using paint, mark the cap "Bottom".

Remove all the bolts that hold the coring tube in the connector sleeve of the mainweight. Withdraw the coring tube until it is free of the mainweight and piston. Sound the tube with a rod and measure the length of the core. Record the length on oceanographic log sheet M. Pack the unsupported end of the sediment with a good wad of clean rags. If the sediment is not near the end of the tube, a well-packed wad of a foot to a foot and a half thick should hold. Place a metal cap over the upper end and tape securely. Using paint, mark the cap "Top". With paint, record on the coring tube the ship, cruise, core number, station number, date, and position. Record this information also on the log sheet together with a description of the core.

6–52 Securing the Corer.—After each lowering, the cutting edge, core catcher, and piston must be washed and rinsed carefully to remove all evidence of bottom material. All sediment must be removed from the mainweight. The filled coring tubes should be secured in racks and the mainweight securely lashed in a cradle.

6–53 Maintenance of the Ewing Piston Corer.—Owing to its sturdy construction, the corer generally requires little maintenance. However, the cutting edge may be chipped or bent from striking hard or rocky bottom. If not too badly damaged, the cutting edge may be hammered and filed back into shape.

Bent coring tubes usually result from partial penetration into the sea floor rather than from contact with a hard bottom. On striking a hard bottom, the cutting edge may be damaged and the corer topples over without bending the tube. When penetration is stopped at about 10 feet or so by striking firmer sediment, the part of the coring tube in the sediment is held upright while the remaining portion falls over of its own weight. In such cases, minor bends may be straightened, but usually the core tube is beyond repair.

Core-catcher springs should be examined for free play of action. Inasmuch as the spring leaves are delicate, care must be taken in handling and packing for shipment.

If cores are extruded into core boxes instead of being stored in the tubes, the tubes may be used again. After extruding, while the sediment is still damp, the inner walls of the tube must be washed thoroughly to remove all traces from the previous core, and a coating of light oil applied.

6–54 Extruding Ewing Cores.—When it is desired to take additional cores for which there are no coring tubes, the cores already obtained may be extruded into a core box. The wooden core box has partitions running the long way of the box in which sections of the core are placed. The sections must be wrapped in waterproof paper.

An extruding rod is made from a length of pipe having a diameter slightly smaller than the inside diameter of the coring tube. A piston is bolted to the end of the pipe. The pipe should be equal to or slightly longer than the coring tube.

Bolt or tape the coupling holes at the ends of the coring tube to keep the sediment from coming through during extrusion. The coring tube with the core to be extruded is placed on deck and the piston inserted into the *bottom* end of the tube. *A core is never extruded from the top.* The top part of the coring tube is lined up with a core box. The end of the extruding rod opposite the piston is placed against any rigid stationary object. A line is secured about the coring tube and taken to the gipsy head of a winch. When a strain is taken, the line pulls the coring tube while the core remains stationary. The top end of the coring tube should be held so the core will be laid into a section of the core box with minimum disturbance. Figure 6–10 illustrates the method for arranging the waterproof paper in each section of the box and placing the core. It is important that the edge of the waterproof paper be kept free of the core. If this is not done, the folds will cut into the core and disturb it when the core is wrapped. The free edge of the paper is folded over and stapled to the side of the partition. If the core is shorter than the box, a block of wood is placed against the end of the core and the waterproof paper stapled to it.

Each length of the core must be marked carefully to show the cruise and core number and the top and bottom of the core. A diagram of the contents of each box must be drawn in the coring log.

6–55 Storing and Shipping Ewing Cores.—Because of the length of Ewing coring tubes and core boxes, it is necessary to store them in a horizontal position. When shipping, they must be marked "Handle With Care" and the covers marked "This Side Up". Trigger-weight cores must be shipped in an upright position and similarly marked. Cutting-edge and core-catcher samples should be shipped in a wooden box. All boxes should have the ship's name and the cruise number placed on it. Cases and coring tubes to be shipped to the Hydrographic Office are to be addressed as follows:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430.

6–56 BOTTOM SIGNALING DEVICE, THE BALL BREAKER.—Coring and sampling activities in deep-sea areas present the problem of determining the moment of contact of the instrument with the bottom. A bottom signaling device, or ball breaker, has been developed and is employed aboard Navy survey ships.

In shallow waters, a satisfactory method for determining when the bottom has been reached is the spring scale and block assembly described in section 6–18. In deep waters, the weight of the coring apparatus is often a small part of the total weight of the wire out and of the variable loads caused by the ship's rolling; hence, no apparent drop in tension may be observed on the scale when the bottom is reached. Therefore, it is necessary to employ an instrument which is independent of the ratio of corer to total wire weight, rolling of the ship, and depth of water. To meet this need the ball breaker, which implodes a 3½-inch glass ball when the bottom is reached, was designed. The resulting implosion may be heard on some types of echo sounders or received on a Brush recorder wired to the echo sounder. Another method of receiving the implosion signal is to use a Brush, or similar, recorder and amplifier with a hydrophone.

6–57 Assembling the Ball Breaker.—The device is easy to assemble for lowering. Raise the weighted piston to the top of the frame and hook in place with the trigger. *Insert the safety pin into the trigger until ready for lowering.* Secure a glass ball with tape so it is resting on the three points at the bottom of the frame. For most bottom sampling instruments, the ball breaker is attached to the wire above the instrument as shown in figure 6–11. When

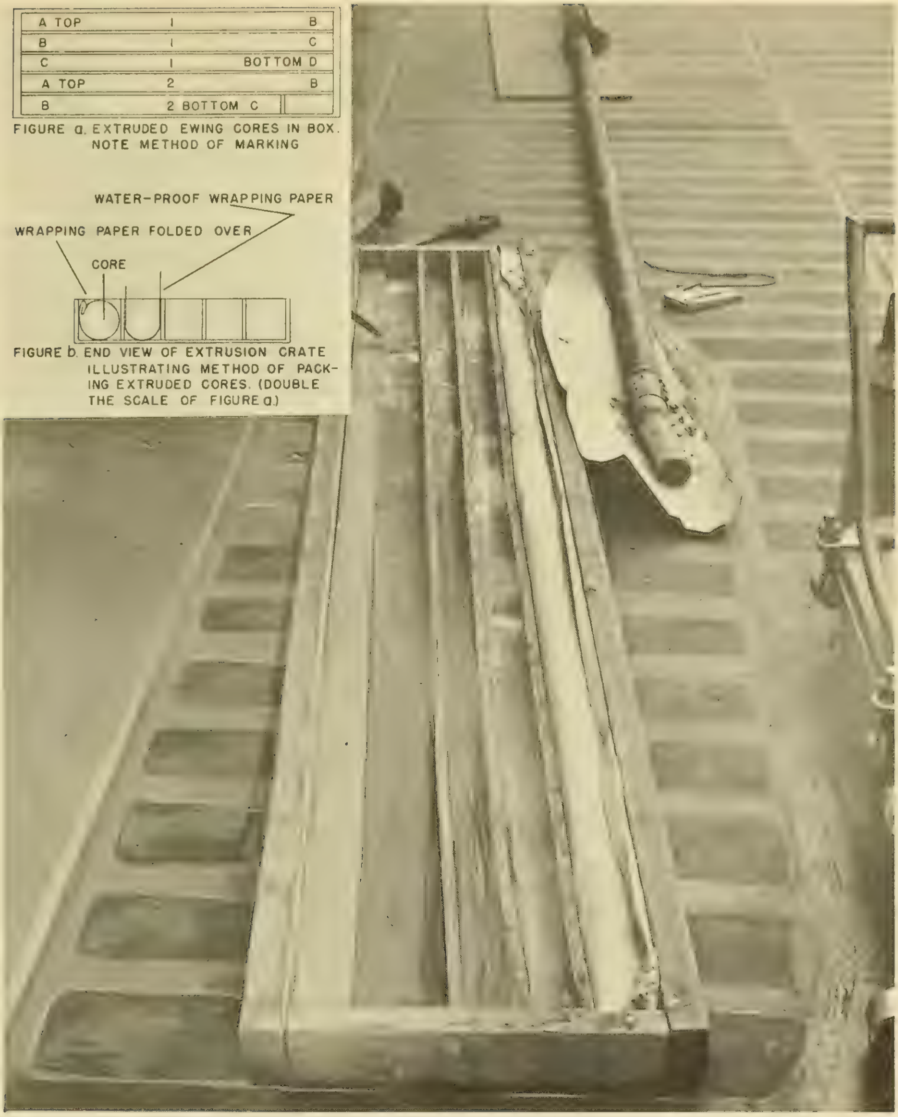


Figure 6–10. Extruding and packing Ewing cores.

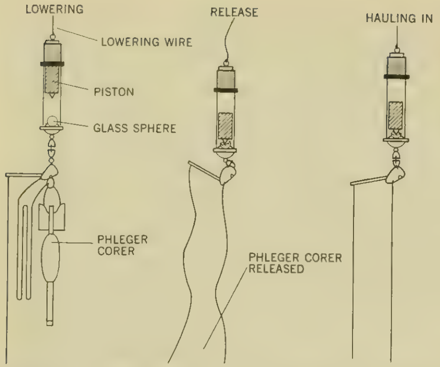
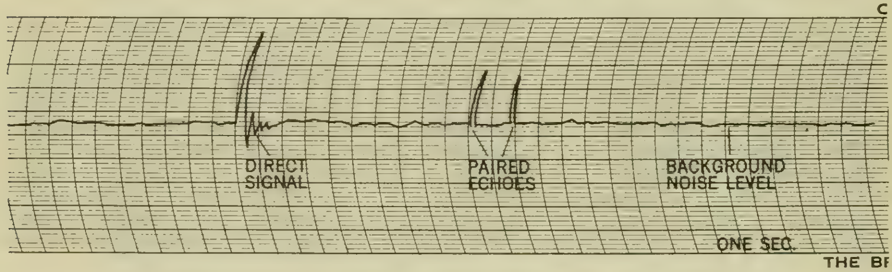


Figure 6–11. The ball breaker—principle of operation.

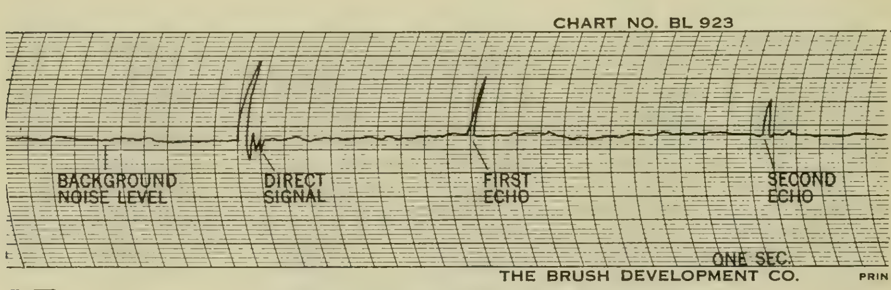
being used with piston corers, it is attached to the trigger line above the trigger weight.

6–58 Operating the Ball Breaker.—*Once the ball breaker is over the side and there is full tension on the trigger the safety pin is removed.* During lowering a careful watch must be kept to observe the signal. Upon contact with the bottom, the slack produced in the wire allows the ball breaker piston to be released from the trigger and fall freely, imploding the glass ball. The instant the implosion signal is received the winch must be stopped.

6–59 Receiving the Implosion Signal.—Two methods of reporting the implosion signal have been used successfully aboard Navy survey ships. One method is to connect a Brush recorder to the echo sounder and observe the signal from the pen trace. The other is to listen for the audible signal on the echo sounder. The first method is recommended, as a complete record of the direct signal and its echoes are obtained as shown in figure 6–12. The



IMPLOSION OF SPHERE HALFWAY DOWN TO BOTTOM (500 FATHOMS)



IMPLOSION OF SPHERE AT BOTTOM (1000 FATHOMS)
(SPEED OF BRUSH RECORDER SET AT 25mm/sec.)

Figure 6–12. Recorder tapes showing ball breaker signals.

direct signal and the echoes are quite distinct and may be distinguished from the background noise. The echoes aid in verifying the implosion, and further, from the spacing of the echoes, the relative depth of the implosion can be determined. Should the glass ball break before reaching the bottom, paired echoes are received, whereas only single equally spaced echoes are received when the glass ball is broken on the bottom.

6–60 Recording Ball Breaker Data.—Graph traces of direct signal and echoes obtained with a Brush recorder are forwarded along with the M-sheet. The ship's name, cruise number, core number, station number, date, and time should be noted on the graph.

6–61 Maintenance of the Ball Breaker.—After each lowering, the ball breaker should be washed to remove any sediment that might hinder its action. When necessary, it should be wire brushed and painted to prevent corrosion.

6–62 SMALL BOTTOM SAMPLERS.—Various bottom samplers are used to obtain small samples of the superficial layers of bottom sediments (fig. 6–13). They are particularly useful where it is desired to gather rapidly large numbers of small samples in a particular area. The samples are stored in canvas sample bags or mason jars and properly labeled. All sample data are recorded on the M-sheet.

6–63 Clamshell Snappers.—There are 2 general types of clamshell snappers currently used on Navy survey ships. One is about 30 inches long and weighs about 60 pounds. It is ruggedly constructed of stainless steel. The cast stainless steel snapper jaws are closed by heavy arms actuated by a strong spring and lead weight. There is a foot device which triggers the jaws. In the open position, the foot extends below the jaws so that it strikes the bottom first. The impact moves the arms up releasing the jaws which snap shut with considerable force. The jaws trap about a pint of bottom material. This snapper is equipped with tailfins and is lowered from the oceanographic winch.

A smaller type of clamshell snapper, called a mud snapper, is about 11 inches long and weighs 3 pounds. It is attached to the bottom of a sounding lead by means of a hole drilled in the lead. The jaws are cast bronze and are actuated by a spring. The tension on the spring may be adjusted by tightening or loosening a screw cap. The jaws are held open by engaging two trigger pins within the jaws. Care should be observed when handling the snapper in the open position as a slight jar may accidently snap the jaws causing injury to the fingers or hands. The mud snapper and sounding lead may be operated in shallow waters by hand lowering or it may be lowered from a bathythermograph or oceanographic winch.

6–64 Orange Peel Bucket Sampler.—Orange peel bucket samplers are used to obtain bottom samples in shallow waters. Those used on Navy survey ships weigh 45 pounds and hold about 300 cubic inches of sediment when full. They are operated from the oceanographic winch. A small hook attached to the end of the lowering wire supports the sampler as it is lowered and also holds the jaws in the open position. When contact is made with the bottom, the sampler jaws sink into the sediment and the wire tension is released, allowing the hook to swing free of the sampler. Upon hoisting, the wire takes a strain on the closing line which closes the jaws and traps a sample. One end of the closing line is attached to the wire and the other end is fixed to the handle which activates a ratchet chain and sheave that close the jaws. The closing line supports the sampler as it is being hoisted. To prevent washing out of the sample from the top, it is recommended that a canvas cover be used. Once on deck, the sample is discharged by slacking off the closing line. The sample is placed in a mason jar and properly labeled.

Owing to its sturdy construction, the sampler requires very little maintenance. After each lowering, the sampler must be washed to remove all sediment. All moving parts should be lubricated with light machine oil. When necessary, the sampler should be wire brushed and painted to prevent corrosion.

6–65 Underway Bottom Sampler, The Scoopfish (fig. 6–13).—The underway bottom sampler, or scoopfish, is designed to sample rapidly without stopping the ship. It is lowered from the bathythermograph winch in depths less than 100 fathoms from a ship underway at speeds not over 15 knots. The sampler weighs 11 pounds and is 15 inches long. Samples ranging from mud to coral have been obtained. Mud samples weigh up to about 50 grams, but gravel and coral samples may contain only a few fragments. The instrument is made of stainless steel and is quite rugged. When lowering, care must be taken that the nose lid is not prematurely released as the sampler enters the water. The scoopfish is allowed to fall freely in the same manner as the bathythermograph. During its descent, the towing arm is engaged toward the rear, and the nose lid is hooked back in open position. Upon striking

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Figure 6–13. Small bottom samplers—orange peel, clamshell snappers, scoopfish, dredge.

the bottom, the removable cup is pushed back releasing the catch on the nose lid and towing arm. The nose lid snaps shut trapping sediment in the cup, and the towing arm is rotated forward. The latter movement shifts the center of gravity, allowing the scoopfish to free itself from the bottom and be raised without end-over-end spinning. Once on deck, the cup is removed, and for rapid sampling another cup inserted, the nose lid and towing arm reset and the scoopfish is ready for another lowering. The sample from the cup is placed in a canvas sample bag or mason jar and properly labeled. When lowerings are completed the scoopfish is washed down and all moving parts given a coat of light machine oil.

The scoopfish is used where a large number of samples are to be obtained in a limited amount of time. It has been used to record on the echogram the type of bottom found while obtaining soundings.

6–66 DREDGES.—Dredges used aboard Navy survey ships are based on a type designed by the U. S. Navy Electronics Laboratory. Bottom dredging operations require very sturdy gear, particularly when dredging for rock samples. The apparatus is constructed of ¼-inch steel plate, and is 1 foot deep, 2 feet wide, and 3 feet long. The forward end is open, but the aft end has a heavy grill of ¾-inch round steel bars. This grill is designed to retain large rock samples. When it is desired to obtain finer sized material, a screen of heavy hardware cloth is placed over the grill. A bridle consisting of 7-foot lengths of galvanized steel chain or ½-inch wire is attached to shackling tabs on the sides of the dredge. The bridle is attached to a swivel which is made fast to ½-inch diameter lowering wire (fig. 6–13).

During dredging operations, the ship is hove to as the dredge is lowered. A boom or boat crane, ½-inch wire, and dynamometer similar to that used for Ewing core operations is used.

Towing the dredge along the bottom should be done only by ships that can operate at very slow speeds; i. e., at 2 or 3 knots. Ships which cannot operate at such slow speeds can dredge by drifting when wind and sea conditions are favorable.

During lowering, the dynamometer must be watched for a decrease in tension indicating the dredge has made contact with the bottom. Then some extra wire is payed out to provide scope for towing, and the winch stopped. Increase in dynamometer tension and wire angle will indicate that the dredge is towing. A careful watch of the tension must be kept. If the tension is very irregular, showing decreases in tension, the dredge is probably skipping on the bottom. More wire should be payed out to increase the scope. If rocky irregularities such as ledges are encountered, the dredge will tend to foul. If this occurs, the ship is stopped and if possible reversed and maneuvered to free the dredge.

Rocks and representative samples of other bottom material obtained should be packed in a wooden box and properly labeled. The data should be recorded on the M-Sheet. Samples to be shipped to the Hydrographic Office are to be addressed as follows:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430.

CHAPTER 7

UNDERWATER PHOTOGRAPHY

7–1 **GENERAL REMARKS.**—Recent years have seen a marked increase in the development and use of underwater photography. Location and identification of sunken vessels and other submerged objects, studies of shellfish beds, studies of fish and other biological life, studies of reefs and coral growth, and studies of the ocean bottom in relation to its sediment structures are a few of the many uses of underwater photography.

The newest medium to be utilized in the field of visual underwater observations is television. Although at present limited to relatively shallow water use, it has been successfully applied in salvage operations. The potential uses for such an instrument are great, and include action studies of various types of equipment either lowered into or towed through the water.

7–2 **Underwater Cameras.**—Underwater cameras may be classified under two general categories; those operated by divers and swimmers, and those that are lowered with a winch and remotely operated by bottom contact, messenger, or mechanical means. The first category includes both still- and motion-picture cameras using either color or black and white film. The second category usually includes only still cameras. One type is the single shot, taking only one picture on each lowering. Another type is the multiple shot, taking a series of pictures during the lowering operation.

7–3 **INSTRUCTIONS FOR OPERATING THE SINGLE-SHOT BOTTOM CONTACT CAMERA.**—The single-shot, bottom-contact camera is designed to obtain photographs of the ocean bottom at great depths. It will take one picture on each lowering, and the camera shutter is tripped by contact with the bottom. The tripping mechanism obtains a small Phleger-type core at the time of tripping. The camera is contained in a heavy pressure case capable of withstanding water pressures up to 12,000 pounds per square inch. It has taken successful photographs at depths greater than 3,000 fathoms.

7–4 **The Camera Assembly.**—The camera assembly consists of a canvas vane, the camera pressure case, camera, photoflash pressure case, battery and firing mechanism pressure case, trigger mechanism and coring tube, all of which are mounted on a frame of aluminum tubing 14 feet long (fig. 7–1).

The assembly is attached to the oceanographic wire by a shackle at the top of the frame. A small canvas vane is mounted near the top in order to reduce spinning of the camera assembly

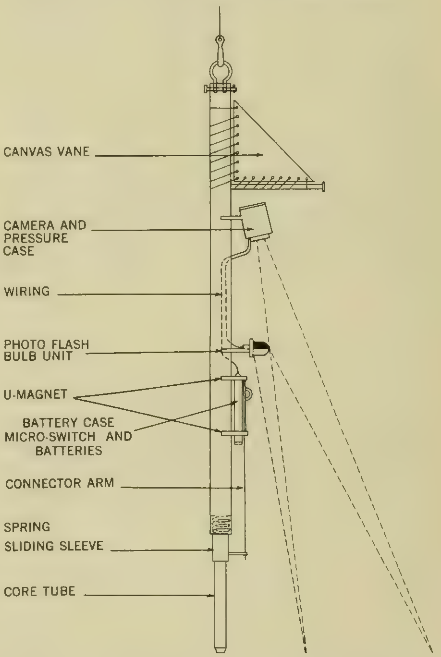


Figure 7–1. Single-shot underwater camera assembly.

during lowering and thus prevent a blurred picture. The camera pressure case is mounted below the vane. The case is made of aluminum approximately 1 inch thick. The glass port in the bottom of the case is nearly ¾-inch thick. Next to the port are 2 spark-plug-type connectors with plastic insulators, pressure sealed with O-rings. They are connected to male banana plugs inside the case. The cover plate on the top of the case is secured with about eight stainless steel bolts and pressure sealed with an O-ring. On the inner side of the cover plate is a spring for holding the camera in position (fig. 7–2).

The camera is mounted in a cylinder which fits inside the pressure case. It has a compur-type shutter and uses 616 roll film. The shutter is actuated by a solenoid. There are 3 female banana plugs on the front which fit over those inside the pressure case: 1 for the batteries, 1 for the photoflash bulb, and the third for the ground. The lens has a fixed focus set for the distance from the camera to the bottom of the assembly.

The photoflash unit is mounted approximately 5 feet below the camera pressure case. The case contains the flashbulb and socket in a removable glass housing which protects them from water and pressure effects.

The firing mechanism and battery case are located below the photoflash unit. The upper part of the case holds a microswitch wired through the top of the case via a spark-plug-type connector to the camera case. The four flashlight batteries to power the system are mounted below the microswitch. They are inserted through the bottom of the case. A spark-plug-type connector in the bottom cap is grounded

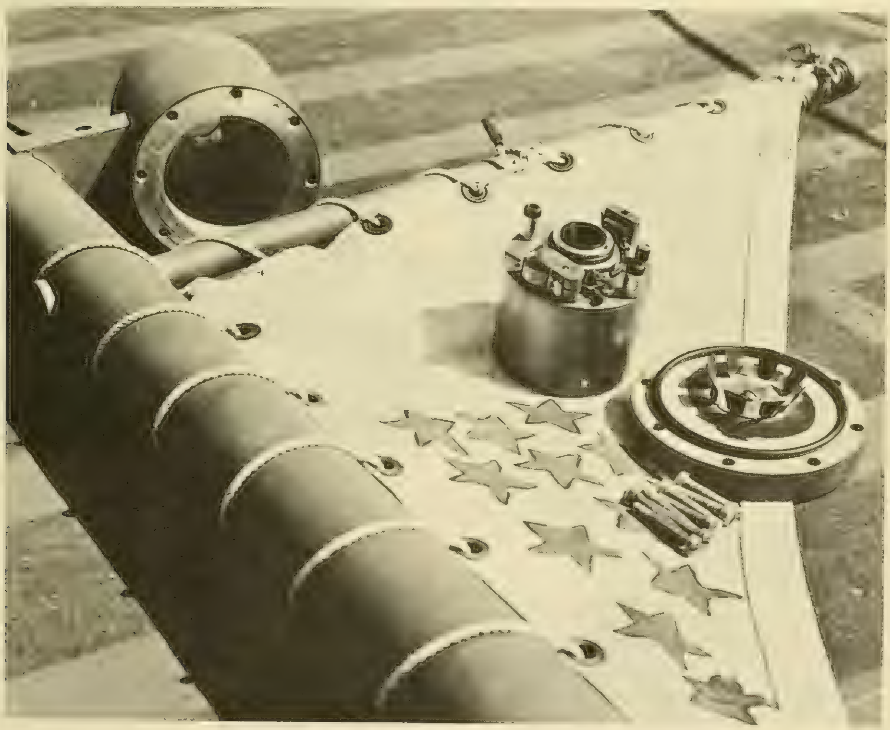


Figure 7–2. Underwater camera and pressure case.

to the assembly frame. The top and bottom caps of the battery case are pressure sealed with O-rings. The microswitch is actuated by a U-magnet mounted outside the battery case on a movable connecting arm. The connecting arm is attached to a sliding sleeve at the bottom of the assembly frame. If a soft bottom condition is expected, a circular perforated brass foot plate is attached to the bottom of the assembly frame to prevent excessive burial of the unit with resultant damage to the external mounted components of the camera.

A Phleger-type coring tube is attached to the sliding sleeve with a threaded union. This coring tube uses a plastic liner, core catcher, and cutting edge similar to those described in section 6–12. Contact with the bottom forces the coring tube, sliding sleeve, connecting arm, and U-magnet upward. This actuates the microswitch which in turn fires the camera and photoflash bulb.

7–5 Equipment Needed to Operate the Single-Shot Bottom-Contact Camera.—In addition to the assembly described above, the following components are needed to operate the camera.

1. Roll film, size 616, panchromatic plus X or super XX.
2. Photoflash bulb, size No. 50.
3. Dry cell flashlight batteries.

7–6 Spare Parts Needed for the Single-Shot Bottom-Contact Camera.—The following spare parts are needed to operate the camera. Quantities are dependent upon the data requirements of the survey.

1. Roll film, size 616, panchromatic plus X or super XX.
2. Photoflash bulbs, size No. 50.
3. Dry cell flashlight batteries.
4. Camera lens assembly.
5. Spring for camera pressure case cover.
6. Two coil springs for camera shutter.
7. Glass pressure housing for photoflash unit.
8. Microswitch assembly.
9. Eight stainless steel bolts for camera pressure-case cover.
10. Six brass bolts for spark-plug connectors.
11. Six plastic insulators for spark-plug connectors.
12. Two O-rings for camera pressure case; 2 for photoflash pressure case; 2 for battery pressure case; 12 for spark-plug connectors.
13. A small tube of stopcock grease.
14. Thirty feet of rubber-covered, watertight, single-conductor, electrical cable.
15. Two rolls of electrical waterproof tape.
16. Six rolls of rubber tape.
17. Two tubes of weatherstrip adhesive.
18. A spare coring tube.
19. Four core catchers
20. Four cutting edges.
21. Plastic liner, 1½-inch outside diameter. Enough lengths as needed to conduct survey program. One liner is needed for each sample.
22. Rubber stoppers, solid, size No. 7. Two stoppers are needed for each sample.
23. Bottom sample jars. Enough sample jars as are needed to conduct the survey program. One sample jar is needed for each bit of sample.
24. Glass wool, used to pack the unfilled portion of the plastic liners above the core samples.
25. Small bags of desiccator (silica gel) to place in camera case, photoflash case, and battery case when storing.

7–7 Tools Needed to Operate the Single-Shot Bottom-Contact Camera.—The following tools are needed to operate and maintain the camera.

1. Pliers, 8-inch combination.
2. Screwdriver, large.
3. Screwdriver, small.
4. Strap wrench.
5. Adjustable end wrench.
6. Allen wrenches.
7. Test lamp for photoflash socket and electrical circuit.
8. Oil can.
9. Sharp knife or small saw for cutting plastic liners.
10. Steel wool.
11. Rags for cleaning.
12. Lens tissue.

7–8 Assembling the Single-Shot Bottom-Contact Camera for Operation.—Remove the cover plate from the camera pressure case and take out the desiccator bag. Clean the pressure lens with lens tissue. Clean the banana plugs in the case. Remove the photoflash glass case and take out the desiccator bag. Clean the flashbulb socket. Remove the bottom cap of the battery case and take out the desiccator bag. Inspect all electrical wiring and contacts. Check the movement of the sliding sleeve and U-magnet. Check the action of the microswitch when the U-magnet passes over it.

Insert four new flashlight batteries in the case. Coat the O-ring in the cap with a very thin even layer of stopcock grease and hand tighten the cap onto the case.

Insert the test lamp into the flashbulb socket. A simple test lamp can be made by wiring a 6-volt flashlight bulb into the base of a used photoflash bulb.

Remove the camera from the carrying case and cock the shutter trigger. Place the unloaded camera in the pressure case so that it is seated firmly on the banana plugs.

Now test the firing circuit by moving the sliding sleeve up so that the U-magnet passes over the microswitch. The test lamp should light and the camera shutter trip. If they fail to do so, make a check for short circuits. When the system is operating properly, remove the test lamp and camera (fig. 7–3).

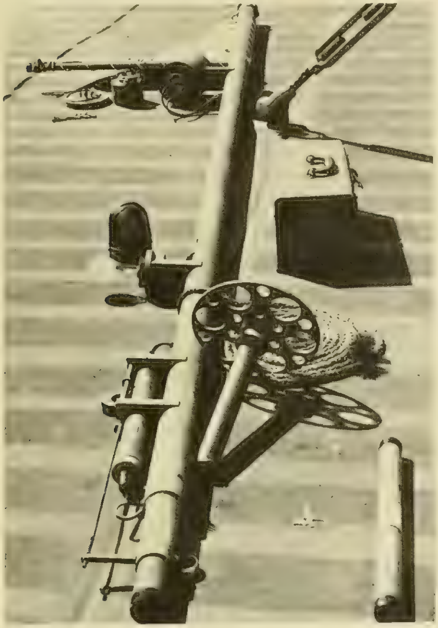


Figure 7–3. Exploded view of underwater camera assembly.

Attach brass foot plate (when needed) and the coring tube to the sliding sleeve. Insert a length of plastic liner, a core catcher, and cutting edge as described in section 6–15. *Once the coring tube is assembled, be careful not to trip the firing circuit.*

Put a photoflash bulb into the socket. Coat the O-ring of the glass housing with a very thin even layer of stopcock grease, and fasten it in place. The housing should be tightened slightly by hand. *Do not use a wrench or other tool to tighten it.*

Load the camera with film. Set the lens opening and shutter speed. Recommended setting for plus X film is 1/50 second at f9, and for super XX is 1/50 second at f11. Variations to these settings may be desired owing to slight differences in cameras. The first few lowerings should reveal whether changes in settings are needed.

Cock the shutter trigger of the camera and insert the camera into the pressure case in the same manner as during the circuit test. Check the cover plate to insure that the O-ring is properly seated. Coat the O-ring with a very thin even layer of stopcock grease. Bolt the cover plate to the pressure case. The operator must be cautioned that only a small amount of pressure must be applied in tightening these bolts and this pressure must be evenly applied around the plate. *If too much pressure is applied, the O-ring will be flattened and its intended purpose defeated* (fig. 7–4).

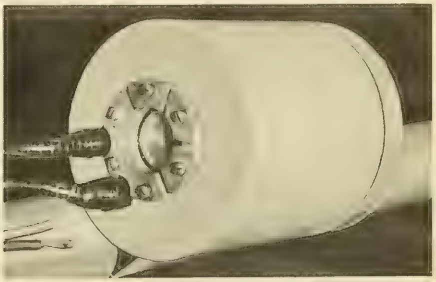


Figure 7–4. Front of underwater camera pressure case.

The camera assembly is now ready for attachment to the oceanographic wire. The procedures described above must be carried out before each lowering. If the camera assembly has not been used for several days, it is strongly recommended that a test lowering be made *without* the camera to inspect for leaks. A lowering to 500 meters will usually reveal any leakage.

7–9 Rigging for Lowering.—The camera assembly is shackled to the oceanographic wire. It is recommended that if available, a bottom-signalling device such as the ball breaker be used. Attach the ball breaker to the oceanographic wire and rig as described in sections 6–57, 6–58, and 6–59. Shackle the camera assembly to the ball breaker. It is advisable to splice a length of manila line around the frame just below the photoflash bulb housing to use as a retrieving line.

Lift the camera and lower carefully over the side, using the retrieving line to lower the camera until it is suspended in a vertical position from the oceanographic wire. Great care must be taken during this operation not to compress the sliding sleeve and fire the camera inadvertently. When the camera is in the vertical position and ready for lowering, secure the end of the retrieving line to the shackle at the top of the frame. Lower the camera to the waterline and set the meter wheel to zero. Commence lowering.

7–10 Obtaining the Bottom Photograph and Core Sample.—Lower the camera slowly until the apparatus is well clear of the ship. When the camera approaches the sonic depth, measure the wire angle. Using the method described in section 6–7 determine the approximate amount of wire to be payed out to reach bottom. Slow the winch down to prevent violent contact with the bottom. Stop the winch the instant contact is signaled by means of the ball breaker or dynamometer. This is to prevent the wire from being laid on the bottom with resultant kinking and damage. The picture and core having been taken at contact, now commence hoisting slowly until the camera is well clear of the bottom then increase to normal hoisting speed. Again, slow the winch as the camera approaches the surface. When the camera is at the platform unfasten the retrieving line, swing the camera to a nearly horizontal position, and bring it aboard. Care must be taken not to raise the bottom end to the horizontal as this will disturb the core sample.

7–11 Removing the Core Sample and Recording the Data.—The core sample is removed, the data recorded, and the core stored in the same manner as described in section 6–20, 6–21, and 6–24 for Phleger cores. All data are recorded on the M-sheet. In addition to the data required for the core, the following information pertaining to the photograph should be recorded in the Remarks column. Record the type of film used, the type of flashbulb, lens, stop and shutter speed, and number of the picture. If necessary use more than one line of the log sheet, writing across the columns.

7–12 Removing the Camera and Securing the Camera Assembly.—If operations are in shallow waters (such as less than 100 fathoms) and the camera is to be lowered again, it may be removed from the case, the film advanced, the shutter trigger cocked, and then reinserted in the case. The old flashbulb is removed and a new one placed in the housing. If the housing is tight, use a strap wrench to loosen it. A new core liner is placed in the coring tube and the core catcher and cutting edge replaced. The core catcher, cutting edge, and coring tube must be thoroughly washed clean of all sediment before using again. The camera is then ready for another lowering.

If operations are in deep waters and the camera is to be lowered again, it is recommended that the film be removed from the camera and a new reel used for each lowering. Thus loss of several valuable photographs is prevented should some accident occur to the camera.

Whenever photographic laboratory facilities are available aboard ship, it is advisable to develop the film as soon as possible. Thus, necessary adjustments in stop and shutter speed can be made. After the negative has been developed and prints made on glossy paper, the information recorded on the log sheet should also be recorded on the back of the print. Negatives and positives should be kept together and forwarded with the log sheets and core samples at the end of the cruise (fig. 7–5).

If the camera is not to be used for a day or so, the following procedure should be carried out. Remove the camera from the pressure case, insert a desiccator bag, and secure the cover plate. Remove the used flash bulb, insert a desiccator bag in the glass housing, and replace the housing. Remove the batteries from their case, place a desiccator bag in the case, and recap. Place the camera in its shipping box and store the coring tube and parts. Secure the camera frame to prevent damage. It is desirable to secure it in some overhead location where it will be out of the way of traffic and protected from the sun. The camera box must be kept in a safe dry place.

7–13 Maintenance of the Single-Shot Bottom Contact Camera.—It is most important to watch for pressure leaks if the camera is to remain in proper operating condition. Leaks will cause damage to the camera and short circuits in the electrical system. All 0-rings must be kept in good condition. They should be replaced if there are any indications of wear, cuts, or chafing. If short circuits develop, the electrical cable should be replaced and a careful watertight connection to the spark plug connectors made.

The watertight connection is made in the following manner. Attach the cable to the connector. Cover the connector and about 8 inches of the cable with a layer of tightly wound rubber tape. Cover the taped area and about an inch of exposed cable with a layer of

Figure 7–5. Underwater photograph taken at depth of 3,400 fathoms.

weatherstrip adhesive compound. Cover the adhesive and an inch of exposed cable with a second layer of rubber tape. Cover the tape and another inch of exposed cable with a second layer of weatherstrip adhesive. Cover this with a layer of electric tape, such as Scotch Electric.

The bolts and bolt holes in the camera pressure case should be kept greased to prevent corrosion.

The sliding sleeve and connecting arm should be oiled to prevent corrosion and maintain free movement.

When necessary, the frame and other painted parts should be wire-brushed and painted to prevent corrosion.

CHAPTER 8

OBTAINING BIOLOGICAL SPECIMENS

8–1 **GENERAL REMARKS.**—There are different ways by which biological organisms can be taken out of the oceans. Some of the most commonly used samplers are plankton nets and mid-water trawls. The former has a net mesh size which is capable of sieving microorganisms such as zooplankton and phytoplankton from water; the latter has a net-mesh size which permits plankton to pass through, but filters out larger forms.

Plankton nets vary in that there are some types which can be used only when a ship is stopped or at anchor, while other types are designed to take samples while a ship is underway. Plankton nets are further diversified in construction to allow sampling at one or several depths. For example, some nets, such as the qualitative plankton nets, can be used only at the surface level. On the other hand, there are plankton tows that can be used at different depths, as well as at the surface. Such a sampler is the Clarke-Bumpus sampler.

Plankton nets can be subdivided into qualitative and quantitative samplers. A qualitative sampler sieves organisms from the water, but does not measure the volume of water that has passed through the net. A quantitative sampler measures the volume of water filtered by the net; thus, the concentration of the organisms in a unit volume of water can be determined.

The midwater trawl is a specially designed net for rapid trawling at great ocean depths. This trawl can move at such speed through the water that active, fast-swimming fish are unable to swim out of the net once caught. Ships towing a certain type of trawl can travel as fast as 5 knots.

The plankton nets and trawl used by the Hydrographic Office survey ships and discussed in this chapter are the half-meter plankton net, the Clarke-Bumpus sampler, and the Issacs-Kidd midwater trawl.

8–2 **THE HALF-METER PLANKTON NET.**—A typical net is a half-meter (diameter) conical net with a No. 0 mesh. A special bottle or bucket fits the small end of the cone. The bottle is secured to the net by several turns of strong thread or twine. The bucket is secured by fastening to a metal ring on the net. Three lines, each about 18 inches long, are attached at equidistant points to the brass ring at the large end of the net and are joined at 1 point to the towline, forming a bridle. The towline should be approximately 150 feet long (fig. 8–1).

Figure 8–1. The half-meter plankton net.

The mesh size of a plankton net varies. The selection of mesh size depends on the size of the plankton organisms sought. An identification number is on every net; the larger the number, the finer the mesh.

8–3 Assembly of the Half-Meter Net.—The opening at the large end of the net is one-half meter in diameter and fitted with reinforced eyes so that it can be lashed to the metal ring. The metal ring is bridled to the towline. At the small, or cod, end of the net is a metal headpiece; the bucket is attached to this. It is necessary for the operator to make certain that the mesh number stamped on the metal bucket is the same as the mesh number on the canvas edge at the large end of the net.

8–4 How to Operate the Net—Lowering and Streaming.—The net should be lowered over the weather side of a drifting ship, keeping the bucket clear of the side of the ship. From an anchored vessel, however, the net should be streamed to leeward. The operator should ascertain that the net is open and streaming properly before lowering it out of sight. Care should be taken to prevent the net from fouling in the ship's screws. In some instances it may be necessary to add weights to the net to stream it more than 2 or more meters below the surface. Ordinarily, the net is streamed for 30 minutes; however, if the plankton are sparse, the time should be increased to 60 minutes.

8–5 Retrieving the Net.—The net is hauled in by a slow but steady pull on the line. Caution must be taken to keep the net from turning inside out. By catching the net just above the bucket with one hand and by swinging the mouth ring aboard with the other, the net can be brought aboard in safety.

When the net has been retrieved, any plankton clinging to the side of the net should be rinsed down into the bucket with sea water. The bucket is then detached, and its contents emptied into the sample jar. The inside of the bucket should be rinsed with sea water and the rinsings also emptied into the sample jar. The plankton sample is then ready for preservation.

8–6 Preservation and Storing of Specimens.—The method for preserving and storing plankton samples are given in sections 8–32 and 8–33.

8–7 Labeling the Plankton Sample.—A label is the only means of identifying a plankton sample. Labels are made of a special material and must be filled out in *pencil* rather than ink. The following information is included on the label: date, time (GMT), latitude and longitude, duration of the tow in minutes, depth of tow, mesh number of the net, diameter of the mouth ring, the name of the collector, and the sample number. Include the water temperature, salinity, and oxygen content at the depth of tow, if available. Any other pertinent remarks such as "Raining," "Sargassum Patches," etc., should be added. *This label must be placed inside the sample jar, facing outward.* The bottle must be recapped tightly. This information should be transcribed to a log sheet, using consecutive lines for each tow.

8–8 How to Secure the Net After a Tow.—After using the sampler, rinse the net and bucket carefully in fresh water. Care must be taken to rinse the cod end carefully since some plankton may adhere to it. The net should be hung to dry in a place where it will be protected from fraying or snagging.

8–9 Care and Repair of Nets.—Owing to the fragility of the nets, great care must be used in handling and storage. They are expensive and difficult to replace because of their special mesh sizes. Oil and grease affect the silk used in making the nets and great care must be taken to prevent contamination. Should oil or grease get on a net, it must be washed with soap and warm water immediately.

Small holes in a net may be repaired temporarily with a drop of rubber cement, shellac, or other suitable material. Large holes must be patched with linen, closely sewn with thin thread. When badly damaged, rotten, or excessively patched, the net must be replaced.

8–10 Spare Parts Needed.—The following spare parts are recommended for the half-meter net:

a. Silk plankton net—one of each size used.

b. Detachable metal bucket—one of each size used.

c. Brass mouth ring—one.

d. Sash cord or manila line—about 100 feet.

e. Formalin (37–40 percent solution of formaldehyde).

f. Sodium Bicarbonate—one box.

g. Linen for patching—1 square yard.

h. Silk thread for patching—one spool.

8–11 CLARKE-BUMPUS QUANTITATIVE PLANKTON SAMPLER.—This sampler is equipped with a flow meter so that quantitative plankton investigations can be made. An impeller is geared to the meter so that the number of revolutions made by the impeller is recorded by the counter. From the reading, the volume of water which has passed through the sampler can be determined. This quantity of water filtered by the sampler per revolution of the impeller is determined by calibrating the meter, either in a laboratory equipped with flume tanks or in the field. As a result of many calibrations, an approximate rating of 4 liters per revolution has been found to be satisfactory for all instruments whose impellers spin freely when blown on by the operator.

The sampler is equipped with a shutter; this is opened or closed by means of a specially shaped messenger which travels along the wire to which the sampler is attached. When the shutter is in the open position, water passes through the flow meter causing the impeller to spin and on through the net thus filtering out zooplankton and phytoplankton. The impeller stops spinning when the shutter is closed by a second messenger. Thus, a sample can be taken at a desired depth by means of this sampler without contamination from plankton in the overlying water strata.

The Clarke-Bumpus sampler is therefore unique in that an uncontaminated sample can be taken from any desired depth, and an estimate of the filtered volume of sea water can be determined.

This sampler was designed to be towed horizontally from a wire kept as nearly vertical as possible by means of a weight attached to the lower end. The weight should be as heavy as is feasible. Weights from 100 to 150 pounds are suitable for large vessels such as the survey ships of the Hydrographic Office, but lighter weights can be used when working from small boats.

When towing this sampler, a vessel can travel at 0.5 to 3 knots, preferably between 1 and 2 knots. Moreover, it can be used when a ship is stopped and drifting at 0.5 knot or faster. If a ship is at anchor, however, currents of 0.5 knot or more must be present in order to get a reading on the meter. Should currents be less than 0.5 knot, a vertical tow can be made with the meter traveling at this minimum speed. If the investigator desires a plankton sample at a specific depth under these conditions, he can obtain it with the Clarke-Bumpus sampler; however, it would not be a quantitative sample since there would be no way to measure the volume of water filtered.

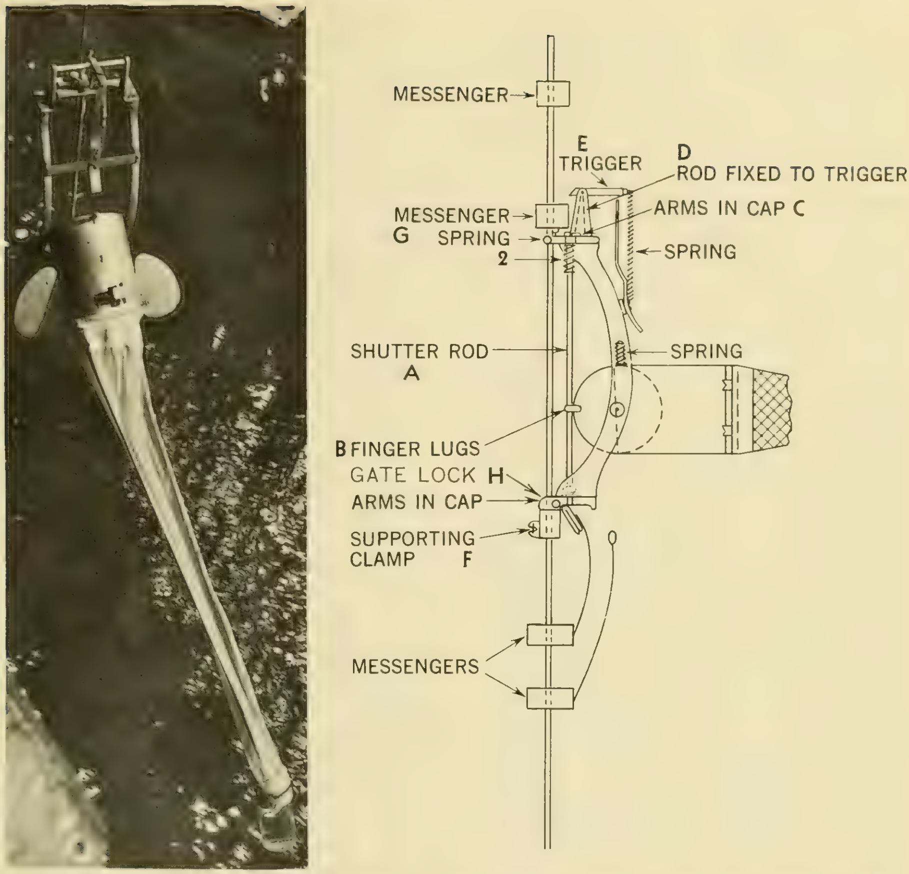
The instrument consists essentially of a brass tube, 5 inches in diameter and 6 inches long. To the rear end of this, any one of a set of interchangeable nets, of any desired mesh which are approximately 2 feet long, may be secured by means of a ring with a bayonet lock. The tube is mounted on the frame and this is attached directly to the supporting wire. The frame attaches to the wire by means of a loosely fitting spring pin at the top and a gate lock at the bottom. The latter closes around the neck of the supporting clamp which is secured rigidly to the wire. Thus, the frame is allowed to swivel freely around the wire, and the opening of the tube is always directed forward when the ship is moving ahead.

The shutter at the front end of the tube consists of a disk mounted on vertical pivots. Special messengers open the shutter when the sampler is at the desired depth and close it before hauling begins.

An impeller is mounted within the rear half of the tube. This is geared to a cyclometer-type counter which indicates the number of revolutions of the impeller and, thus, the volume of water which has passed through the tube and net. The meter starts when the shutter opens and stops when it closes. The bucket is attached to the cod end of the net by means of a throw clamp. The bucket is provided with a draining window covered by fine wire netting. The mesh of the wire netting in the draining cup must be at least as fine as that of the silk netting used. The mesh of the silk netting may be as fine as No. 10 (109 threads per inch) but with this and finer meshes, the meter will not record accurately if excessive clogging of the net occurs.

8–12 Assembly of the Clarke-Bumpus Sampler.—The sampler is delivered by the manufacturer already assembled except for the net, bucket, and towing rod. When preparing to make an observation, the net is attached to the sampler by means of a bayonet lock. The plankton bucket with the same mesh is then fastened to the cod end of the net with a throw clamp. Next, the towing rod must be installed. This keeps the net open and prevents it from getting fouled on the instrument or cable. The forward end of the rod passes through a guide at the upper rear edge of the main tube and is clamped to the bucket. The sampler is now ready for a plankton observation.

8–13 How to Operate the Net.—It is best to set the shutter of the sampler before the instrument is attached to the cable. Start with the shutter in the final closed position. Now rotate the shutter through 90° against its spring (counterclockwise looking down on sampler) and at the same time rotate rod (A) clockwise against its spring (2) until the edge of the shutter engages the longer of the two finger lugs (B) (fig. 8.2). At this point, the first of the short horizontal arms (C) mounted in the cap at the top of the rod (A) should engage with the rod (D) extending downward from the trigger (E). If the position of this arm is not exactly correct, adjust it by means of the set screw in the cap. Then the shutter must rotate through a second arc of 90°, also counterclockwise, and at the same time rotate rod (A), clockwise as before, until the semicircular rod attached to the shutter engages the shorter of the finger lugs (B) and



THE FIRST MESSENGER TRIPPED THE TRIGGER FOR THE FIRST TIME. THE FIRST MESSENGER OF THE SECOND SET BELOW THE INSTRUMENT HAS BEEN CAST OFF.

Figure 8–2. Side view of Clarke-Bumpus plankton sampler.

the rod (D) from the trigger engages the second of the horizontal arms (C). The tension of the springs may be increased by removing the stops and giving the shafts extra turns in the direction opposite to their operation. The shutter has now been brought into the cocked closed position; the sampler is ready for attachment to the cable.

Another important advantage of the Clarke-Bumpus sampler is that it can be used in series on the same wire; hence, quantitative vertical tows can be made. In case more than 1 sampler is to be used, 2 messengers must be hung from the hooks at the base of rod (A) when the shutter is set. It is necessary that the wire of 1 messenger be about 10 inches long; the loop at its upper end should be passed outside the guard rod, through 1 slot in the base of the frame, and then slipped over the longer of the hooks when rod (A) is rotated for the first time. The wire from the other messenger should be about 13 inches long. It is passed through the other slot and hung on the short hook when rod (A) is rotated to its final cocked position. To make a quantitative plankton investigation, it is necessary to record the reading of the cyclometer before the sampler is lowered into the water. It is read again when the sampler is brought aboard after an observation. The difference between the 2 readings multiplied by 4 is the approximate number of liters of water filtered by the sampler.

The Clarke-Bumpus plankton sampler is attached to the wire by a hinged clamp, a spring pin, and a gate lock. To attach the sampler to the wire open the hinged clamp (F), slip it around the supporting wire, then close and tighten it by means of a wing nut so that the clamp cannot slide on the cable. Next, snap the top of the frame of the sampler onto the cable by means of a spring pin (G) and close the gate lock (H) around the neck of the clamp. Make sure that the hinged clamp (F) is closed sufficiently to allow the gate lock (H) to swivel freely around it. If messengers are to be placed below the sampler, snap them around the wire beneath the clamp, being sure that messenger hoop wires pass outside the guard rod and that the cutout surface of each messenger is uppermost. When towing the sampler, a slight bend is produced in the wire where it passes over the spring pin (G); the magnitude of the bend depends upon the amount of horizontal resistance and the size of the weight at the end of the cable. If messengers fail to strike the trigger (E) when the heaviest weight is used, the trigger should be extended by sliding out the adjustable tip of the trigger.

8–14 How To Secure the Net After A Tow.—After each use of the sampler, it must be rinsed completely with fresh water. The salt water should be removed from the metal parts, and any plankton remaining on the netting must be washed off. The sampler should be hung in a protected place so that the netting or meter will not be damaged.

8–15 Preserving and Storing Plankton Samples.—The instructions are given in sections 8–32 and 8–33 for preserving and storing plankton samples.

8–16 Maintenance of the Clarke-Bumpus Sampler.—One of the primary precautions to be taken for keeping the sampler in good operating condition is to see that all movable parts are well lubricated. For a sampler which will be used in salt water, skunk oil is the best lubricant for all exposed parts. After each use, the sea water must be washed off the sampler, especially from the cyclometer. Then dry and lubricate the sampler, clamp, and messengers with a suitable light machine oil or tectyl. The cyclometer may be kept full of oil if so desired.

If a sampler is to be used in salt water, it is advisable to have all parts of the instrument nickel-plated at the time of construction to prevent corrosion.

8–17 Spare Parts Needed.—The following are the spare parts which may be required when making observations with this sampler:

a. Silk nets of various mesh size.

b. Plankton buckets of the same size mesh as the netting.

c. Special Clarke-Bumpus messengers, 1 spare.

d. Supporting clamp, 1 spare.

e. Preserving jars for storing and shipping plankton samples collected. Pint or half-pint mason jars are recommended.

f. Formalin (37–40 percent solution of formaldehyde).

g. Sodium bicarbonate—one box.

h. Linen for patching—1 square yard.

i. Silk thread for patching—one spool.

8–18 THE MIDWATER TRAWL.—The Isaacs-Kidd midwater trawl was developed at the University of California, Scripps Institution of Oceanography. It is capable of collecting some of the larger and more active animal forms found in the ocean. As implied by its name, the trawl was primarily designed for use in midwater, that is, ocean water below the surface layers. An ordinary net will surface behind the towing vessel unless hauled at extremely slow speeds. To counteract this tendency, the midwater trawl has an inclined plane surface rigged in front of the net entrance to act as a depressor, in a manner opposite to the elevating action of a kite surface.

The midwater trawl has been manufactured with both a 10- and 15-foot mouth, and in 31- and 72-foot lengths, respectively. The following descriptions and instructions will apply primarily to the 10-foot model, but with minor modifications they will also fit the 15-foot model.

8–19 The Net Assembly.—The net is essentially an asymetrical cone of 2½-inch stretch mesh with a pentagonal mouth opening and a round cod end. From a point 3 feet in front of the cod end to the terminus of the net, an additional netting of ½-inch stretch is attached as a lining. A steel ring (or rings) is fastened in the cod end to maintain the tubular shape. A container, consisting of a specially constructed perforated can, is fastened by draw strings on the cod end of the net to retain the sample in a relatively undamaged condition.

8–20 **The Depressor Assembly.**—In front of the net, the spread-V-shaped depressor vane is rigged in such a manner as to deflect the incoming water up and into the net during towing operations, thereby depressing the vane and attached net. A spreader bar attaches to the leading edge of the top panel of the net.

8–21 **The Towing Cable and Bridle.**—The towing cable should be wire rope of sufficient strength to withstand the towing strain, such as ½-inch cable. The net may be streamed off the stern of the towing vessel, or from a boat crane off the side. If streamed off the stern, a boom or large A-frame will be necessary to facilitate handling. The breaking point of the towing cable should be determined, and a dynamometer installed in the towing system to prevent exceeding this point.

The bridle consists of 3 lines, 1 of which is divided in order to be attached to the ends of the spreader bar; the remaining 2 are shackled to the side arms of the depressor.

8–22 **Materials and Parts.**—The following table lists some of the specifications for the 10- and 15-foot trawls.

	10-foot trawl	15- foot trawl
Bridle:		
Material	0.250-inch wire rope.	0.380-inch wire rope.
Spread (feet)	10	15.
Vane:		
Area (square feet).	21	64.
Weight (lbs.)	150	400.
Material	0.125-inch steel	0.75-inch marine plywood.
Net:		
Length (feet)	31	72.
Inlet area (square feet).	80	160.
Material	2.5-inch stretch, No. 24 medium lay seine.	2.5-inch stretch No. 36 medium lay seine.
Liner: Material	0.5-inch stretch bait netting.	0.5-inch stretch bait netting.
Cod end can:		
Material	Steel	Aluminum.
Length (inches)	13.5	24.
Diameter (inches).	9.5	16.
Number baffles.	None	2.

8–23 **Assembling the Midwater Trawl.**—In assembling the trawl, the towing bridle is attached to the main hauling line with a ring and swivel, and the two lower lines of the bridle are shackled to the hinged side arms of the depressor. The net is then fastened at the three lower points to the trailing edge of the depressor. The two upper hauling points of the net are attached to the ends of the spreader bar, which in turn is shackled to the third (divided) line of the bridle. Figure 8–3 illustrates the component parts of the trawl in assembled condition. Modification and strengthening of certain parts, such as the compression strut, the tension member, and the hinge pins of the side arms may be advisable, although the depressor is designed to fold before the breaking strength of the towing cable or netting is reached.

8–24 **Streaming the Trawl.**—Placing the trawl in the water is dependent upon the characteristics of the towing ship and upon the number of men and equipment available for handling. Generally speaking, however, the cod end is put over the side with bare way on. As soon as the cod end is streamed and the net is flowing freely, the depressor should be lowered just below the surface. If the trawl is lowered over the side rather than the stern, fouling in the ship's screws can be avoided by making a gradual inside turn until the trawl is streaming well aft.

If properly streaming, the V-shaped depressor will not only cause the net to dive, but will funnel additional water into the mouth of the net, keeping the net billowed out. As soon as this occurs, and the net is well clear of the ship, the ship's speed should be increased to that desired for trawling, plus the speed of the winch as it pays out the towing cable. A continuous watch on the dynamometer should be maintained, especially during lowering and retrieving, or during changes in weather conditions, to avoid straining or parting the towing cable or trawl.

An alternate and perhaps better way of streaming the net is to pay out cable with the ship having just enough way on to prevent the trawl from fouling itself. This method allows the trawl to sink more rapidly to the desired trawling depth. When it is estimated that this depth has been reached, the ship's speed should be increased to the desired trawling speed. The trawl will then stabilize itself at a depth dependent upon the trawling speed, cable diameter, etc., and an adjustment will have to be made in the amount of cable payed out, unless this has been calculated beforehand by means of a graph.

Figure 8–3. The midwater trawl.

8–25 Towing the Trawl.—When it is estimated that enough cable has been payed out to place the trawl at the desired trawling depth, the ship's speed should be slowed to the intended trawling speed simultaneously as the winch is stopped. Reasonable maneuvering can be accomplished by the ship during trawling. The length of the trawling period should be at least several hours. At an early point in operations, a trial series of tows should be run so that a graph can be drawn showing the necessary amount of cable to be payed out for a certain depth when hauled at a certain speed.

8–26 Retrieving the Trawl.—After the trawling period is over, the ship should be slowed to the desired trawling speed less the speed of cable recovery by the winch. The slowing of the ship as the winch begins to retrieve the wire must be a smooth operation, so that the actual net speed always remains the same. Any time the retrieving action is stopped, the ship's speed should be increased again to the desired trawling speed. Caution should be taken at all times to see that the actual trawling speed of the net is kept constant, to avoid excessive strain from an increase in speed, and to avoid allowing entrapped animals to escape with a decrease in speed.

8–27 Additional Instructions.—Any increase in trawling speed may cause the trawl to dive more steeply. This additional deepening must be taken into consideration if tows are being made close to the bottom.

Because of the additional strains due to the surging of the towing ship during heave swells, the trawl normally will be used in fair weather. Special emphasis should be placed on trawling when a pronounced deep scattering layer is indicated on the echo sounder.

The depth of towing is of prime importance, and any depth gauge available and suitable should be used if possible. Experimentation may be desirable such as the use of explosives or fish poison (a seepage container of rotenone) in front of the net entrance, the use of a half-meter plankton net of coarse mesh in place of the cod-end can, or the installation of several truncated cones of netting within the cod end (similar to a fish weir) to prevent fish from escaping the net.

8–28 Removal of Specimens.—Carefully and immediately remove *all* specimens from the net. Small specimens should be kept in addition to larger specimens. Immediately place specimens in containers of sea water for subsequent preservation. Color photographs in daylight should be taken of each catch if possible, but must be taken almost immediately, as fish lose their color rapidly when exposed to air or when preserved. Photography may best be done by placing the specimens in sea water in a shallow tray which has been marked off with painted 1-inch squares or other suitable scale. Print the trawl serial number on a slip of paper and place it in a corner of the tray to be photographed, in order to provide positive identification.

8–29 Preservation of Specimens.—Preservation should be made immediately after photographs have been taken. The specimens should be placed in suitable containers as described in sections 8–33 and 8–34. A Mid-Water Trawl Sample label (N. H. O. 1338) should be filled out and placed inside the jars or containers, facing out. These labels (fig. 8–4) are printed on a special linen paper which will last many years in preserving solutions. They must be filled out with pencil (No. 2½ or 3H is most desirable), and not ink nor indelible pencil. If samples are split into more than one container, label each container and note in the Remarks column. Fish over 3 inches in length should also have some of the formalin injected into their body cavity.

If bottles are not available, contents of various trawls may be tied up in porous cloth and placed in a larger container of preservative, and each bag thus formed properly marked.

8–30 Shipping Instructions.—Pack sample containers in wooden cases for shipment to the U. S. Navy Hydrographic Office (Code 5430), along with all log sheets and photograph negatives.

8–31 Precautions.—After using the net, it is not necessary to rinse it in fresh water, but it should be spread and thoroughly dried; never store it in a damp condition.

8–32 PRESERVATION OF BIOLOGICAL SPECIMENS.—Specimens taken by plankton tows are stored in quart or pint-size mason jars. Those specimens taken by midwater trawls that are too large to fit in glass jars may be wrapped in cloth and placed in a container after the preservative has been injected. Specimen jars should be nearly full to prevent damage to the specimens due to sloshing, but leave a small air space to allow for expansion within the closed jar. Do not overcrowd specimens in the jars as this will prevent keeping enough sea water in the container. Overcrowding will also cause fish to harden in distorted shapes. Fill the jars only *one-third* full of specimens then add sea water to about 1 inch from the top. If the bucket and net contain more samples, use additional jars.

8–33 Preservative Used.—The best and most easily prepared preservative is a 5-percent solution of commercial formalin (37- to 40-percent solution of formaldehyde gases). The specimens are preserved by adding to the sea-water-filled sample jar a pinch of sodium bicarbonate (baking soda) and the following amounts of formalin (which will give approximately a 5-percent solution):

to a pint jar, add 20 ml. of formalin;

to a quart jar, add 40 ml. of formalin.

Insert the special sample label, face outward, before sealing the jar.

8–34 Preservation of Fishes.—Small fishes are stored in jars and preserved in the same manner as described for plankton. Specimens more than 3 inches long should have some of the 5-percent solution of formalin inserted into the body cavity with a syringe before storing in the solution. If the fish is too large to be stored in a jar, it should have the body cavity filled, be wrapped in formalin-saturated cheesecloth, and be packaged in a waterproof material. Long thin fish may be stored temporarily in preservative-filled coring tubes.

350676 O—56——7

PLANKTON TOW SAMPLE

Sample No.: 26

General Location: STATION RE-15-34

Lat.: 43° 30′ N Long.: 29° 39′ W

Date: 27 AUG 1955 Time (GMT): 2000

Duration of Tow: 15 MINUTES

Mesh No.: 0 Mouth Diam.: ½ M.

Depth of Tow: 2 meters

Temp.: 21.36 °C. at 1 meters

Collector: B S Richmond

Ship: USS REHOBOTH (AGS-50)

Remarks:

N.H.O. 1338a (New 5-52)

MID-WATER TRAWL SAMPLE

Trawl Sample No.: 5

Date: 27 AUG 55 Net Used:

Start: Time (GMT): 2315

Latitude: 43° 32′ N

Longitude: 29° 31′ W

End: Time (GMT): 0340

Latitude: 43° 20′ N

Longitude: 29° 38′ W

Depth of Tow: 212 meters

Average Depth of Bottom: 2340 fms.

Depth of Deep Scattering Layer, if present: fms.

Observer: B S Richmond

Remarks:

N.H.O. 1338 (New 11-51)

Figure 8–4. Plankton tow sample label and midwater trawl sample label.

CHAPTER 9

CURRENT MEASUREMENTS

9–1 GENERAL REMARKS.—Probably more types of instruments are used for measuring currents than for any other single oceanographic measurement. Devices range from the simple drift bottle to the automatic radio transmitting and monitoring system of Roberts radio current meters. Although many types of current-measuring instruments have been developed most of them are limited in their use, either by cost or design. A simple, rugged, and accurate instrument that can indicate weak as well as strong current speeds, direction, and depth is still one of the most important needs of oceanographic instrumentation.

Types of current-measuring instruments may be divided into three broad and general categories: free floating, shallow water, and shipboard. Those in the first category include drift bottles, dye marks, and floats that could be observed from ship, shore, or aircraft. Those in the second category include instruments that are attached to piers, buoys, or beacons, or are placed on the bottom in rivers, bays, estuaries, and other nearshore areas at more or less set depths. Those of the third category include instruments that can be operated when the ship is underway and those operated when the ship is anchored. Representative instruments of the second and third categories are discussed in this chapter.

To take surface current measurements when underway, Navy survey ships use the GEK. From this instrument the speed and direction of surface currents can be calculated rapidly. Subsurface currents at various depths are determined from a ship at anchor with the Ekman, Price, or Roberts current meters. The Ekman and Roberts meters record both speed and direction while the Price indicates speed alone.

9–2 INSTRUCTIONS FOR OPERATING THE GEOMAGNETIC ELECTROKINETOGRAPH (GEK).—The GEK is a shipboard surface-current measuring device designed to record the electrical potential developed by the movement of an electrolyte (ocean current) through a magnetic field (the earth's) in depths of more than 100 fathoms.

The essential physical equipment constituting the instrument is:

1. A matched pair of electrodes mounted 100 meters apart on a 2-conductor cable long enough (ordinarily 3 times the length of the ship) to stream them astern, away from the magnetic influences of the ship.
2. A recording potentiometer assembly to which the cable is connected.
3. A gyrocompass repeater, mounted above or close to the recorder assembly.

With the above equipment, observations of the potential difference between the electrodes along the ship's course and at right angles to it are made underway. These potential differences are due to the motion of the water through the earth's magnetic field. They are rigidly related to the set and drift of the ship and to the electrodes. The potential difference changes sign when currents set the ship to port or starboard. The magnitude of the potential difference depends on the rate of drift normal to the course, the length of cable between electrodes, the local strength of the vertical component of the earth's magnetic field, and to some extent on the vertical distribution of water velocities in the vicinity. Through measurements of the potential differences on 2 courses nearly at right angles, the drift or component velocities in these 2 directions are known. The vector sum or resultant of these velocities is the surface current vector for that locality.

9–3 Electrical Power Requirements.—The power required to operate the GEK is usually 110 volts, 60 cycles, AC, with a power consumption under 100 watts.

9–4 Isolation Transformer.—It is necessary to isolate the power with an isolation transformer to block any possible DC leakage that may be present on the lines. The voltage and frequency of the input power should be monitored to arrest any variation of timekeeping on the synchronously driven strip chart. Moreover, monitoring assures maintenance of optimum sensitivity of the recorder amplifier, which is slightly sensitive to supply voltage. All components of the power supply and the instrument side of the isolation transformer should be insulated from the ship.

9–5 Signal Input Leads.—The signal input leads connect the overside cable and electrodes to the recording potentiometer. They should be shielded and insulated from the ship. Grounding is not often necessary, but when it is, the safest ground is the first electrode on the overside cable.

9–6 Recording Potentiometer.—The potentiometer component is a recorder having a 2-second pen movement, and ⅓-inch-per-minute basic strip-chart speed. The upper part of the instrument scale and the strip chart is calibrated in centimeters per second and the lower part in knots. A set of the ship to port is indicated to the left and starboard set to the right of the instrument zero at the center of the scale.

9–7 The Cable.—The primary function of the cable is to bring aboard a signal from far enough astern to be unaffected by the ship's magnetic field. The cable may tow in the wake, for turbulence there is usually too small and rapid to be resolved. But it is easier on the cable and better practice to tow it from the end of a boom similar to that used for the bathythermograph. The clearance between the ship and tow point should be sufficient to allow the cable to pass clear of the stern even during rapid turns. An outhaul to the end of the boom permits convenient handling in streaming and retrieving the cable when underway. In streaming the cable, it is necessary to avoid kinks and to keep the cable clear of the screw.

9–8 Cable Connections.—Cable connections to the recorder should be made according to the following convention for the northern magnetic hemisphere: the conductor leading to the more distant electrode is connected to the input terminal which is made positive and gives a right-hand deflection of the pen. This convention allows the observer facing the recorder to see the pen on the same side of zero as the direction toward which the ship is being set. The connections must be reversed in the southern magnetic hemisphere to have the same convention apply.

9–9 Electrodes.—The electrodes have been specially lagged in order to withstand repeated changes of salinity and temperature. Allow at least 30 minutes wetting time when first towing the electrodes. Once wetted, the electrodes should respond without delay even though they may have been on deck several hours.

9–10 Spare Parts Needed for the GEK.—The following spare parts are needed to operate and maintain the GEK.

1. Spare cable with electrodes.
2. Electronic service kit with a spare set of electron tubes for servicing the amplifier.
3. Spare 1.5-volt dry cells.
4. Spare glass pen with stopper and cleaning wire.
5. Bottle of red recorder ink.
6. Spare strip-chart rolls.
7. Instruction Manual, "Directions for Speedomax Type-G Recorders."

9–11 Tools Needed for the GEK.—For normal operations, a medium-size screwdriver and a pen cleaner are all that ordinarily are needed.

9–12 GEK Models.—Navy survey ships have two models of the GEK in use. The earlier type was developed and constructed at the Woods Hole Oceanographic Institution and is referred to as the WHOI Model. The later type is commercially made and is called GEK Model V. Although the two models operate in almost the same manner, there are minor differences in locations and arrangements of operating switches and dials. The GEK Model V is more compact than the earlier WHOI Model. Both use Speedomax Type-G Recorders. Operating and maintenance manuals for this type of recorder are supplied by the manufacturer (fig. 9–1).

9–13 OPERATING THE GEK MODEL V.—Operation of the GEK Model V is carried out in the following manner.

9–14 Stream the Electrodes.—Rig out the boom and stream the electrodes. If they have not been used for several days, allow 30 minutes for wetting. Turn all switches on the panel of the GEK recorder to *OFF* (*DOWN*) position. Plug in the electrodes at the input terminals, and turn on the 110 AC power supply.

9–15 Main Power.—Turn main *POWER* switch to *ON* position.

9–16 Paper Motor.—Move *PAPER MOTOR* switch inside the recorder door to *ON* position.

9–17 Semiautomatic Current Adjustor.—After 1 minute of power-on, turn the *SEMIAUTOMATIC CURRENT ADJUSTOR* (small knob to left of the strip chart in the recorder) *clockwise* for an instant and repeat until the recorder pen does not respond. The pen should indicate zero; i. e., lie at the center of the chart paper.

9–18 Sensitivity Control.—Turn the *SENSITIVITY CONTROL* (knob marked *X* in

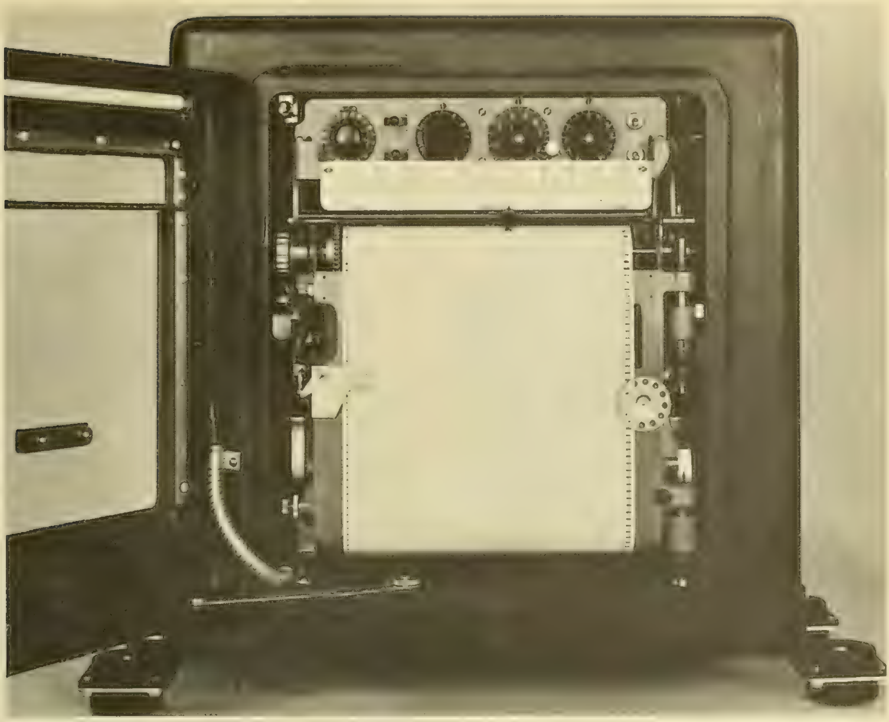


Figure 9-1. GEK Model V recorder showing locations of operating switches and dials.

upper left-hand corner of panel) *clockwise* all the way, and then return it to the point where the pen just ceases to quiver.

9–19 Vertical Intensity (H_z).—Set the *VERTICAL INTENSITY* knob, marked *H_z OERSTED*, to the value of the nearest standard isodynamic line shown on H. O. Chart No. 1702 for the position of the ship at the time of the observation.

9–20 Wave Signal Suppression.—If sea conditions cause the recorder pen to oscillate with more than a 15 cm./sec. range, increase the *FILTER RESISTANCE* dial setting from zero until the wave signals are sufficiently suppressed to give a readable trace. Do not suppress the wave signal excessively as it will make it too sluggish. An oscillation with a range of about 15 cm./sec. is best. Log the total suppression used as indicated on the *FILTER RESISTANCE* dial. When the circuit is secured after an observation make sure that the dial is turned to zero position and move the *SUPPRESS WAVE SIGNAL* switch to the *CAP. SHORT* position. This short-circuits the capacitors and releases any accumulated dielectric strain.

In rough weather when heavy wave signal suppression is needed it is well to examine the wave signal without suppression from time to time. To do this move the *RC* switch momentarily to the *RC*=0 position. In case a capacitor is faulty or the sea is on the beam, the suppressed signal will not coincide with the densest part of the unsuppressed signal. If a change of *FILTER RESISTANCE* has no effect, the asymmetry is due to the direction of the waves. The amount and sign of asymmetry and its probable cause should be noted on the log sheet.

9–21 Signal Multiplier.—The *SIGNAL MULTIPLIER* dial increases or adjusts the size of the input (wave) signal.

9–22 Electrode Zero Point Control.—Before the initial base course run is begun, the zero point can be adjusted to approximately the instrument zero (centerline) by use of the *ELEC. ZERO* dial. By slowly turning this dial to the right or left, the pen can be brought to the instrument zero point. Once this setting is made, it should not be changed during the period of the actual current observation.

In the vicinity of the continental margin of the Gulf Stream, the changing temperature and salinity will shift the zero point at each crossing. Study the zero-point trends, and if necessary adjust the zero point before the GEK run so that it will shift symmetrically about the instrument zero with each crossing.

9–23 Maneuvering the Ship for a GEK Observation.—The course the ship is required to steer for a GEK observation is determined by the requisites: (a) That potentials must be measured on at least two headings at right angles if possible and (b) that for each current fix the electrodes must be reversed end for end to determine the zero point (the average of the 2 voltages obtained by making a 180° course change). This is accomplished by executing a current fix as follows:

1. After the electrodes have become thoroughly soaked and the pen motion has steadied, remain on base course for 4 minutes.

2. Change course 90° and run for 4 minutes after the electrodes steady-on the new course. This is the first fix course.

3. Change course 180°, turning in the direction of the base course, and run for 4 minutes after the electrodes steady-on the new course. This is the second fix course.

4. Change course 90° and resume the base course. Run for 4 minutes after the electrodes steady-on the base course to obtain the resumed base course data.

9–24 Recording the GEK Data.—The data obtained by executing the current fix are recorded on oceanographic log sheet—GEK 1. Instructions for filling in this log sheet are given in chapter 14. When filling in the log sheet, it is well to remember that the instrument zero is the centerline of the strip chart and the range is *plus* and *minus* 250 cm./sec. to the *right* and *left*, respectively, of this line.

9–25 Marking the Strip-Chart Record.—The measurements require the continuous attention of a trained observer. In addition to keeping the log sheet, it is necessary to record the following information on the recorder strip chart:

1. The GEK observation serial number.
2. The day, month, and year.
3. The Greenwich mean time for the beginning of the first 4-minute base-course run. Additional information as to depth, wind direction and speed, and sea state is helpful to those interpreting the data.
4. Electric zero setting.
5. Filter resistance setting.

During the current fix, the following information is recorded on the strip chart as indicated:

1. A change of wave signal suppression

$$\frac{\text{C8}}{\text{C6}}\ \text{0932Z}$$

2. A course change

$$\frac{135^\circ\ \text{T}}{045^\circ\ \text{T}}\ \text{2055Z}$$

The strip chart moves downward under the pen; hence, the line between the changed values of any quantity indicates the moment of change, and the lower value is the condition existing earlier than the upper value (fig. 9–2).

Figure 9–2. Marking the GEK record.

9–26 Reading the Strip Chart.—In reading the voltage signals on the strip chart, some variability of results will be inevitable from person to person. The principal sources of this variability arise in making estimates of the average voltage due to the mean water current through the confusion of turbulence and wave signals, and making estimates of each turn signal. Better results are obtained in determining the average voltage if done entirely by eye without the use of pencil marks or a ruler. Estimation of the beginning and end of a turn signal can be aided by measuring the interval of time during execution of a turn. Inasmuch as the electrodes are towed at a considerable distance behind the ship, there is a lag in the electrode's turn signal. Thus the electrodes do not steady on the new course for a minute or so after the ship has steadied and similarly do not commence their turn when the ship commences turning. The turn signal lasts as long as the ship's turning time and is received approximately L/C_s minutes after the ship has commenced turning. L is the length in meters of the cable towed astern, and C_s is the ship's speed in meters per second. Anticipating and marking the beginning and ending of the turn signals as they occur will improve the consistency of interpretation of the data, both at sea and in later study of the records. It is well to be extravagant in delineating the turn signals, for if the voltage shift on two courses is large, both the electrodes and the capacitors in the wave signal suppressor (filter resistance) must have time to come to equilibrium.

Best results are obtained if the first half of a fix signal is viewed with suspicion and greatest weight is given the latter portion of the trace when the ship's heading, the electrochemical system of the electrodes, and the capacitors in the wave signal suppressor system have all had time to come to equilibrium. Although instrument zero lies in the center of the chart paper, the electrode zero point does not necessarily coincide with the instrument zero point, unless adjusted by the electric zero control.

9–27 Securing the GEK After a Current Fix.—After a current fix, the instrument is secured by turning all switches on the panel inside the instrument door to *OFF* (*DOWN*) position (sec. 9–20). In addition, the cable must be retrieved if the ship is to be stopped before taking the next current fix. In the case of a long cessation of operations, the AC power supply should be unplugged from the recorder, and the automatic current adjuster should be taken out of the operating (standard cell) position (sec. 9–20).

9–28 MAINTENANCE OF THE GEK.—Both routine and special maintenance for the recording unit are described in detail in the direction manual supplied with the instrument.

The parts of the recorder are easily accessible. The door opens wide to the left. The chart-drive-reroll unlatches to swing out to the right, bringing the chart to a handy position for replacement and exposing the main slidewire. With or without the chart-drive-reroll latched in place, the entire assembly swings out around the same hinge making the balancing motor, paper-drive motor, standardizer, and dry cell completely accessible. Amplifier, fuses, and terminal boards are then exposed on the back of the recorder case. To inspect the amplifier, remove the entire unit from the case. A small indicator at the left edge of the strip chart shows a red signal when a new dry cell is needed.

9–29 The Strip-Chart Paper.—A roll of strip-chart paper is 120 feet long. It is driven at a speed of ⅕ inch per minute; consequently, it should last for about 5 days of continuous operation. Note how the roll in the instrument is threaded through the guides so that the fresh roll can be threaded properly when it is necessary to change rolls. Sometimes the paper on the take-up roll tends to bunch or bind at one end. This can be straightened by adjusting the thumb screw at the left end of the feed roll until both edges of the paper line up in the slot cut in the platen above the telltale wheel at the right. Badly bunched paper should be rerolled before adjusting the thumbscrew.

9–30 The Recorder Pen.—If the pen stops inking while it still contains ink, moisten a finger and draw it across the penpoint. If this fails to start the flow of ink remove the pen from the carriage, and push a fine wire through the point to clean out any particle clogging it. If the ink still does not flow, install a new pen. Place the clogged pen in alcohol or boiling water for a short time. Remove the pen from the solution, and insert a cleaning wire as previously directed. Then fill the pen with alcohol or warm water, and blow the liquid out through the penpoint. Allow the pen to dry thoroughly before using.

9–31 Cable and Electrodes.—In case of cable and/or electrode failure, the entire unit of cable with electrodes must be replaced. Inasmuch as the electrodes are matched and balanced very carefully, any damage to one electrode requires replacement of both.

9–32 Junction Box.—The junction box, where the cable plugs into the recorder line, usually is located in a relatively exposed position. It must be kept dry and clean as it is likely to be the principal source of instrument failure.

9–33 The Recorder.—Both routine and special maintenance for the recording unit are described in detail in the operating and maintenance manuals supplied by the manufacturer for the instrument.

9–34 COMPUTING THE CURRENT FIX.—It is usually unnecessary to process the data aboard ship. In the event that the results of a current fix are required at sea for special studies, they can be obtained by completing oceanographic log sheet GEK 2 in accordance with the instructions given in chapter 14.

9–35 STORING AND SHIPPING RECORDS AND DATA.—Each used chart roll should be placed in its container and plainly marked with the ship's name, cruise number, dates of the beginning and end of the chart, and the roll number. The associated oceanographic log sheets GEK 1 and 2 should be placed in a manila envelope and similarly marked. At the end of a cruise, these records should be forwarded along with the other survey data to:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430

9–36 SUMMARY OF IMPORTANT POINTS.—To insure proper operation of the GEK, always be certain that:

1. The distant electrode (black lead wire in the electrode string) is connected to the positive input terminal (sec. 9–8).
2. The dry cell in the recorder is in good condition.
3. The junction box is dry and its contact bright.
4. The cable is plugged in properly at the junction box when the instrument is in operation.
5. The recorder is not stopped for an extended period with the automatic current adjuster in the operating (standard cell) position.

9–37 INSTRUCTIONS FOR OPERATING THE EKMAN CURRENT METER.—The Ekman current meter was developed by Dr. V. Walfrid Ekman, a Swedish scientist, whose original design, although modified, remains basically unchanged. The meter is designed to give speed and direction of the current at any depth. It consists of an impeller or screw, and shaft connected to a set of dials. The number of shaft revolutions per unit of time is read from the dials on the main body of the meter. A reservoir of bronze balls is connected by a narrow tube to a compass box containing a compass needle. Below the needle is the compass-ball receptacle which is divided into 36 chambers, each representing 10° of azimuth. As the impeller rotates, the balls fall, one at a time, onto the top of the compass needle which guides them into one or another of the chambers, depending on the heading of the current meter. This gives the direction *toward* which the current is flowing.

The current meter is lowered on either the oceanographic or bathythermograph wire. The impeller is locked while lowering or hoisting. A messenger is sent down the wire to unlock the impeller and set the meter in operation. A second messenger is sent down to lock the impeller and stop the meter before hoisting (fig. 9–3).

Figure 9–3. The Ekman current meter.

Valid measurements cannot be made with an Ekman current meter unless the ship or buoy from which it is suspended is anchored.

Instructions for operating the Ekman current meter are given in the U. S. Coast and Geodetic Survey Special Pub. No. 215, Manual of Current Observations. They are given briefly here.

9–38 The Carrying Case, Spare Parts, and Accessories for the Ekman Current Meter.—The components, spare parts, and accessories for the Ekman current meter are contained in a carrying case. When assembling a meter, care must be taken in removing parts from the case. All parts must be checked before assembling the meter. After completing a current survey, each part must be removed from the body of the meter and thoroughly rinsed in fresh water before returning it to the proper compartment in the case. In addition to the main body of the meter, the following parts are included in the carrying case:

1. One tail section or vane.
2. Two individually calibrated impellers and shafts.
3. Two compass-ball receptacles.
4. Two messengers.
5. One metal container of bronze balls.
6. One graduated reading frame.
7. One key for tightening the vane tubes to the body of the meter.

9–39 Assembling the Ekman Current Meter.—The meter is seembled for operation as follows:

1. The vane, or tail, is attached to the meter by two brass tubes which are secured to the vane with left-hand threads and then fastened to the main body by right-hand unions. The unions are tightened with a special key provided in the case.
2. The impeller is inserted by releasing a bar at the front of the meter perpendicular to the axis of the shutters. Insert the worm gear end of the impeller shaft through the hole in the gear box and secure the bar. The forward bearing of the impeller shaft is held by this bar. The impeller is very delicate and has been tested and calibrated; therefore it must be handled with great care. Needless to say, the calibration would be worthless should one of the blades be bent or its axis changed.
3. To place the compass needle in the compass box, the compass-ball receptacle must be removed from the main body of the meter. The compass box then becomes removable by pressing the catch on the bottom of the frame just above and forward of the compass box. Remove the cover and set the compass needle on the pivot point in the box. When replacing the cover, the bevel of the slot for prying off the cover should face downward and the small lug on the box should fit into the small notch on the cover. Replace the compass box on the frame, then the compass-ball receptacle.
4. Attach a 15-pound streamlined lead weight, such as the Columbia type, to the bottom of the meter frame.
5. Fill the reservoir with bronze balls, close the shutters, and lock the impeller. The meter is now ready for operation.

9–40 Operating the Ekman Current Meter.—This meter is a complicated, delicate instrument; therefore, it must be handled carefully. Check it over carefully before each lowering. All movable parts must be oiled and must work freely. It is necessary that the bronze balls be deposited regularly according to the speed with which the impeller rotates. The reservoir of balls should be filled and the compass-ball receptacle empty before each lowering.

The dial readings must be recorded or the pointers set at zero before lowering. The pointers on the meter dial are adjustable, but as they are held on the shafts by friction, adjustments should be kept to a minimum or they will become worn and loose. A recommended method is to set the dials to zero at the beginning of survey operations and record the settings before and after each lowering without further adjustments. This way, the last dial reading of an observation will be the first dial reading of the following lowering. It will be noted that the numbers on the dials are in reverse order to give decreasing readings; thus, the number of shaft revolutions for each lowering may be obtained by subtracting the final from the initial reading.

9–41 Lowering the Meter and Obtaining the Current Data.—The meter may be lowered from either the oceanographic winch or the bathythermograph winch. Successful lowerings from the latter have been made on Navy surveys.

After the meter is lowered to the desired depth, a messenger is attached to the wire and released and the time recorded. After a definite time interval, usually 10 minutes, a second messenger is attached to the wire and released. This time is also recorded. The first messenger opens the shutters and unlocks the impeller; the second messenger stops the impeller. After permitting sufficient time for the second messenger to stop the meter, allowing 200 meters per minute as the rate of drop for the messengers, the meter is hoisted to the surface and brought aboard. When bringing the meter aboard, care must be taken to keep it in a vertical position until the compass-ball receptacle is removed. Tilting of the meter may cause the balls in the receptacle to transfer from one compartment to another thereby making the lowering worthless. Record the dial readings and time in the Record of Current Observations for Ekman Current Meter PRNC–NHO–1507.

9–42 Computing the Current Direction.—The compass-ball receptacle containing the bronze balls is removed from the meter and placed in the graduated reading frame. When fitting the receptacle in the graduated frame the red or north compartment of the former is alingned with the 0 graduation of the latter. A ball in any compartment indicates a current having an approximate azimuth corresponding to the number on the frame with a zero added.

For example, a ball in compartment 35 indicates a current flowing approximately 350° magnetic. Balls may be found in more than one compartment. In this case, a system of weighted averages will determine the current direction. For example:

Compartment No.:		*No. of balls*		
310	×	3	=	930
320	×	5	=	1, 600
330	×	4	=	1, 320
340	×	7	=	2, 380
Total		19		6, 230

$\frac{6{,}230}{19}$=328° current direction (magnetic)

In computing the current direction, the local magnetic variation must be applied to obtain true direction.

If it is desirable to resume observations with minimum delay, the second compass-ball receptacle may be used. The meter can then be returned to the water immediately after the dial reading has been taken and the instrument prepared for operation.

9–43 Computing the Current Velocity.—Each meter used for Navy surveys is calibrated to determine the relation of the speed of the current to the speed of rotation of the impeller. Each meter usually is provided with an extra impeller and each is calibrated separately. Either a rating formula for computing current speed is provided for each impeller, or a calibration curve is drawn with revolutions per minute and current speed in knots as coordinates.

From the times recorded on the log sheet, the number of revolutions per minute can be calculated. Knowing this, the current speed is obtained either by inspection of the calibration curve or by applying the formula.

9–44 INSTRUCTIONS FOR OPERATING THE PRICE CURRENT METER.—The Price current meter was originally designed by Assistant Engineer W. G. Price, Corps of Engineers, U. S. Army. It is designed to measure current speeds from 0.1 to 11 feet per second (0.06 to 6.6 knots). It does not measure current direction. Current direction must be determined by other means when using this instrument.

The meter consists of a number of cone-shaped cups mounted on a vertical rotating shaft called the cup shaft. For every 1, 5, or 10 revolutions of the cup shaft, depending on the model being used, an electrical circuit in a contact chamber is closed and transmits a signal to the observer through a 2-conductor electrical cable and a set of earphones. In place of earphones, an automatic recorder with a time-marking system may be connected to the circuit. Power for the circuit can be supplied by dry-cell batteries. The number of revolutions of the cup shaft, when applied to the calibration or rating table, indicates the speed of the current (fig. 9–4).

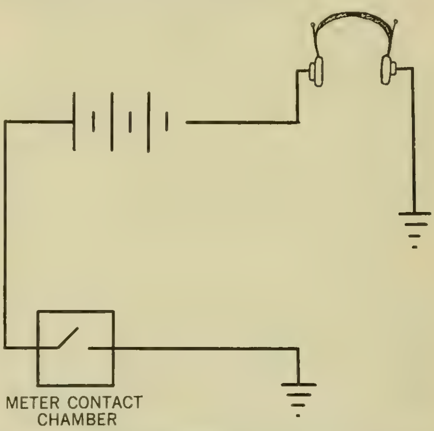


Figure 9–4. Wiring diagram for Price current meter.

Complete instructions for operating the Price current meter are given in the U. S. Coast and Geodetic Survey Special Pub. No. 215, Manual of Current Observations. Given briefly below are general operating instructions and recommendations.

9–45 Price Models.—A number of different models of the Price meter are available for use. The meter generally used for ocean surveys is the deca-count model which transmits a signal for every 10 revolutions of the cup shaft. An old and new model of the single- and penta-count meter is also available.

9–46 Contact Chamber.—In the old model, the single- and penta-count gears and contact points are housed in separate contact chambers. If it is necessary to change the entire contact chamber in the older type meter to obtain a different count, the small spindle at the top also must be changed. In the new model, the 2 gears are contained in 1 chamber and either is made operative by connecting the proper wire. Electric power is supplied by 1 or 2 dry cell batteries.

9–47 The Cable.—The meter is suspended from a 3-strand, 2-conductor cable. Two insulated copper wires provide the electrical connections while the third strand, a steel piano wire, supports the meter. This cable should be inspected frequently for breaks. Extreme care must be taken to insure watertight connections of the cable to the contact chamber gland. Should the piano wire require replacement, $\frac{3}{32}$-inch stainless steel wire rope (bathythermograph wire) may be substituted.

9–48 The Vanes and Supporting Rod.—The meter is kept facing into the current by two tail vanes set at right angles and a streamlined lead weight at the bottom of the vertical supporting rod. Proper balance of the meter is made by adjusting a small movable weight on one of the vanes.

9–49 The Stopwatch.—Whenever taking observations directly with the earphones, it is necessary to have a reliable stopwatch. Be sure to check the stopwatch against a chronometer of known rate before using it. In the past, much time and data have been lost because of faulty stopwatches.

9–50 Recording the Data.—The method of recording the Price current meter data directly by earphone is simple. At the instant the signal is heard start the stopwatch and count a predetermined number of clicks. When the last click is heard, stop the watch and record the number of seconds elapsed in the Record of Current Observations for Price Current Meter, PRNC-NHO-1506. The calibration or rating table is then used to convert to current speed.

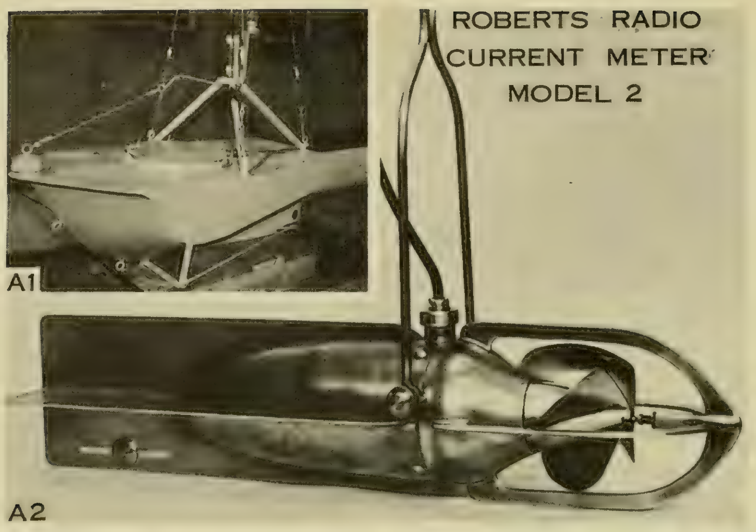
Special emphasis should be placed upon the collection of supporting meteorological data. Visual observations should be made of surface wave and current directions and conditions. The data, ship's name and position, Greenwich mean time, depth to the bottom, and depth of the meter must be recorded also.

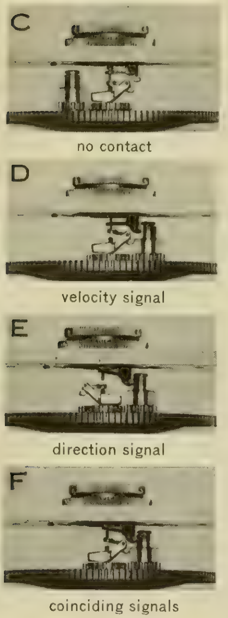
9–51 Care and Maintenance of the Price Current Meter.—Prior to lowering the meter into the water, a close inspection of all splices and connections should be made to prevent loss of the instrument or parts. Loose splices and worn cables must be replaced. Electrical connections should be soldered wherever possible. The cup shaft bearings should be kept clean and well oiled. To prevent corrosion of the contact points, the contact chamber should be filled with a light oil when in use. The meter should be rinsed in fresh water and all moving parts oiled after use.

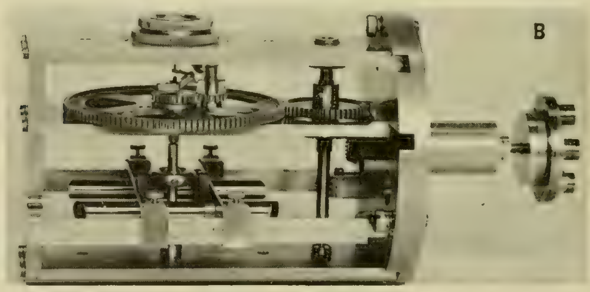
9–52 INSTRUCTIONS FOR OPERATING THE ROBERTS RADIO CURRENT METER.—The Roberts Radio Current Meter is an instrument designed specifically to record subsurface current speeds accurately and simultaneously indicate the direction of the flow. The basic components consist of a buoy from which 1 to 3 meters may be suspended, an automatic radio-transmitting system within the buoy, and a ship- or shore-based radio-receiving monitoring system which can monitor up to 15 meters. The buoys usually are anchored in bays, rivers, channels, or other relatively shallow areas. Meters have been operated successfully at depths as great as 2,500 meters from anchored ships.

A current study of an area, employing Roberts meter and associated equipment, is a large-scale field operation, requiring approximately 10 men including experienced technicians and observers. A vessel capable of handling the survey equipment and shore facilities for repair of the gear is necessary for efficient operation.

9–53 The Principle of Operation.—The current meter is suspended at any desired depth from a buoy of special design which contains a battery-powered radio transmitter and selecting device, and supports an antenna and warning lights (fig. 9–5). The meter aligns itself to the direction of the current flow. The current drives an impeller, or screw, in the nose of the meter. The impeller is connected by a magnetic drive through a watertight bulkhead to an enclosed mechanism which makes and breaks an electrical circuit by means of two contacting devices. One device makes a contact at each fifth turn of the impeller and the other at every tenth turn. The frequency of the contacts serves as a measure of velocity. The first contacting device is connected with a built-in magnetic compass and the second is fixed relative to the position of the meter body. The contacting mechanisms are so arranged that when the instrument is heading south both contacts will close at the same time. When the meter heads in any other direction the time relation between the two sets of contacts changes with the meter heading. This serves as a measure of direction. The contact makes and breaks, relating to direction and speed, are relayed via watertight electrical cable to the buoy where the transmitter is keyed to produce radio signals on a designated frequency. The operating frequency is controlled by a crystal selected for maximum results in the specific area. These signals are received, amplified, and recorded on tape by means of a chronograph at the ship- or shore-based monitoring station. Observers at the monitoring station record the signals on tape from several current meter stations by adjusting the receiver to different frequencies at timed intervals. Up to five stations can be







THE ROBERTS RADIO CURRENT METER (A2) is streamed from a buoy (A1) anchored at the desired station and containing a battery-operated radio transmitter and antenna. It is suspended below the buoy at the desired depth and is connected by an electric cable. As the meter aligns itself in the direction of flow its impeller reacts to the flow actuating an interior contacting mechanism (B) which in turn communicates to the buoy, where the radio transmitter is keyed to produce radio signals indicating current direction and velocity which are received, amplified, and recorded at a radio station ashore or afloat. The details of the contacting sequence as actuated by the contacting mechanism (B) are shown in Figures C, D, E, F.

Figure 9–5. Roberts radio current meter, Model 2.

monitored by a single shore station. The data are interpreted, scaled, and plotted on graphs at the station for processing at the Hydrographic Office.

9–54 Equipment Needed To Operate the Roberts Radio Current Meter.—In addition to the current meter itself, the following listed accessory equipment is necessary (fig. 9–6).

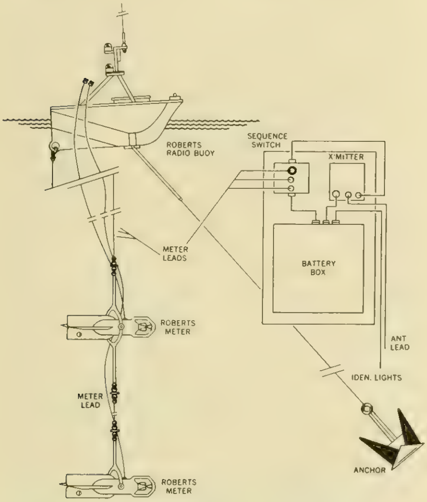


Figure 9–6. Buoy-operated Roberts radio current meter.

1. A Roberts buoy, which is designed to permit a minimum resistance to surface wave action, is constructed to house the power supply transmitter and sequence switch, and is fitted with an antenna and identification lights.
2. A suitable anchor, usually a 150-pound Danforth type, with 5/16-inch chain or 1/4-inch wire rope, depending upon the requirements of the area.
3. Wire rope, 3/32-inch diameter of 7 x 7 stranded stainless steel with nylon covering, to suspend the meters and electrical cable from the buoy. The nylon covering is necessary to provide minimum magnetic resistance to the meter mechanism.
4. A compact transmitter, such as Rixon Model 161, capable of transmitting the meter signals over a 15- to 20-mile range from the anchored buoy.
5. A sequence switch designed to facilitate multiple meter operation from one buoy. The switch serves as a selector for three meters suspended from the buoy, giving identification signals and permitting a transmission period for each.
6. A whip antenna of stainless steel, 96 inches long, fitted with an insulator and supporting bar.
7. A battery power supply for the system.
8. A monitoring radio receiver to receive the band width of the crystals used at various meter stations and locations. A National HRO–50 has been found satisfactory.
9. A crystal-controlled oscillator, at the monitor, to permit accurate pinpointing of the desired frequency.
10. A chronograph, electrically driven or spring wound, depending upon types available.
11. A break-circuit chronometer, 6 volts.
12. A relay box, specially constructed, containing essentially 2 relays of 1,000 and 10,000 ohms. The 1,000-ohm relay serves to isolate the chronometer from the higher powered chronograph circuit whereas the 10,000-ohm relay transposes the audio signal from the receiver to a DC pulse which is supplied to the chronograph to produce graphic representation of current speed and direction.

9–55 Equipment Check List and Spare Parts Needed for Operation of the Roberts Radio Current Meter.—In addition to the equipment listed in the preceding paragraph, the following check list of necessary equipment and spares for the operation of 10 meters and 6 buoys is given.

1. Hanger, meter, brass (included in meter case)—10 sets.
2. Cable, electric, 2 conductor stranded, Tirex 16 Jr. or Navy DCOP–2—2,000 feet.
3. Oil, instrument, Esso formula 1191—10 gallons.
4. Bearings, impeller, lignum vitae, spares—10 sets.
5. Parts, meter, spares, in kit—10 sets.
6. Tools, tweezers, jeweler's screwdrivers, pins, etc.—2 sets.
7. Volt-Ohm-Milliameter, Triplett Model 630—2 each.
8. Electron tubes, spare, as required by various instruction and operating manuals listed in section 10–55 below.
9. Relays, spare, Sigma 5R 1000S and 5R 10,000S—5 each.
10. Crystal, RF, selected frequencies—24 each.
11. Rubber, sponge, for shock mounting instruments, sheets 36 x 24 x 2 inches—5 sheets.
12. Batteries, dry, 1.5-V fil. and light, Burgess 20F or Eveready 740, 32 batteries per set—15 sets.

13. Batteries, dry, 45 V, plate supply Burgess 5308 or Eveready 482, 8 batteries per set—15 sets.

14. Batteries, dry, 4.5 V, relay circuit, Burgess 232 or Eveready 771, 1 battery per set—15 sets.

15. Receptacle, Transmitter power input, AN–3102–A–20–24S—5 each.

16. Plug, Transmitter power input, AN–3108–A–20–24P—5 each.

17. Clamp, Transmitter power input, AN–97–3057–12–6—5 each.

18. Receptacle, Sequence Switch, AN–3102–A–12S–3S—10 each.

19. Plug, Sequence Switch, AN–3106–A–12S–3P—10 each.

20. Clamp, Sequence Switch, AN–3057–4—10 each.

21. Receptacle, Antenna, AN–3102–8S–1P—5 each.

22. Plug, Antenna, AN–3106–A–8S–1S—5 each.

23. Clamp, Antenna, AN–3057–3—5 each.

24. Receptacle, Transmitter, battery box, AN–3102–A–20–24S—5 each.

25. Plug, Transmitter, battery box, AN–3106–A–20–24P—5 each.

26. Clamp, Transmitter, battery box, AN–97–3057–12–6—5 each.

27. Receptacle, Sequence Switch, battery box, AN–3102–A–12S–3S—5 each.

28. Plug, Sequence Switch, battery box, AN–3106–A–12S–3P—5 each.

29. Clamp, Sequence Switch, battery box, AN–3057–4—5 each.

30. Receptacle, Identification Lights, battery box, AN–3102–A–12S–3S—5 each.

31. Plug, Identification Lights, battery box, AN–3106–A–12S–3P—5 each.

32. Clamp, Identification Lights, battery box, AN–3057–4—5 each.

33. Lamps, Identification Lights, Mazda No. 40—48 each.

34. Fluted globe, fisherman's buoy light, color, red—5 each, color, white—5 each.

35. Tube tester—1 each.

36. Battery Charger, Mallory 6V AC 4–6 Amp.—2 each.

37. Cable Vulcanizer, complete, Joy Mfg. Co.—1 each.

38. Receptacle, watertight, with cover and plug, brass, Lovell—6 each.

39. Wire, hookup, No. 16—100 feet.

40. Tape, "Scotch Electric"—50 rolls.

41. Tape, rubber, Navy Stock G 17–T–1445—50 rolls.

42. Silica Gel, dehydrant—50 pounds.

43. Waterproofing compound, D–4, Dow Chemical Co.—10 tubes.

44. Cable clamps, ⅛″, $\frac{3}{16}$″, and ½″—200 each.

45. Shackles, ¼″, ⅜″, and ½″—200 each.

46. Thimbles, ¼″, ⅜″, $\frac{3}{16}$″, and ⅛″—100 each.

47. Paint, Chrome yellow—5 gallons.

48. Flag, Baker, Navy Stock G 5–F–369—10 each.

49. Rubber tubing, ¼″ ID, ⅜″ OD—15 feet.

50. Funnel, plastic—2 each.

51. Chronograph tape, reels, as required by length of survey.

52. Tools, hand, complete set.

53. Radiotelephone, ship to shore—1 each.

9–56 Operating and Instruction Manuals.—The following listed operating and instruction manuals are of assistance when operating and maintaining the Roberts Radio Current Meter components.

1. Roberts Radio Current Meter, Mod. II, Operating Manual—Department of Commerce, Washington, D. C., 1950.
2. Operating and Maintenance Instructions for Direct Heat Type Cable Vulcanizer—Joy Manufacturing Co., St. Louis 10, Mo.
3. Instruction Manual Triplett FM Signal Generator, Model 3433—Triplett Electrical Instrument Co., Bluffton, Ohio.
4. Instruction Manual Triplett Model 630 Volt-Ohm-Milliammeter.
5. Instruction Manual National HRO–50–1 Radio Receiving Manual—National Co. Inc., Malden, Mass.
6. Care of Amglo Constant Speed DC Motors—Amglo Corp., Chicago, Ill.
7. Specifications of the Materials and Construction Details of the Sequence Switch—U. S. N. H. O.
8. General Specifications, Roberts Radio Current Meter Model II—U. S. N. H. O.
9. Specifications, Roberts Radio Current Buoy, 120- and 80-inch models—U. S. N. H. O.
10. Instructions, Type 161 Radio Transmitter—Rixon Electronics, Inc., Kensington, Md.
11. Instructions, Type 162 Test Oscillator—Rixon Electronics, Inc., Kensington, Md.

9–57 Assembling the Roberts Radio Current Meter for Operation.—The current meters are suspended at the desired depth below the buoy as shown in figure 9–5. The whip antenna is rigged on the buoy and the batteries and the crystal inserted in the transmitter. The system is then checked for operation with the power supply and the transmitter tuned to peak output. Signals produced can be checked either by the survey vessel radio or by a volt-ohm-milliammeter. All this work can be accomplished by the shore station or the survey vessel, depending upon facilities. If the initial work can be carried out ashore, and the final check made on the vessel before the buoy is planted, much valuable time can be saved. The buoy complete with meters is now ready for the plant.

9–58 Planting the Roberts Buoy.—At the current meter station the buoy is lowered into the water from the survey vessel. Caution should be exercised when carrying out the plant to prevent entangling the meters and supporting cables. The three types of plants most commonly used, depending on the placement of the ship's gear, are as follows:

1. *Bow Plant*—Boom and winch forward. The vessel approaches the station *with* the current, lowers the meters and then the buoy over the bow. It then backs down slowly and drops the buoy anchor.
2. *Fantail Plant*—Boom and winch aft. The meter station is approached with the vessel *heading into* the current. Lower the meters and then the buoy from the quarter; then proceed ahead slowly and drop the buoy anchor.
3. *Stationary Plant*—Bow or fantail. The vessel lays to at the meter station. Plant the buoy from the *weather side* of the vessel. Allow the ship to drift away from the buoy and drop the buoy anchor.

9–59 Inspection and Servicing During Operation.—Once the buoy is planted and in operation, it should operate independently for the duration of the station. Each meter station should operate normally for approximately 15 days on 1 supply of batteries. Inspection and servicing of the station is made every 100 hours. Should the meters show evidence of marine fouling, they must be cleaned. In areas of silty water, the impeller lignum-vitae bearings must be inspected for evidence of scoring and replaced if necessary.

9–60 Operation of the Instrument and Recording the Data.—After the buoy plant, further observations will be taken from the ship or shore monitor station. Fifteen meters, representing 5 operating buoys, can be monitored at a single receiver, although the normal load is usually 9 meters operating from 3 buoys, with 1 meter held in reserve. A crystal-controlled oscillator duplicating the crystals at each meter station is provided at the receiver. This serves to pinpoint the operating frequency for maximum accuracy. Once the receiver has been tuned to the required frequency, the observer is ready to record the data in the Record of Current Observations for Roberts Radio Current Meter, PRNC-NHO-1505. Recording time is usually 1 minute per meter for each station, with observations being taken at half-hour intervals. The signals produced by the meters are transmitted to the receiver which converts the audio signals to electrical impulses, routes them through a relay box, and records them on a tape chronograph. The break-circuit chronometer introduces a time signal, enabling the velocity to be interpreted correctly. A diagrammatic sketch of the receiving station is shown at top of figure 9–7. If the signals produced are too far below

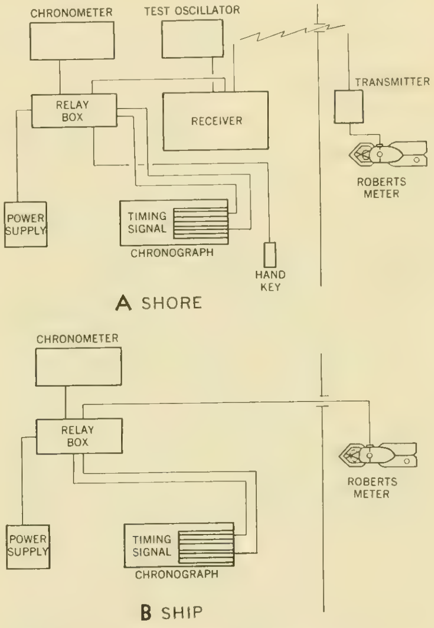


Figure 9–7. Diagrammatic sketch of the receiving station.
(*a*) Using station. (*b*) Using direct contact.

the noise level to be recorded automatically, but are distinguishable audibly by loudspeaker or earphone, automatic recording is then switched off by the controls provided. The chronometer continues operation, and the observer produces hand-controlled signals by key to represent the signals from the buoy. Care must be taken in distinguishing the meter signals from outside interference.

Where facilities do not permit the installation of a shore station, the receiver is placed aboard a survey vessel with much the same equipment and observational procedure.

9–61 Operating the Roberts Current Meter Directly From Aboard Ship.—When current studies are made directly from a survey ship with a Roberts meter, there is no need for the transmitter and receiver as the meter may be connected directly to the relay box. A diagrammatic sketch for shipboard meter use is shown at bottom of figure 9–7.

The ship must be anchored to obtain current readings. The meter is lowered to the desired depths by its cable, which is then connected to the relay box; signals are recorded on the chronograph.

9–62 Maintenance and Repair of Roberts Radio Current Meter Equipment.—Extensive repairs to the interior mechanism of the meter are practically impossible in the field because of the meter's delicate construction. The outer shell, however, where damage commonly occurs, usually can be repaired where ordinary machine shop facilities are available. In most cases, ordinary repairs or replacements of accessory equipment can be carried out easily.

9–63 OBSERVING AND SCALING PROCEDURE.—1. *Method of Recording.*—The signals from a radio current meter station, having been identified according to the wavelength broadcast by the buoy, are carefully tuned to produce the maximum signal as nearly as possible clear of interference or noise and then switched to the chronograph. The latter, running and marking seconds of time, records the signals on a trace superimposed on or closely parallel to the seconds record. This is possible only if the buoy signal strength is clearly above the noise or interference level.

A tape record is obtained, free of interference, or with only slight interference which the observer identifies as such and marks out on the tape as it occurs. This need not be long; ordinarily ¼ to ½ minute of unmistakable signals is sufficient. The tape, shown in figure 9–8, is scrutinized to find a series of valid marks at regular intervals, which are labeled "V" (velocity). Between each second pair of such marks should be found another mark, which is labeled "D" (direction).

If the radio signals are below the noise level, and cannot be recorded clearly, though distinguishable by ear over the earphone or loudspeaker, the chronograph may be run,

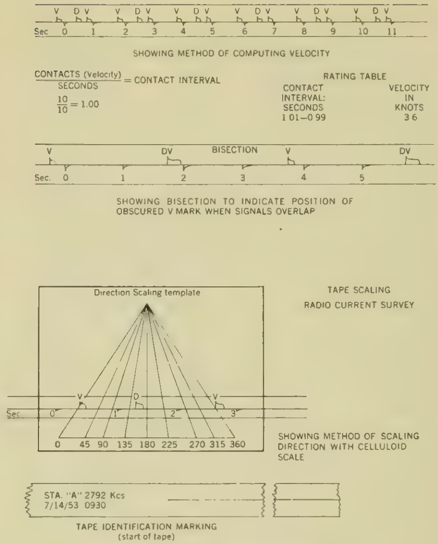


Figure 9–8. Tape scaling.

automatically marking seconds while the observer produces hand-controlled marks (by key or by tripping the stylus) to represent the buoy signals. This procedure is less accurate than that inherent in fully automatic recording.

A special case occurs when the direction of current flow is N (magnetic), causing the velocity and direction signals to merge or overlap. If it is an unmistakable overlap, producing alternate long and short marks, the short ones may be taken to be V-signals, and the (obscured) intervening V-marks plotted by bisecting the space between two of the short marks, as shown in figure 9–8. If the coincidence is so perfect as to indicate no systematic difference in signal length, then the current direction may be regarded as N (magnetic) and the marks labeled alternately V and VD.

2. *Determination of Velocity.*—A definite number of V-signals is counted from the tape. The corresponding time interval is determined, using a chronograph scale if necessary (though experience will demonstrate that a substantial portion of the observations can be made by estimation of the second fractions). A simple division affords the time-per-contact interval with which to enter the rating table for velocity. At high current velocities where the intervals

Contact interval: Seconds	Velocity: Knots	Contact interval: Seconds	Velocity: Knots	Contact interval: Seconds	Velocity: Knots
30-16	0. 2	1. 68–1. 61	2. 2	0. 86–0. 85	4. 2
15-11. 5	0. 3	1. 60–1. 55	2. 3	0. 84–0. 83	4. 3
11. 4-8. 5	0. 4	1. 54–1. 48	2. 4	0. 82–0. 81	4. 4
8. 4–7. 0	0. 5	1. 47–1. 43	2. 5	0. 80–0. 79	4. 5
6. 9–5. 8	0. 6	1. 42–1. 37	2. 6	0. 78	4. 6
5. 7–5. 0	0. 7	1. 36–1. 32	2. 7	0. 77–0. 76	4. 7
4. 9–4. 4	0. 8	1. 31–1. 27	2. 8	0. 75	4. 8
4. 3-3. 9	0. 9	1. 26–1. 23	2. 9	0. 74–0. 73	4. 9
3. 89-3. 50	1. 0	1. 22–1. 19	3. 0	0. 72–0. 71	5. 0
3. 49-3. 22	1. 1	1. 18–1. 15	3. 1	0. 70–0. 68	5. 2
3. 21-2. 93	1. 2	1. 14–1. 11	3. 2	0. 67–0. 66	5. 4
2. 92–2. 73	1. 3	1. 10–1. 08	3. 3	0. 65–0. 64	5. 6
2. 72–2. 52	1. 4	1. 07–1. 05	3. 4	0. 63–0. 61	5. 8
2. 51–2. 37	1. 5	1. 04–1. 02	3. 5	0. 60–0. 59	6. 0
2. 36–2. 21	1. 6	1. 01–0. 99	3. 6	0. 58–0. 57	6. 2
2. 20–2. 08	1. 7	0. 98–0. 97	3. 7	0. 56	6. 4
2. 07–1. 96	1. 8	0. 96–0. 94	3. 8	0. 55–0. 54	6. 6
1. 95-1. 86	1. 9	0. 93–0. 92	3. 9	0. 53	6. 8
1. 85-1. 77	2. 0	0. 91–0 89	4. 0	0. 51	7. 0
1. 76-1. 69	2. 1	0. 88–0. 87	4. 1		

NOTE.—Derived from calibration tests.

are less than 4 seconds, the averaging of a series as described above should be so performed as to result in values of time-per-contact interval correct to 0.01 second. For values between 4 and 12 seconds, the time-per-contact interval should be determined to the nearest 0.1 second. For greater intervals, whole seconds will suffice. The foregoing presupposes final results correct to 0.1-knot current velocity.

If the chronograph has a speed control, it is convenient to condense the record by operating at slow speed where the time intervals are long and do not require close scaling.

3. *Direction Indications.*—These are determined by use of a transparent scaling device, shown in figure 9–8, having converging lines representing 10-degree increments from 0° at the left to 360° at the right. Being sure that the tape is laid before the observer with chronological order advancing from left to right, this scale is laid over the tape so that the outside (0° to 360°) lines coincide with the beginning points of two successive V-marks, having a D-mark between them. The beginning point of the D-mark is read from the scale to the nearest 5° or 10°. This is the magnetic direction of current flow.

Obviously, depending on the mechanical construction of the chronograph and the nature of its recorded marks, these instructions may require modification. For instance, if the chronograph record is more conveniently used with chronological order reversed (advancing from right to left) the direction indicator scale can be marked to show 0° at the right and 360° at the left.

General uniformity of spacing of marks will prevail. However, irregularities may result from swirl conditions at the current station, or choppy waters combined with weak current. Here mean values of several readings should be employed.

Good practice includes a plot of each direction and velocity against time, as soon as recorded, on any convenient coordinate paper. The resulting curves will, in most cases, reveal promptly any fault of operation or scaling which might require immediate correction.

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CHAPTER 10

SEA AND SWELL OBSERVATIONS

10–1 GENERAL REMARKS.—Because of the almost complete lack of quantitative reports concerning wave conditions in all parts of the world, it is most important to take observations of wind waves and swell whenever possible while afloat or airborne. These data may be used for the following: Planning air-sea rescue or aircraft carrier operations; selecting seaplane landing areas; studying local and distant wind systems and their effect on sea conditions; determining drift and breakup of ice floes; and the movement of supplies and personnel through surf zones.

Every effort should be made to standardize visual observational procedure so that different observers studying similar waves will reach the same conclusions as to what they see, and will record the same data. Unless a standardized procedure is agreed upon, an observer might also have difficulty in comparing two of his own observations made at different times, or in deciding if the waves had changed since the last observation. Conscientious attention to the observations will therefore be required.

A standardized method for recording visual sea and swell observations on a log sheet has been developed. Instructions for making these observations are given in H. O. Pub. No. 606–e, "Sea and Swell Observations." The log sheet used to record these observations is the "Shipboard Wave Observation Log," PRNC–NHO–1192. A sample log sheet is shown in chapter 14.

10–2 Wave Forecasting.—Recent developments in wave forecasting theory indicate that a much more thorough description of the sea surface is needed than is possible by visual observations alone. Consequently, automatic wave recorders of various types have been developed to produce a height-versus-time profile of the sea surface at a given point. One of these, the electric wave staff, is described and instructions for its operation given in this chapter. This instrument is intended for use in waters having a depth greater than one-half the wave length.

Automatic shipboard equipment designed to provide wave data on a continuing and scheduled basis is now in the developmental stage. This equipment will eventually enable the Oceanographic Forecasting Central of the Hydrographic Office to predict sea conditions over large portions of the ocean on a round-the-clock basis. The immediate need, however, is for accurate observational data, preferably instrument data, to be used in checking and improving forecasting procedures.

10–3 DEFINITIONS OF OCEANOGRAPHIC TERMS.—To enable the observer to have a better understanding of the various factors involved in sea and swell observations, definitions of certain oceanographic terms are given below.

10–4 Wind Waves.—The character of the sea surface caused by action of the local wind can be described in terms of height, period, length, and direction of the wind waves being formed. Waves which are still growing under the force of the wind are known as wind waves. These waves travel in a direction within about 20° of the local wind, and their dimensions are determined by three factors:

1. The STRENGTH of the wind.
2. The DURATION of time the wind has been blowing.
3. The FETCH or distance of the sea surface over which the wind has acted.

If the waves are newly formed and have not had a chance to consolidate themselves in a a series of regularly connected crests and troughs, the sea surface will be choppy and make description difficult. As the waves grow, they form themselves into a regular series of connected troughs and crests with the H/L ratio (wave height/wave length) customarily ranging from 1/12 to 1/35, or 12 to 35 times their height.

10–5 Swell.—Swell is a system of waves that has moved out of the generating area into a region of weaker winds, a calm, or opposing winds. Thus, swell usually travels in a direction more than 20° from the direction of the wind although this is not necessarily always the case. Swells decrease in height with travel, and although there may be difficulty in distinguishing between wind waves and swell, the latter usually possesses a more or less smooth, well-rounded profile, has greater wave length and period, and disturbs the water to a greater depth. The H/L ratio for swell normally ranges from 1/35 to 1/200. Under certain conditions, extremely long and high swells will cause a ship to take solid water over its bows regularly in a glassy sea.

The reporting of a swell is exceedingly important, for its presence in the local area indicates that recently there may have been a very strong wind, possibly even a severe storm, hundreds or thousands of miles away. The direction from which the swell is coming tells in what direction the strong wind was located. In certain instances the onset of a swell is the first indication of an approaching storm.

10-6 Wave Height.—The vertical distance from the trough to the crest is termed the wave height. In view of the considerable variation in height between waves observed in a 7-minute period, reference is conveniently made to the significant wave height. This wave height is the average of the higher, well-defined waves present during the observation. Statistically, significant waves are defined as the average of the ⅓ highest waves observed in a given time. As the height is the most important wave characteristic from the operational point of view, care should be taken to observe and report it accurately. While this value for height is about the best that can be expected from visual observation, efforts are being made to perfect the power spectrum analysis of instrument records which will be more valuable for forecasting purposes.

10-7 Wave Period, Length, Velocity, and Direction.—The *wave period* is defined as the time interval between successive wave crests as the wave passes a fixed point. *Wave length* is the horizontal distance between successive crests. The *wave velocity* is the rate of travel of the wave form through the water. Here again, as in the case of height, there is considerable variation in these characteristics in any given wave train. For observational purposes, one should determine the average values for the significant waves. *Wave direction* is the direction, in degrees true, from which the waves come.

If wave systems cross each other at a considerable angle, the result is a very irregular sea surface comprised of apparently unrelated peaks and hollows and is termed a *cross sea.* Waves are said to be *short-crested* when the crests are short compared to the wave length and *long-crested* when crests are long compared to the wave length. Waves are commonly short crested in cross seas and in the early stages of generation, while swell is generally long crested. In deep water, where the orbital motion of water particles is uninhibited by the bottom while the waves proceed through the water, the wave period is related mathematically to the wave length and wave velocity in such a manner that they travel at different speeds, and are constantly overtaking or pulling away from their neighbors. If the crests of two waves happen to be at the same point at the same time, their combination results in a crest that is higher than either of the component crests. This phenomenon, known as *wave interference,* accentuates the variability in wave height. Conversely, interference also can cause flat zones when the trough of one wave meets the crest of another. The hydrodynamics of surface wave motion is such that as the period increases, the speed and wave length increases as well. The following approximate formulas show this relation, where the units are knots, feet, and seconds,

$$\text{Wave speed} = 3.0\ (\text{Period})$$
$$\text{Wavelength} = 5.12\ (\text{Period})^2$$
$$\text{Wave Period} = 0.3\ (\text{Wave Speed})$$

10-8 Whitecaps.—In deep water the wind may blow strong enough to raise steep and choppy wind waves. When the ratio of height to length becomes too large, the water at the crest moves faster than the crest itself, causing the water to topple forward and form *whitecaps.* The term whitecap is confined to deep water waves while the term *breaker* is used to describe waves breaking in shoal water or in strong-tidal currents which oppose wave motion. Whitecaps owe their instability to a too rapid addition of energy from the wind to the wave form and breakers to the restrictive effect of the sea bottom or opposing currents upon the water movement in the wave form.

10-9 Breakers.—A *breaker* is an ocean wave, either wind wave or swell, which has traveled over a gradually shoaling bottom and reached the point in its transformation where it is no longer stable and plunges over or breaks. As a rule, when swell is definitely predominant, the breakers are regular with smooth profiles. When wind waves are predominant, the breakers are choppy and confused. Swell coming into a beach increases in height up to the point of breaking. Wind waves, on the other hand, are already so steep that there is little if any increase in height just before breaking. Thus, swell often defines the period of the breakers even though the wind waves appear to predominate in deep water. A long, low swell in deep water may be obscured by choppy wind waves and be detectable only on the beaches.

10–10 Surf.—The zone of breakers, termed *surf*, includes the region of white water between the outermost breaker and the waterline on the beach. During a storm, it may be difficult to differentiate between surf inshore and whitecaps in deep water just beyond.

10–11 Wave Refraction and Longshore Currents.—When waves approach a coastline at an angle, they tend to swing around and break parallel to the beach. The waves are slowed down as they come into shallow water by the inhibiting effect of the bottom, and owing to the change in velocity, are deflected, or refracted from their original parts. Consequently, refraction is only noticeable on beaches with gradual profiles, since the bottom must influence the waves over several wavelengths. When waves do not swing all the way around before breaking and break at an angle with the shoreline, a current in the direction of the open angle is generated. The strength of this current depends chiefly on the height, period, angle of approach of the waves, and beach configuration. If a longshore current develops during unloading operations, it may swing vessels sideways and broach them.

10–12 Effect of Tidal Currents.—If tidal currents acquire velocities of 2 or 3 knots or greater, they affect the waves which travel into the area of their influence. Waves opposing currents tend to steepen and increase in height; those moving with currents flatten and decrease in height. Unless the current is effective over a considerable area with a moderate to high velocity, wave changes are not usually noticeable. Near headlands and in tidal races, however, they may be appreciable, and zones of whitecaps where the waves are breaking because of this effect occur at many places.

10–13 Effect of Shoals.—Waves (either sea or swell) in passing over shoals or bars tend to steepen and increase slightly in height. Long swells may feel the effect of a deeper shoal more than wind waves and may steepen more noticeably, but will not break as quickly because their height to length ratio is initially very low. Wind waves, on the other hand, may suddenly steepen and break.

10–14 Wave Reflection.—At steep coasts, where there is no beach and deep water is close inshore, wind waves and swell will travel to the coast without undergoing shallow water transformation. Under these conditions, the waves will be reflected from the shoreline and proceed seaward, causing an interference pattern. If this phenomenon is pronounced, one can see pyramidal waves shooting upward where the crest of a reflected wave meets the crest of an oncoming wave. Beach gradients generally must be steeper than 1 in 10 before reflection occurs.

10–15 INSTRUCTIONS FOR OPERATING THE ELECTRIC WAVE STAFF.—The Electric Wave Staff is an instrument designed to record wave heights and periods at sea. It consists of three 12-foot lengths of watertight 3-inch aluminum tubing, a 3-foot circular steel damping disk, a Brush recorder, a transformer-rectifier circuit, electrical cables, floats, retrieving lines, and balancing weights. The upper section of tubing has 36 contact points set 4 inches apart, and is covered with black waterproofing material. It is called the step-resistance gage and has a connection for the electrical cable at the top. The remaining two sections of tubing provide proper buoyancy to the step-resistance gage so that it will float vertically in the water with one-half of its length exposed. Below the end of the lower tube is suspended the damping disk. Its function also is to provide weight to keep the staff vertical and to damp the tendency of the staff to rise and fall with the passing waves. As these waves pass, the water rises and falls along the step-resistance gage, thereby increasing and decreasing the resistance in the gage as it passes successive contact points. This variation in resistance is transmitted to the Brush recorder aboard ship by the electrical cable and transformer-rectifier circuit. A record of the wave height and period is thus recorded on a strip chart. The usual length of recording time is from 7 to 20 minutes. These observations are made when the ship is lying to and the wave-staff assembly put overboard to windward so that the normal drift of the ship will be away from the staff. The overboard assembly of the wave staff is shown in figure 10–1.

10–16 The Recorder and Transformer-Rectifier Assembly.—The Brush recorder and transformer-rectifier are mounted in a single case. A cover on the top of the case gives access to the Brush recorder. The transformer-rectifier, electrical cable connection to the wave staff, and the power supply cable are reached by a door in the back of the case. The dimensions of the case are 22 x 15 x 20 inches and the assembly weighs about 97 pounds. The electrical power requirements are 120 volts,

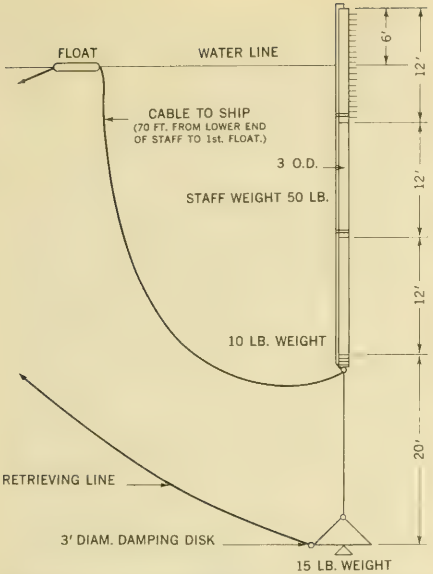


Figure 10–1. Overboard assembly of the electric wave staff.

60 cycles, AC; power consumption is about 75 watts. The assembly must be mounted in an area secure from spray or rain, yet accessible to the working area where the wave staff is assembled and tended when over the side. The recorder should be mounted off the deck at a height where it is easily readable. Good communication between the recorder operator and those tending the wave staff on deck is essential.

10–17 Accessories and Spare Parts.—Accessories and spare parts, such as recorder pens, recorder ink, chart paper, damping disk suspension line, balancing weights, wax, shackles, waterproof tape, waterproof sealer, snaphooks for floats, and grease are included in a spare parts kit, which accompanies the wave staff. In addition, seven floats, or life rings, are supplied to provide suspension for the electrical cable. A 1,000-foot length of cotton sash cord, or heaving line, is also provided for use as a retrieving line.

10–18 Assembling the Electric Wave Staff for Operation.—Assembling the wave staff and preparing for lowering is carried out as follows:

1. Lay out on deck the three sections of the wave staff, the damping disk, weights, suspension line, electrical cable, floats, and retrieving line.
2. Check the contacts on the step-resistance gage to see that they are clean and bright. If necessary, burnish the contacts lightly with fine emery cloth to produce a bright surface. Rub down the gage section with a clean dry cloth and apply the wax provided and wipe off as needed to produce a water-repellent surface, *avoiding the contact points.* Grease the end fittings of all three sections.
3. Assemble the 3 sections of the staff as shown in figure 10–1.
4. Secure the damping disk to the bolt at the lower end of the wave staff by means of the suspension line and shackles provided, so that the face of the damping disk is 20 feet from the lower end of the staff.
5. Shackle the 15-pound weight to the eye on the underside of the damping disk.

Note.—Sufficient weight should be used to float the assembly with about 6 feet of the step-resistance gage exposed in calm water. On some staffs only a 10-pound weight is required.

6. Plug in the electrical cable connector (Joy plug) to the upper end of the step-resistance gage. Tape the connection lightly to insure a watertight seal. Next, tape the electrical cable along the rear of the three sections of the staff and put it through the shackle which secures the damping disk suspension line to the eye on the bottom bolt.
7. Make fast the end of the 1,000 feet of cotton retrieving line to the eye on the edge of the damping disk.
8. Secure two 30- to 40-foot long handling lines to the staff just above the two joints.
9. Fasten the floats to the electrical cable. The first should be 75 feet from the bottom of the wave staff, the others about 100 feet apart.
10. Set the gage on the deck with the contact points upright and clear of all metal objects.

10–19 Calibrating and Testing the Electric Wave Staff.—Before the wave staff can be lowered over the side for operation, the gage and recorder must be calibrated and tested. This must be done before each lowering. The procedure is carried out in the following manner.

1. Test the pen of the recorder for proper inking and pen pressure. Instructions for this are given in the Brush Recorder Operating Instruction Manual along with other information concerning maintenance of the recorder. A copy of this manual is included in the spare parts box.
2. Connect the electrical cable from the wave staff to the connector at the back of the

recorder case. Plug in the power-supply cable. Adjust the dial on the front of the recorder case to read about 52. This is done with the large knob in the center of the case. Stand clear of the step-resistance gage of the wave staff. Turn the main power supply switch to *ON* position. Next, adjust the manual lever on the side of the Brush recorder so that the pen trace is on the bottom line (nearest the front of the case) of the chart paper. After this is done, turn the main power switch to *OFF* position.

3. After making sure that the main power switch is off, attach the 25-foot-long-wire leads to the uppermost and lowermost contact points, and lower the leads over the side into the water. Have about a foot of exposed wire at the overboard ends, with small weights attached to steady them in the water.

4. When both leads are in the water, about 12 feet apart and away from the ship, stand clear of the gage and turn the main power supply switch to *ON* position. With the large variac knob in the center of the case adjust the voltage so the recorder pen is on the top line (nearest the back of the case) of the chart paper. Turn *OFF* the main power switch.

5. After making sure that the main power switch is off, detach one of the leads from the contact points. With the voltage setting obtained in 4 above check the zero trace again by turning *ON* the main power switch and adjusting the manual lever on the side of the pen motor so the trace is on the bottom line of the chart paper.

6. Turn the main power switch to *OFF* position, attach overside lead and repeat step 4.

7. Repeat steps 4 and 5 as often as necessary to achieve the specified results.

8. Label the calibration run on the chart paper and record the voltage setting. Retain the calibration run with the record of each wave staff observation.

10–20 Lowering and Operating the Electric Wave Staff.—The procedure for lowering the wave staff over the side and obtaining the observation is carried out as follows:

1. Make sure that the main power supply switch is in the *OFF* position. Lift the staff and damping disk over the side. With the two handling lines and the retrieving line on the damping disk, lower the assembly into the water.

2. When the staff is waterborne, cast off the handling lines, keeping them clear of the contact points, and continue to lower the damping disk. Allow slack in the electrical cable and retrieving line.

3. Turn the main power supply switch to *ON* position, and mark the point on the chart paper when the staff becomes upright in the water and settles to its normal depth. About 6 feet should be projecting in calm water.

4. Pay out the cable, with the floats attached, and the damping-disk retrieving line. Allow slack at all times. If either line becomes taut, the staff will list and record incorrectly. Pay out both line and cable, of which there is about 1,000 feet, until a record of *at least 7 minutes* has been obtained from the time the staff became upright. A 20-minute record should be obtained whenever possible. If the cable should run out and become taut during the observation, shut off the recorder and make note of this point on the chart, then haul the staff an appropriate distance toward the ship by means of the damping-disk retrieving line. Some of the cable should be hauled in at the same time to prevent excessive slack and possible fouling of the damping disk. Slack the retrieving line and cable. When the staff again becomes upright, turn *ON* the main power switch and complete the observation.

10–21 Retrieving and Securing the Electric Wave Staff.—The procedure for retrieving and securing the wave staff is carried out as follows:

1. After the run is completed, turn *OFF* the main power and haul in the retrieving line and cable, keeping the strain on the line and not on the cable.

2. When the staff is alongside, retrieve the handling lines with a boathook or grapnel. With the two handling lines and the damping-disk retrieving line, hoist the staff and damping disk aboard.

3. Lay the staff on deck, keeping the contact points clear of the deck or any metal objects. *Stand clear* of the gage and turn the main power switch to *ON* position. Check to see that the zero trace has returned to the lowest line of the chart paper, the one nearest the front of the case. If the zero trace is off by more than 5 lines, the step-resistance gage must be cleaned with fresh water, dried, and waxed, and the entire run repeated.

4. If the zero trace has returned properly to the lower line, turn *OFF* the main power switch and disassemble the wave staff. Wipe dry the step-resistance gage and clean and grease the coupling joints. It may be necessary to wash down the gage section with fresh water once in a while to prevent formation of a salt coating which would tend to hold a film of water on the gage. This film would produce erroneous recordings.

10–22 Recording the Electric Wave Staff Data.—After the last wave trace of a run, a line must be drawn across the chart paper to separate that run from subsequent ones. All printing should be done with the curved lines of the chart paper bowed to the right. The following information should be printed in ink on the recorder chart paper to the right of the drawn line and to the left of the last wave trace (fig. 10–2):

1. Ship, cruise, and visual wave observation serial number followed by W for example, RE–15–34W. This number should also be recorded in the Remarks column of the Shipboard Wave Observation Log (PRNC–NHO–1192) on the same line as the visual observation taken during the wave-staff run.
2. Date. Give the day, month, and year.
3. Time. Use Greenwich mean time (GMT). Record the hour and minute at the beginning of the run and again at the end of the run. It is helpful during the run to mark numerically each minute signal made by the recorder on the chart paper: 1, 2, 3, 4, 5, 6, 7, etc.
4. Position. Give the latitude and longitude of the observation.
5. Record the wind speed in knots and direction in degrees true.
6. If known, give the current speed in knots and direction in degrees true.
7. Give the apparent direction of wave motion in degrees true.
8. Record the voltage used throughout the run as shown on the variac during the calibration.
9. Record the electric wave staff serial number.

10–23 Storing and Shipping of Electric Wave Staff Records.—The used chart paper should be kept continuous, if possible, until the roll is completed and shipped along with the associated shipboard wave observation log sheets to:

Hydrographer
U. S. Navy Hydrographic Offic[e]
Washington 25, D. C.
Attn: Code 5430

10–24 The Wave-Staff Electrical Circuit.—The shipboard electrical circuit is shown schematically in figure 10–3. The step-resistance gage wiring is shown in figure 10–4. The design values of resistance in the gage section are as follows:

	Ohms		*Ohms*
Top	1000	(above top contact)	226
	65		252
	67		279
	72		313
	75		351
	80		398
	85		456
	90		526
	96		615
	103		726
	117		873
	126		1068
	136		1338
	147		1723
	159		2304
	173		3200
	189		4920
	206	Bottom	8210

10–25 Summary of Important Operating Instructions.—To insure proper operation of the electric wave staff, always be sure that:

1. The step-resistance gage is clean and water repellent.
2. The contact points are clean.
3. The cable is kept slack during operation.
4. The cable connection to the step-resistance gage is waterproof.
5. The recording pen is properly set for zero and full-scale deflection.

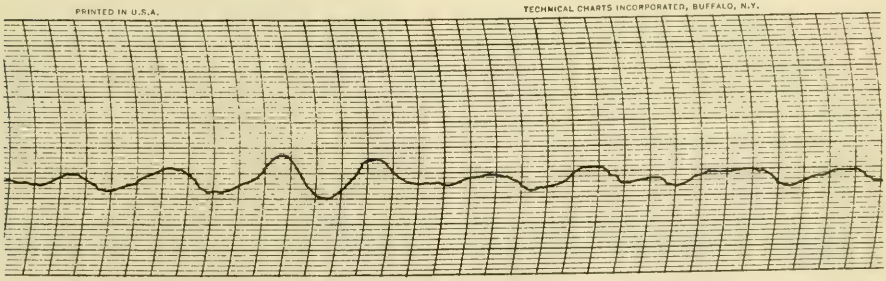


Figure 10–2. Wave record obtained with electric wave staff.

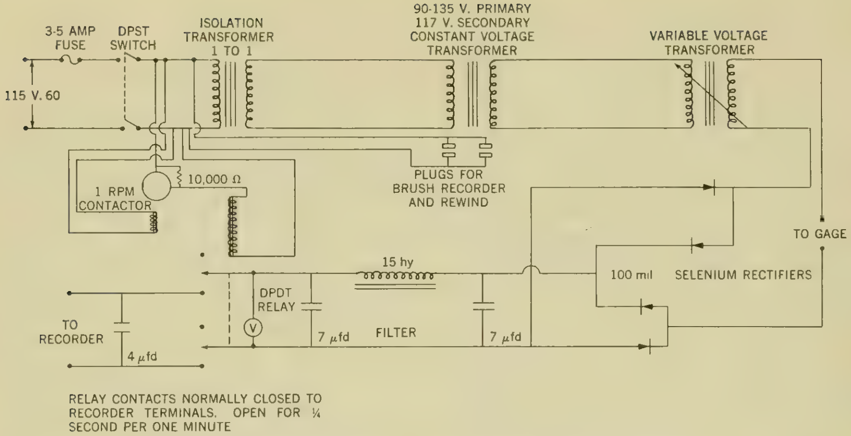


Figure 10-3. Schematic diagram of electrical circuit of electric wave staff.

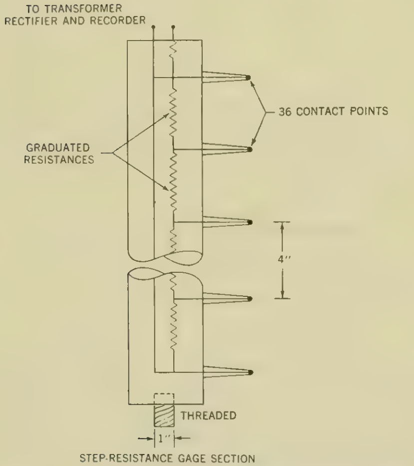


Figure 10-4. Electrical circuit of step-resistance gage of electric wave staff.

6. All the required information is properly recorded on the chart paper for each observation.

10-26 ANALYSIS OF WAVE TRACES.—The analysis of wave traces made by the electric wave staff are usually carried out ashore. However, there are times when special studies require that analyses be carried out aboard ship during the course of a survey. This may be done in the following manner:

1. From the chart record of the observation pick out the dominant wave train.
2. Find the average period (T) in seconds. This can be done quickly by dividing the total time in seconds (excluding hauling in, etc.) by the total number of dominant waves, if the dominant waves, which are the ones to be measured, are continuous throughout the record. If they are not continuous, the individual periods will have to be averaged.
3. Divide the total time in seconds, of actual wave recording (excluding any time on record which represents hauling in, etc.) by T (average period) to obtain the total number of possible waves of this period.
4. Divide this total by 3.
5. Measure this number $\left(\frac{\text{total number}}{3}\right)$ of highest waves starting with the highest wave and working down, using the calibration scale drawn up on the side of the calibration card. This card is calibrated and provided for each wave staff.
6. Take the average height of these n highest waves. This gives the apparent significant height.
7. Using the dynamic calibration curve for the 50-foot system, shown in figure 10-5, pick off the true significant height using the apparent significant height and average period. It should be noted in interpolating values from the curves in figure 10-5, that because the con-

tact points on the gage are set 4 inches apart, the apparent wave heights are only accurate to 4 inches and the true heights can only be accurate to the same degree.

8. Record the value for the true significant height on the chart paper under the notation of voltage for each run.

9. Record the average wave period on the chart paper under the value, in 8, above.

10. Record the maximum true characteristic height under the value, in 9, above.

10–28 Calibration Curve for the Electric Wave Staff.—The calibration curves for the motion of the staff (fig. 10–5) are not calculated for use where the bottom affects the wave action significantly; that is, at depths less than ½ the wavelength. ($L=5.12T^2$ unless currents are present. See H. O. Pub. No. 602, Wind Waves at Sea, p. 53.)

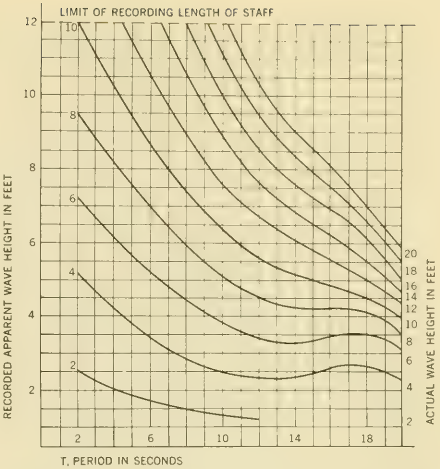


Figure 10–5. Calibration graph of electric wave staff.

CHAPTER 11

METEOROLOGICAL OBSERVATIONS

11–1 GENERAL REMARKS.—As mentioned in chapter 1, the interaction of sea and air is extremely important in the studies of various oceanographic problems. Almost all oceanographic observations must be accompanied with simultaneous meteorological observations. Spaces for such observations are provided on oceanographic log sheets A, B, and E. Codes and tables required to record these observations are included in part II of this manual, and instructions for the proper use of these tables and log sheets are given in chapter 14. An oceanographic observer must be able to take and record marine meteorological observations that are called for by the various log sheets. These codes are adapted from the new international code, by the U. S. Weather Bureau, for recording marine meteorological observations.

11–2 TYPES OF OBSERVATIONS.—The types of meteorological observations required with the oceanographic log sheets include: weather, cloud type and amount, visibility, wind wave (sea) and swell, wind direction and speed, air and wet-bulb temperatures, relative humidity, and barometric pressure. On certain special surveys, other measurements are sometimes required. Often these are obtained with special recording instruments. For example, incoming solar radiation studies are made with data recorded by the pyrheliometer. Also, precise temperature measurements taken and recorded simultaneously at different levels on the ship are made with the temperature-lapse-rate indicator. Such measurements are valuable in explaining varying conditions in the upper layers of the ocean. The following information has been extracted from the U. S. Weather Bureau's Instructions for Recording and Coding Marine Meteorological Observations in the New International Code, and they are intended as guides. For more complete instructions reference should be made to the above manual, also the U. S. Weather Bureau's Circular M, Instructions to Marine Meteorological Observers and Circular S, Manual of Cloud Forms and Codes for States of Sky.

11–3 Weather.—Table 1 contains the code used in indicating the state of the weather at the time of observation. (See pt. II.) The table is divided into 10 decades, each of which contains 10 numbers. These decades correspond to the 10 main types of weather. The first digit of any number in the table indicates the decade to which that particular number belongs. After the observer has selected the decade which best applies to the prevailing weather condition, he should pick out from that particular decade the number which most correctly describes the weather at the time of observation or during the hour preceding. Neither when selecting the decade nor in the determination of the complete number must account be taken of weather phenomena which occurred more than 1 hour preceding.

11–4 Clouds.—The form of the significant cloud layer should be recorded using the code given in table 2. If the sky is cloudless at the time of observation, a dash should be entered. If fragments of a cloud layer (i. e., covering less than 1/10 of the sky) are observed under a cloud layer covering 1/10 or more of the sky with bases below 8,000 feet, the fragments will be disregarded and the code figure selected to indicate amount of the next higher cloud type. The height of the cloud is the distance from sea level to the base of the cloud. The amount of total cloud cover is indicated in tenths of sky covered and is recorded using the code in table 3. In the thin types of mackerel sky there are almost always gaps or spaces through which clear sky can be seen. When these conditions prevail, the amount of cloud should never be recorded as greater than 9/10 even though such clouds are spread over the entire sky.

11–5 Visibility.—Observations of visibility should be made using the code in table 4. Horizontal visibility is often very useful as an indicator of the condition of the lower atmosphere, which in turn has effects on the sea surface. As a general rule, the visibility is good when the air temperature is lower than the sea temperature and very poor when higher. The reason for this is that in the former condition, the lowest layers of the atmosphere are being heated by the sea. This tends to make the atmosphere thermally unstable and favors active vertical mixing, which in turn tends to disperse haze or fog particles that may have accumulated at low levels. An unstable atmosphere is characterized by cumuliform clouds and a showery type of weather

On the other hand, when the sea temperature is lower than the air temperature, it follows that the sea cools the lowest layers of the atmosphere. This tends to make the atmosphere thermally stable and prevents active vertical mixing, which in turn favors the production of haze and at low levels. The cooling of the surface air also favors the production of fog. A stable atmosphere is, therefore, characterized by poor visibility and, if it is sufficiently moist, by fog, low stratus clouds and drizzle.

11–6 Wind Speed and Direction.—When a ship is equipped with an anemometer the true wind speed is recorded in knots and the direction in degrees True rather than magnetic. The data may be recorded in such manner on the A-sheet, but speed must be converted to meters per second and direction coded when transcribed to the E-sheet. These values are found in tables 10A and 8, respectively. When observing aboard a ship without an anemometer, the Beaufort scale given in table 9 is used and the force estimated.

The appearance of the sea surface serves as the best means of estimating the true wind speed, just as it affords the best means of ascertaining wind direction. The direction can be determined by making use of the fact that the crest lines of the smallest ripples on the sea surface are perpendicular to the direction of the wind. These ripples are very sensitive to sudden changes in character of the wind. Accentuation of them by a localized increase in wind velocity produces an apparent darkening of the sea surface, which serves to show the rate of travel of individual gusts or puffs. With wind forces of 6 (Beaufort) or more, the wind direction also may be estimated correctly from the direction of the streaks of foam which are formed.

11–7 Temperature of the Air.—The air temperature should be read from a reliable portable thermometer or the dry bulb of a sling psychrometer and recorded on the A- and E-sheets to the nearest 0.1° C. and on the B-sheet to the nearest 0.1° F. Conversion tables are given in table 13. Wet-bulb reading of the sling psychrometer are read and recorded to the same degree of accuracy. It is important that the temperature of the air and also the wet-bulb temperature be measured by a sling psychrometer since this method is more accurate than that of stationary thermometers. Furthermore, the formula employed for determining the relative humidity from the readings of a psychrometer is not applicable to the readings of a stationary wet-bulb thermometer.

The mercury bulb of the wet-bulb thermometer in the sling psychrometer is covered with a muslin wick. The wick must be wet with *fresh* water before each observation. The wick must be kept clean and free of salt.

11–8 Relative Humidity.—Relative humidity is determined from table 14. The table is entered with the Fahrenheit readings to the nearest whole degree, of the sling psychrometer dry and wet bulbs and the percent of relative humidity is read directly.

11–9 Barometric Pressure.—Barometric pressure may be recorded on oceanographic log sheets—A and B in inches of mercury after correcting for any barometer error; however, the readings must be converted to millibars when transferring the data to the E-sheet. Conversion tables for barometers reading in inches of mercury and millimeters to millibars are given in tables 11A and 11B respectively.

When the barometer is pumping, the observer should take 2 or 3 pairs of readings. Each pair should contain one of the highest and one of the lowest readings obtainable. The reading to be recorded is that which is obtained from averaging the whole set.

11–10 Wind Waves (Sea) and Swell.—Sea and swell have been discussed in chapter 10. Complete instructions for taking and recording these observations are given on H. O. Pub. No. 606–e, Sea and Swell Observations. Tables for recording the data are in the above publication and in tables 5 and 6.

11–11 INSTRUCTIONS FOR OPERATING THE RECORDING PYRHELIOMETER.—The pyrheliometer assembly is designed to obtain data to determine the ratio between total incoming solar and sky radiation and that reflected from the sea surface. The pyrheliometer is a thermopile enclosed in a glass bulb and measures radiation incident on a horizontal surface. The receiving surface consists of two flat concentric disks, a black disk forming an absorbing surface and a white disk forming a reflecting surface. The resulting temperature difference between the two disks acts on the thermopile and produces an electromotive force (EMF) which is proportional to the intensity of the incident radiation. This EMF is transmitted to a recording potentiometer.

11–12 The Pyrheliometer Installation.—The installation consists of 1 topside pyrheliometer (which measures total incoming radiation) and 2 inverted outboard pyrheliometers (which measure reflected radiation from the sea surface). The outboard instruments are fastened to the ends of booms which suspend them well clear of the sides of the ship. The output of these instruments is recorded by an electronic recording potentiometer which is located below deck (fig. 11–1).

11–13 Operating the Recorder.—The outboard pyrheliometers should be uncovered and the booms rigged out after the ship is in open seas. The topside pyrheliometer should be uncovered and then the recorder turned on. The recorder is run continuously from 1 hour before sunrise to 1 hour after sunset. The recorder is turned off during the night to conserve chart paper. It is not necessary to rig in the booms each night unless desired.

11–14 Marking the Recorder Chart.—The following information is entered on the recorder chart every 4 hours at 0800, 1200, 1600, and 2000 local time with the corresponding Greenwich mean time also noted:

a. Date—giving day, month, and year.

b. Time—as above.

c. Ship's position and heading.

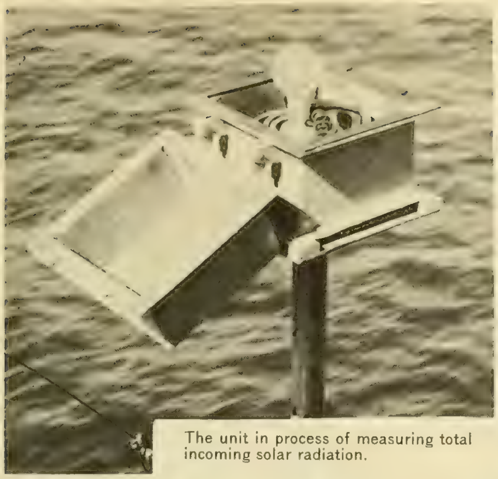
d. Any pertinent remarks concerning operation of the equipment including the time of cleaning the pyrheliometer bulbs.

11–15 Maintenance.—The pyrheliometer bulbs become encrusted with salt spray and must be wiped clean *at least once each day*, and more often as necessary. The recorder should be lubricated occasionally with a special oil, which is provided. The battery should be checked and replaced when the indicator shows red. The chart paper roll should be checked daily to prevent running out during the day. When a roll is about two-thirds used it tends to become loose on the takeup, or bottom roller. When this happens, loosen the takeup and carefully tighten the paper. The printing mechanism should be checked frequently for proper inking on the chart.

11–16 Precautions.—The pyrheliometer assembly is durable enough to withstand fairly heavy sea conditions; however, it is advisable to rig in and secure the equipment if bad storms and abnormally heavy seas are encountered. On naval vessels, the pyrheliometer should be secured and the bulbs removed and stored before any large caliber guns are fired as the bulbs will be shattered by the concussions.

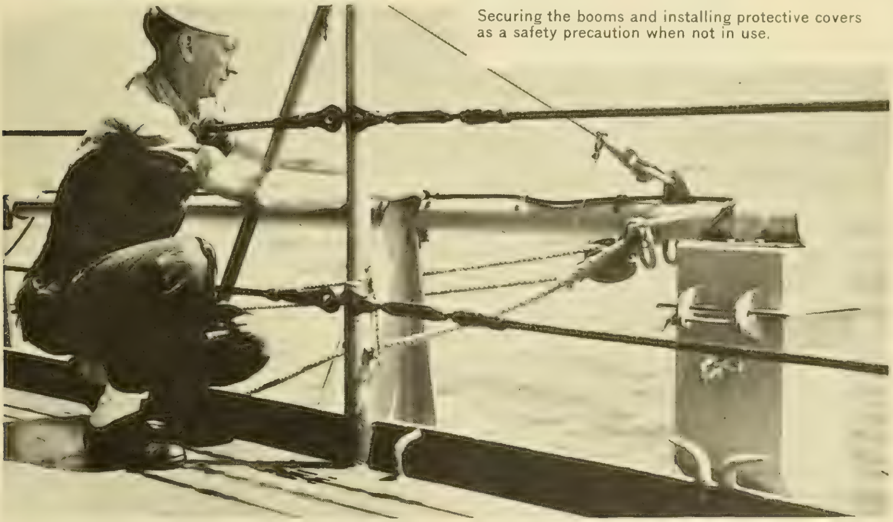
11–17 Storing and Shipping Pyrheliometer Records.—Used chart paper rolls are labeled indicating the ship's name and number, cruise number and name, and dates of beginning and ending of the roll. If the original roll boxes are retained, the rolls may be stored and shipped in them. If there are no such boxes available, the rolls should be fanfolded, inserted in heavy manila envelopes, and shipped in covering envelopes or heavy wrapping paper. These records should be forwarded at the end of a cruise to—

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430



The unit in process of measuring total incoming solar radiation.

Above, inverted painted bulb-type unit, and below, the shielded-type unit, both measuring one half the total radiation reflected from the ocean surface. The boom is extended while underway.



Securing the booms and installing protective covers as a safety precaution when not in use.

The pyrheliometer is used for measuring solar radiation by its thermal effects. The instrument used in this installation is a 180° thermoelectric pyrheliometer. The strip chart recorder used to record the data is a self-balancing potentiometer especially designed for solar radiation work and reads directly in radiation units. The installation is designed for the collection of data that will increase knowledge of the heat budget of the oceans. The specific data problems involved are (1) the measurement of total incoming solar radiation and (2) measurement of total reflected radiation from the water surface and relating this to varying sea surface conditions. One pyrheliometer is used to record total incoming solar radiation; two instruments are installed on booms and suspended in an inverted position over the sea surface, each picking up radiation from one half the sea surface.

Figure 11–1. Shipboard arrangement of pyrheliometer cells.

CHAPTER 12

WATER TRANSPARENCY AND LIGHT ABSORPTION MEASUREMENTS

12–1 GENERAL REMARKS.—The physical relationships governing the penetration and absorption of light, the color, and the transparency of the sea are of prime importance to physical and biological oceanography. For such measurements, three general types of instruments are in use: The submarine photometer, the hydrophotometer, and the Secchi disc.

The submarine photometer detects and records directly, in footcandles, the light existing at the surface and all depths down to approximately 150 meters. Through the use of filters, observations are made in the infrared ultraviolet ranges of the spectrum. The instrument consists of two 2-pen Brown potentiometer recorders and a detecting unit of 3 photoelectric cells and a Statham strain gage.

The hydrophotometer has a self-contained constant light source which allows greater latitude in observation. It may be used at any time of day or night and will measure finer graduations of transparency.

The Secchi disc with its simplicity of theory becomes difficult in operation owing to currents, drift, and light reflection from the sea surface and provides only an approximate index of transparency of sea water.

Color measurements by use of the Forel scale are only approximate because of practical allowances concerning operation.

12–2 TRANSPARENCY MEASUREMENTS WITH THE SECCHI DISC.—The Secchi disc is a circular plate, usually of wood, having a diameter of 30 centimeters. It is covered with a flat white paint. A ring attached at the center of the upper surface allows a graduated line to be secured. Opposite the ring on the under surface is attached a lead weight so that the disc will sink rapidly and vertically. This weight should be at least 5 pounds and may be increased when conditions of drift and current warrant. Secchi discs used on Navy surveys are provided with 5- and 7½-pound weights. The line attached to the Secchi disc should be marked off in 1-meter intervals to at least 50 meters. It is recommended that heavy cotton sash cord or heaving line be used.

The Secchi disc is designed to measure transparency and is dependent upon the available illumination which varies with the time of day, cloud formation, and amount of cloud cover. The Secchi disc observations are recorded at the top of the A-sheet and must be taken at the same time the associated meteorological data is taken for that sheet. Complete instructions for recording these data are given in chapter 14.

12–3 Obtaining the Secchi Disc Observations.—The Secchi disc should be lowered into the water from the shaded side of the ship until the disc is just perceptible, and the depth in meters noted. The lowering is then continued until the disc is no longer visible. The disc is then slowly raised until it is again barely visible. The depth reading of this point is then averaged with the reading obtained on lowering and is recorded as given above.

12–4 DETERMINING WATER COLOR WITH THE FOREL SCALE.—The Forel scale used on Navy surveys consists of a series of 11 small vials containing ammonical copper sulphate and neutral potassium chromate in such proportions that a different graduation of color is imparted to each vial. These vials are numerically designated and are compared directly with the water in the manner described below.

The water color is most easily determined in conjunction with the Secchi disc. After completion of the transparency measurement described in 12–3, raise the white Secchi disc until it lies one meter below the surface. The number of the vial that blends most closely with the water color against the Secchi disc is recorded on the A-sheet. The whiteness of the disc provides the background to which the color is referred; this color may not be the color of the sea surface visible away from the ship. The vials must be shaded from open sunlight when the determination is being made.

CHAPTER 13

SHIPBOARD CHEMISTRY

13–1 GENERAL REMARKS.—Shipboard chemistry employed in the analysis of sea water samples is basically the same as that carried out ashore. The seagoing chemist, however, works under certain difficulties and is subjected to some hazards that do not plague his shore based counterpart. Obviously he must be constantly alert to prevent damage to delicate equipment, resulting from ship's motion, with possible injury to himself and his shipmates. He must have sea racks to stow many types of glassware, chemicals, samples, and apparatus. His laboratory space is, of necessity, limited and must be used to the utmost. Efficient arrangement of equipment will reduce unnecessary work and is vital to the chemist and his assistants who may be working in teams to keep ahead of a backlog of samples.

As explained in previous chapters, the most common method of obtaining sea water samples is by means of Nansen bottles. The samples are analyzed by the methods given in this chapter. Nearly all analyses for various constituents involve comparison by one method or other with a standard or sample of known value.

Additional information on the methods given may be found in the references listed at the end of part I.

13–2 GENERAL LABORATORY EQUIPMENT.—Shipboard chemistry laboratories require certain basic equipment regardless of the types of analyses being performed. This equipment also is utilized for biological and geological work at sea. Lists of equipment needed to carry out specific analyses are given with each method described in this chapter.

13–3 Laboratory Furniture.—The properly equipped laboratory requires permanently installed workbenches, storage cabinets, drawers, shelves, tables, and sinks. Workbenches should be of the proper height (approximately 36 inches) for laboratory work. The bench tops must be of acidproof composition. This may be commercial laboratory bench topping or heavy wood top coated with black acid-resistant paint. Storage cabinets and drawers should be compartmented to prevent excess motion of stored materials. They should be equipped with adequate retaining latches to prevent them from flying open during heavy seas. Shelves are necessary over the areas on the workbenches and tables where chemical titrations are run. These shelves are fitted with sea racks to hold the large bottles or carboys of standard solutions to which the titration burettes are connected. A table, or a table-height (about 30 inches) portion of the workbench is necessary for titrations and other analyses that the chemist must run while seated. The laboratory must have one or more sinks. One sink must be big enough to wash large pieces of glassware and small oceanographic instruments. The sinks should be stainless steel and must have acidproof drainboards, drains, traps, pipes, seacocks, and overboard-discharge outlets. They should be furnished with hot and cold fresh-water taps and a salt-water tap.

It is recommended that the laboratory deck be covered with acidproof paint or an acid resistant plastic (vinyl) tile.

13–4 Distilling Apparatus.—Distilled water is required to carry out almost all shipboard analyses of sea water samples. This is especially true in the preparation of standard solutions for salinity and dissolved oxygen determinations. Small ships without evaporators or those with only small emergency evaporators, will have to carry several carboys of distilled water. Electric distilling apparatus of the Barnstead type will provide sufficient distilled water, using fresh water from the ship's tanks, on those ships equipped with steam evaporators. The still produces very pure water when properly operated in accordance with the instructions provided by the manufacturer. The distillate should be collected in 1-gallon, clear glass bottles which have been *thoroughly* washed and then rinsed with distilled water. It must be remembered that a single drop of salt water will contaminate a whole bottle of distilled water. Each bottle should be labeled and dated after it has been filled.

13–5 Electric Hotplate.—An electric laboratory hotplate of the Hotcone type, which is designed for use with beakers and flasks, is used for boiling starch solutions (used in oxygen determinations, preparing other reagents) and sterilizing small equipment.

13–6 Magnetic Stirring Apparatus.—Sea water samples analyzed by titrations must be stirred in a very regular and precise manner during the running of a titration. To best accomplish this a magnetic stirring apparatus is used. This is essentially a horizontal magnet attached to the vertical shaft of a small electric motor. The speed of the motor is controlled by a rheostat. A beaker of sample is placed over this magnet and another magnet, which is plastic covered, is placed in the beaker. The latter is revolved in the beaker at the same speed as the motorized magnet beneath, thus stirring the sample at a constant and controlled speed. Such magnetic stirrers are necessary for salinity and oxygen determinations. The use of plastic-covered magnets is recommended over that of glass covered ones due to the higher breakage rate of the latter.

13–7 Beam Balance.—A good quality triple beam balance, accurate to the nearest 0.1 gram, is used for weighing various chemicals required to make many of the solutions. Naturally, a beam balance cannot be used while the ship is at sea, so all weighing must be done before a cruise or while the ship is in port. Wherever possible, weighing of chemicals that requires accuracy should be done ashore and the beam balance is used only for weighing those chemicals that do not require a high degree of accuracy. Certain chemicals must be dried carefully and weighed on an analytical or gram-atic balance in a shore laboratory and then sealed in vials or jars for use at sea.

13–8 Miscellaneous Laboratory Equipment.—In addition to the major pieces of equipment discussed above, the shipboard laboratory is furnished with a large variety of apparatus used for many types of analyses and other work at sea. The following list of equipment will serve as a guide for equipping a shipboard laboratory although it must be kept in mind that requirements vary considerably for different ships and surveys. Lists of chemicals and equipment required for each type of analysis are listed with the instructions for that analysis.

Aprons, laboratory.
Beaker, Griffin low form, Pyrex, with pour-out capacity: 50, 100, 250, 400, 600, 800, 1,000, and 2,000 ml.
Bottle, sea water sample, with consecutively numbered porcelain stoppers and rubber gaskets.
Bottle, wash, Pyrex, 500 ml.
Bottle stopper extractor.
Brush, beaker, cylinder, or funnel, with wooden handle.
Brush, burette, fantip.
Brush, flexible pipe cleaner.
Burner, liquid petroleum, Bernzomatic type, with complete set of tips.
Clamp, beaker.
Clamp, test tube.
Clamp, burette, symmetrical screw-clamp type, rubber-covered jaws.
Clamp, table, for supporting 19 mm. threaded rod.
Clamp, tubing, Hoffman improved form, ½-inch.
Clamp, tubing, Mohrs, pinchcock, improved form.
Clamp, utility, castaloy, rubber sleeves, large size.
Clamp, holder, castaloy.
Cork borer set, brass with handles.
Corks, assorted sizes 3 to 16 xxxx quality, regular length.
Cotton, absorbent, in 1-pound packages.
Cylinder, single graduated, Pyrex capacity: 10, 25, 100, and 500 ml.
Dish evaporating, Coors, porcelain size Nos. 3 and 4.
File, triangular, 4-inch, for glass cutting.
Filter paper, qualitative circles, smooth white, 18.5 cm. diameter.
Filter paper, qualitative circles, heavy white creped, 40 cm. diameter.
Filter pump (aspirator), brass, ⅜-inch inside pipe size thread, with threaded filter pump coupling.
Flask, boiling, flat bottom, vial mouth, Pyrex, capacity: 250, 500 ml., 1 liter.
Flask, Erlenmeyer, narrow mouth, Pyrex, capacity: 125, 250, 500 ml.
Flask, volumetric, contain and deliver, T. S. stopper EXAX, blue line, 500, 1,000, and 2,000 ml.
Flush plate bases, threaded for 19 mm. support rods.
Forceps, bottle, nickel plated.
Funnel, Bunsen, 125 mm. Pyrex, short stem.
Funnel, ribbed, heavy molded.
Gloves, rubber.
Lamp, titration, fluorescent daylight.
Lubricant, stopcock, 1-ounce tubes.
Mortar, porcelain, Coors, with pour-out lip and porcelain pestle, 80 mm. diameter.

Pencil, glass marking, wax, colors: black and red.
Rod, lime glass, 6 mm. diameter.
Rod, pick up, magnetized.
Rod, threaded support, 19 mm. diameter in lengths: 50, 75, 100, and 125 cm.
Spatula, nickel, double end.
Spatula, stainless steel, narrow blade, wood handle, overall length 7 inches.
Stopper, rubber, regular form, assorted.
Stirring bar, magnetized, plastic coated, 1-inch length, for magnetic stirrer.
Test tube, chemical, with rim, Pyrex, 10 x 75 mm. size No. 1.
Thermometer, laboratory grade, engraved stem, range $-1°$ to $51°$ C.
Tongs, beaker.
Tongs, crucible, stainless steel, double bent.
Towels, cotton, hand.
Towels, paper.
Toweling, part linen for glassware, 17 inches wide 10 yards long.
Tubes, connecting, T-shape, lime glass, 7 mm. outside diameter.
Tubes, connecting, Y-shape, lime glass, 7 mm. outside diameter.
Tubing, lime glass, standard wall, 6 mm. outside diameter.
Tubing, rubber, red, medium wall, inside diameter $\frac{3}{16}''$ x $\frac{1}{16}''$ wall, 50 feet per package.
Tubing, rubber, red, extra heavy wall, inside $\frac{3}{16}''$ x $\frac{3}{16}''$ wall, 50 feet per package.
Tubing stretcher.
Watch glass, Pyrex, 100 mm. diameter.

13–9 GENERAL LABORATORY TECHNIQUES AND PRECAUTIONS.—Although each method of analysis given in this chapter has detailed instructions for handling and cleaning its particular equipment, there are basic laboratory techniques and precautions with which the seagoing chemist must familiarize himself. The chemist will at times have to handle chemicals that are poisonous, corrosive, and toxic. He must know the safest methods for handling and storing them. Because of the dangers involved, extreme care must be taken at all times when handling dangerous chemicals. Most laboratory equipment, being glass, is delicate and some is specially made and difficult to obtain. Costly damage and personal injury can result if such material is handled by an inexperienced person. It is obvious, therefore, that the shipboard laboratory is a space in which only qualified personnel sould be authorized. The laboratory should never, under any circumstances, be used as a general passageway or lounge.

The shipboard laboratory must be well ventilated to remove any poisonous vapors created by chemicals. As several types of equipment for sea water analyses are calibrated at 20° C. (68° F.), it is desirable that the laboratory be kept as nearly as possible at that temperature at all times.

Several types of analyses utilize color change determination of end point in titrations. For this reason, it is important that the lighting of the laboratory be of high quality and of constant source. Fluorescent lights of the daylight type are recommended.

Two things that are very important in operating a shipboard laboratory are neatness and cleanliness. A sloppy laboratory can quickly become chaos. As soon as a piece of equipment is used, it must be cleaned and returned to its proper place of stowage. Considerable time can be lost searching for a particular flask or graduate only to find it broken or too dirty to use. Chipped glassware is dangerous. Avoid using it. Clothing can be ruined and skin burned if spilled acids are not cleaned up immediately.

13–10 Handling and Storing General Laboratory Equipment.—The greater portion of laboratory equipment used at sea consists of chemical glassware. Although these beakers, graduates, burettes, pipettes, flasks, bottles, etc., are each designed for particular functions they unfortunately are of very awkward shapes and sizes for stowage. It is recommended that only those pieces of equipment in fairly frequent use be arranged in sea racks. The remaining spares and seldom-used pieces should be wrapped liberally with cotton or other soft material and stowed in drawers or bins so they will be unaffected by motion of the ship in rough weather. Do not crowd glassware in drawers. Metal apparatus that will corrode should be cleaned and coated with preservative before storing.

13–11 Stowage and Handling of Chemicals.—Chemicals should be stowed in bottles or jars with screw caps or stoppers and packed in cabinets or drawers with dependable latches or locks. Wrap fragile bottles with cotton or other soft material to prevent contact with one another and to keep them from moving about with the motion of the ship. Liquids should be stowed upright in tightly capped bottles in sea racks or compartmented bins.

Strong acids and bases should be stowed in racks or bins that are well ventilated and equipped with a drain to dispose of spilled solution in the event of breakage. This drain should lead to an overboard discharge. One

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method is to construct a rack at the back of one of the laboratory sinks that will drain into the sink.

Some of the strong acids used in the laboratory are hydrochloric, nitric, and sulfuric. Sodium hydroxide is a strong base often used in the laboratory.

Whenever handling chemicals, a laboratory apron or coat should be worn. When handling strong chemicals wear rubber gloves. When mixing acid solutions remember to always *add acid to water slowly* by pouring it down a stirring rod or the side of the beaker to prevent splashing. *Never pour water into acid.* Keep acid away from combustible material.

Strong acids cause burns on the skin and have a destructive action on all tissues. They can destroy clothing and cause severe and permanent damage to the eyes. Fumes and droplets may produce severe irritation of the respiratory tract. Inhalation of the vapors of hot acid may cause loss of consciousness and serious damage to the lung tissue. Sulfuric acid burns are deep and produce scars. Careful handling and adequate ventilation will prevent these things from happening.

13–12 Safety and First Aid Measures.—The most serious accidents that occur in a laboratory usually result from contact with strong chemicals. It is important that safety and first-aid equipment be readily available. In addition to a first-aid kit there should be present a bottle of dilute acetic acid or vinegar and a jar of sodium bicarbonate. These should be plainly marked. If acid is spilled on any part of the body flush it immediately with large quantities of water and then neutralize with a solution of sodium bicarbonate. This solution can be made by mixing a heaping tablespoonful of sodium bicarbonate powder with about a pint of water.

Ammonia and alkalis, or bases, should be flushed immediately with large quantities of water and then neutralized with a solution of dilute acetic acid or vinegar.

Chemical burns should be flushed with cold water and bandaged with sterile dressings. Other burns should be bandaged with sterile dressings only. Pain caused by minor burns may be relieved somewhat with petroleum, vegetable oils, or salves. Always consult a doctor or the ship's medical officer for treatment of all injuries.

Silver nitrate solution, such as used for salinity determinations, will produce dark-brown stains on the skin. Silver nitrate stains can be removed by application of two solutions, which are prepared and applied as follows:

Solution No. 1—Iodine solution. Dissolve a few iodine crystals in about 50 ml. of water.

Solution No. 2—Sodium thiosulfate solution. Dissolve a few crystals of sodium thiosulfate in about 50 ml. of water.

First apply solution No. 1 to the silver nitrate stain with the aid of a stirring rod or something similar. Next apply solution No. 2 liberally. This application fades or even removes the stain.

13–13 Cleaning General Laboratory Equipment.—Keeping laboratory glassware and other equipment clean is of extreme importance. Glassware should never be put away dirty but must be thoroughly washed with soap and water, well-rinsed and dried. Glassware to be used for sea water analyses must be thoroughly cleaned with soap and warm water and rinsed with distilled water. Contamination of samples will result in invalid analyses if dirty glassware is used.

Always clean the workbench tops and tables after completing analyses of samples or after making up various solutions. Wipe dry all surfaces.

13–14 Cleaning and Lubricating Glass Stopcocks.—The special burettes and pipettes used in the analyses described in this chapter require extremely careful cleaning. Each are equipped with one or more tapered ground-glass stopcocks. If these stopcocks are not properly cleaned and lubricated, they may freeze or leak; the latter causes error in analysis while the former may damage the equipment.

To clean the stopcock and barrel, first remove the stopcock and soak it in a beaker of benzine (not benzene). Take some clean absorbent cotton soaked with benzine and insert it into the barrel and rotate it in order to remove all the grease therein. Repeat this several times to remove all traces of grease. Wipe off the stopcock in the same manner and clean the holes with a pipe cleaner soaked in benzine. Lay the stopcock on a piece of clean filter paper to dry. Be careful never to get stopcocks mixed as they are individually ground to each barrel. Allow the stopcock and barrel to become thoroughly dry before lubricating.

Lubricating the stopcock is a very delicate procedure and must be done in a very exacting way. If too much lubricant is used the holes will clog and grease particles may get into the tube of the burette or pipette and will clog the delivery tip. If not enough grease is used the precision ground valve will wear and result in a leaky condition. The correct method for lubricating the stopcock is to take a small amount of stopcock lubricant, about half the size of a match head, and apply it carefully to the stopcock with the index finger. Smooth the grease evenly over the ground-glass surface avoiding the holes by about one-sixteenth of an inch. Insert the stopcock into the barrel. By rotating the stopcock it will be apparent immediately where there is an excess or lack of grease. If too much grease is used, clean the entire assembly again with benzine and repeat the lubricating procedure. When properly lubricated, the stopcock will operate smoothly and provide a nonleaking seal.

Do not use a stopcock lubricant that contains silicon because the acid-dichromate cleaning solution used to clean burettes and pipettes is inaffective in removing it. Silicon stopcock lubricant requires the use of a basic or alcoholic cleaning solution which will not clean as thoroughly as the acid-dichromate solution and in the presence of silver nitrate, as used in the salinity analyses, will result in the formation of a black precipitate inside the apparatus. This deposit is extremely difficult, if not impossible, to remove.

13–15 Cleaning Burettes and Pipettes.—Before titration apparatus can be set up, the burettes and pipettes to be used must be cleaned meticulously. They must be inspected frequently during analyses and recleaned at the first signs of adherence of solutions or samples to the inner sides of the glass. The results of an analysis can be distorted greatly by the presence of a *single* droplet of solution or particle of grease adhering to the inside of the pipette or burette. For example, a one drop error in delivery of the Knudsen pipette can cause an error of 0.16 parts per thousand of salinity.

To clean this glassware remove the stopcocks and clean and lubricate them as described in section 13–14. After reassembling, rinse the instruments inside and out with fresh water and fill them with the special acid dichromate cleaning solution described in section 13–16. This solution is very concentrated and must be handled with extreme care. Before filling, warm the solution to about 60° C. Do not let the solution come in contact with the graduations or other markings on the burette as it will remove the color from the lines and figures. Leave the solution in the instruments for at least 2 hours.

Drain the acid-dichromate solution carefully from the instrument. The solution is returned to its container for reuse. Rinse the instrument for about 5 minutes in tap water and then make a final rinse with distilled water. If there is any sign of water adhering to the inside of the instrument, then fill it again with the cleaning solution and let stand for at least 2 hours.

If the instrument is clean, remove the stopcocks and clean, lubricate, and reassemble them. The pipette or burette is now ready to be set up for titrations. When running the titrations, keep a close watch on the condition of these instruments. At the first evidence of droplets adhering to the inside, they must be cleaned again.

13–16 Making and Handling the Acid-Dichromate Cleaning Solution.—The special acid-dichromate cleaning solution is an extremely powerful and dangerous liquid and must be handled with great care at all times. It must be made up only when there is ample diluting water available for immediate use and only when there are two or more persons present in the laboratory. Wear rubber gloves, use Pyrex glassware, and remember to always *add acid to water slowly* by means of a stirring rod, or down the side of the beaker.

The acid-dichromate cleaning solution is a saturated solution of concentrated sulfuric acid (H_2SO_4) with potassium dichromate ($K_2Cr_2O_7$). This is made up in the following manner:

1. Dissolve 60 grams of technical grade potassium dichromate in 300 ml. of distilled water at about 20° C.
2. Place the beaker in a cold water bath and slowly add 480 ml. of technical grade concentrated sulfuric acid to the saturated solution of potassium dichromate. Stir the solution continuously.
3. When cool, pour the solution into a liter ground-glass-stoppered bottle.

A crystalline precipitate will form at the bottom of the bottle. The precipitate indicates that the solution is saturated and may be used over again as long as it remains. When the dark brown color of the solution begins to show a greenish hue, it is an indication that too many impurities are present and the solution should be disposed of and a new solution made up.

13–17 Purifying Chemicals by Recrystallization.—It is sometimes necessary to use certain solid chemicals of a greater purity than provided by commercial manufacture. In purifying a solid by recrystallization, a roughly weighed amount is dissolved in a sufficient volume of distilled water to give a saturated or nearly saturated solution at the boiling point. The hot solution is filtered to remove insoluble material, which is always present to some degree. Filter paper is placed in a funnel which has had the stem removed to prevent crystals forming within and clogging the bore. The filtered solution is cooled rapidly by stirring to form small crystals which will include less mother liquor than coarse crystals. In the case of very soluble substances, it is advisable to cool in a mixture of ice and water to obtain a good yield. To remove adherent liquid, rinse the crystals with small portions of cold water. The recrystallized salt, if sufficiently purified by one recrystallization is then dried at, or above, room temperature, depending upon the material. The solid thus dried will contain included water unless it has been heated to a high temperature. This water may be removed by reducing the crystals to a very fine powder, by grinding in an agate or porcelain mortar, and again heating. The complete expulsion of water is naturally necessary only when the recrystallized solid is to be used as a standard substance. Included water can be removed from hydrated salts by placing them in a desiccator. The crystals then fall to a very fine powder, both foreign and hydrate water being lost. The pure dry salt thus obtained should be kept in glass-stoppered bottles to protect it from atmospheric contamination.

Bottles with mouths ground on the outside instead of inside are suitable for holding certain standard substances. By lightly covering the ground glass surface with petrolatum or stopcock lubricant, the bottle may be hermetically sealed. This is especially desirable for hydrates which may lose water in air of low humidity.

13–18 Preparing Glass Tubing for Laboratory Use.—Glass tubing is usually supplied in bundles of 4-foot lengths. Tubing must be cut to desired length, bent to desired shape, and the ends fire polished for use. To cut glass tubing, place it on a solid surface and, using a triangular file, scratch the glass in one even stroke at the desired place. Grasp the tubing in both hands with the thumbs back of the scratch. The scratch must face away from the thumbs. Gently apply pressure. The tubing should break cleanly without chipping. The edges are fire polished by holding the tip in the flame of a torch and rotating the tube with a rolling motion between the fingers.

To bend glass tubing, grasp the tubing a few inches back on either side of the region to be bent and, holding this region in the flame of the torch, roll the tubing back and forth just above the blue portion of the flame. When the glass is soft and pliable, withdraw the tubing from the flame and quickly bend to the desired angle. This bending should be done with a single motion. Doing it this way will prevent the tubing from flattening at the bend and constricting the bore.

To thread a piece of glass tubing through the hole in a rubber stopper, first wet the fire-polished end, then grasp the tubing a little above the stopper hole and gently work it through the hole. *Never* cup your hand over the end of a piece of tubing to force it through a stopper. Even if the end is fire polished the tubing may break and a serious cut will result. Never try to put a broken end of tubing or one that is not fire-polished into a stopper or rubber tubing. Always wet glass tubing before inserting it into rubber tubing. Never use a piece of glass tubing or glass rod that does not have fire-polished ends.

13–19 DETERMINATION OF CHLORINITY AND SALINITY OF SEA WATER.—Determining the chlorinity of sea water is of fundamental importance to oceanography. As mentioned in chapter 1, the knowledge of the salt content, or salinity, is of great importance in determining subsurface currents, underwater sound transmission velocities, and water mass transport and identification. The ratios of concentrations of several major constituents of sea water are virtually constant with the concentration of chlorinity. Of these, salinity is probably the most important.

Chlorinity is briefly defined as the number of grams of chlorine, bromine, and iodine contained in 1 kilogram of sea water, assuming that the bromine and iodine had been replaced by chlorine. Salinity is the total weight of dissolved solids in grams, found in 1 kilogram of sea water and may be determined from the concentration of chlorinity.

13–20 The Knudsen Method.—Professor Otto Petterson introduced the titration of chloride, which is now the basis for nearly all measurements of salinity in oceanographic work. Refinements were made by Professor Martin Knudsen and the present method was named after him. This method is used extensively both in this country and abroad, ashore and at sea. Chlorinity is determined by titrating a sample of sea water with a solution of silver nitrate, the strength of which has been determined against a known sample. The known sample, or standard, is standard sea water and is explained in section 13–27.

13–21 Chemicals Required.—The following chemicals are required for salinity titrations. The amounts in parentheses are those required to analyze 10 stations of 24 bottles each.

Iodine, crystals, C. P., A. C. S. (small bottle). (Sec. 13–12).

Potassium chromate, crystals, C. P., A. C. S. (80 grams per jar—1 jar).

Potassium dichromate, fine crystals, C. P., A. C. S. (60 grams).

Silver nitrate, crystals, C. P. (371.1 grams per jar—3 jars).

Sodium chloride, fine crystals, C. P.

Sodium thiosulfate, crystals, C. P., A. C. S. (small bottle). (Sec. 13–12.)

Sulfuric acid, conc. 36N, AS and N_2 pure, sp. gr. 1.84, A. C. S. (480 ml.).

Standard Sea Water, Copenhagen, Eau de Mer Normale (12 vials).

13–22 Apparatus Required.—In addition to the apparatus previously listed in sections 13–2 through 13–8, the following apparatus is required to carry out salinity titrations by the Knudsen method.

Bottle, dropping, S. T. ground pipette, Pyrex, 125 ml. capacity.

Bottle, wide-mouth, 5-gallon capacity.

Bottle, Pyrex, narrow-mouth, S. T. ground flat glass stopper, capacity 1 liter.

Bulbs, rubber, pipette, small.

Burette, Knudsen, automatic type, Pyrex; range: 16–22 double ml., 12–18 double ml., 17–23 double ml.

Pipette, Knudsen, automatic type, Pyrex, capacity, 15 ml.

Reader, meniscus.

Wipes, disposable paper, absorbent, lint free, Kimwipes type.

13–23 The Knudsen Automatic Pipette and Burette.—The titrations are carried out using the special Knudsen automatic pipette and burette. The pipette is calibrated to deliver almost exactly 15 ml. of sample water. It is used to measure the amount required from the sea water sample bottle. At the top is a three-way stopcock for suction filling, neutral, and delivery. Although the pipette is built to deliver 15 ml., each one differs very slightly from the others; therefore, it is important that the same pipette be used throughout a complete set of titrations.

The Knudsen burette is a very delicate and somewhat complex instrument for releasing a measured amount of silver nitrate solution. It is fitted with a filling stopcock at the base, a three-way stopcock similar to that of the pipette at the top, and a delivery stopcock below the graduations. It differs from the ordinary burette in that it is calibrated in double milliliters. A drainage value of 20.00 on the burette is equal to 40.00 milliliters of solution. The Knudsen tables, which are explained in sections 13–30 and 13–31, are designed to take care of the different calibrations for this type of burette. The double milliliter graduations permit the use of a larger amount of less concentrated solution which increases the accuracy of titrations.

13–24 Setting Up the Titration Apparatus.—Before the pipette and burette can be set up, they must be meticulously cleaned and the stopcocks lubricated in the manner described in sections 13–14 and 13–15. Figures 13–1 and 13–2 show schematic arrangements for the

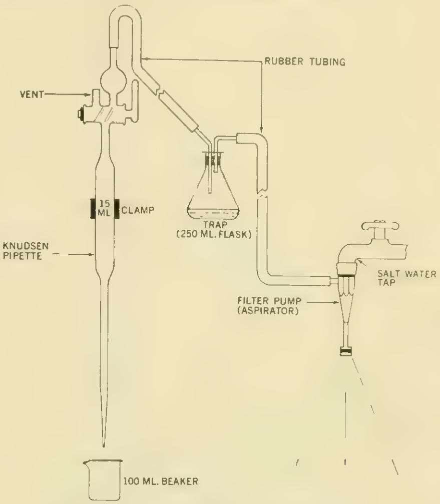

Figure 13–1. Knudsen pipette assembly.

Knudsen pipette and burette. The pipette and burette should be clamped to two support bars which are rigidly attached to the titration table. Attach a filter pump, or aspirator, to the salt-water tap and connect it to the pipette with heavy-wall rubber tubing. A piece of rubber tubing is connected to the overflow valve and terminated in an Erlenmeyer flask, connected to the supporting rod, to collect the overflow of the silver nitrate solution.

Attach the magnetic stirring apparatus to the support rod below the burette so that it will be centered under the delivery tap. It is recommended that a doughnut-shaped piece of half-inch-thick foam rubber be cemented to the top of the stirrer to prevent the 100-ml. beaker, used for titration, from sliding off.

The table should be provided with a sea rack to hold the bottle of standard sea water, the dropping bottle of indicator solution, 2 or 3 100-ml. beakers, and 2 sea-water sample bottles.

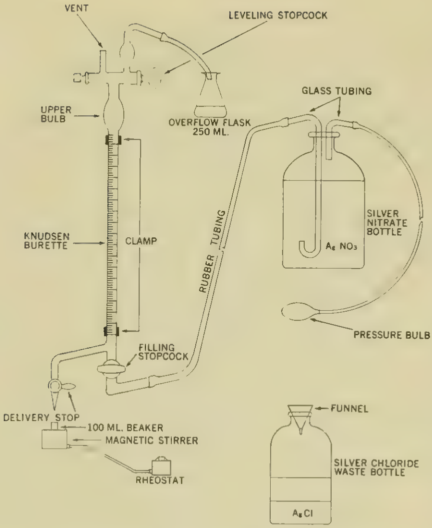

Figure 13–2. Knudsen burette assembly.

The background behind the burette should be painted flat white to aid in reading the burette without glare and give proper light for color interpretation of the titration end point. A fluorescent titration lamp should be rigged behind the magnetic stirrer at a height to provide proper light to the sample.

It is advantageous to have on hand a simple glass stirring rod about 6 inches long, blunted at one end and bent at the other at about a 40° angle for the last half inch. The ends of the rod should be fire-polished. The stirring rod is used for transferring half drops of solution from the delivery tip of the burette to the sample in the beaker during the final stages of the titration run.

If the silver nitrate solution bottle can be placed in a sea rack on a shelf that is high enough to permit gravity flow to fill the burette, then the pressure bulb shown in figure 13–2 will not be needed. Due to low overhead on most ships, this usually is not possible and use of the pressure bulb will speed the refilling of the burette.

Silver nitrate is sensitive to light, and the solution will decompose if exposed to light for long periods. A satisfactory container for the solution is a 5-gallon, wide-mouth bottle or carboy. The bottle must be painted with several coats of black paint to make it light-proof, except for a small (half-inch) vertical slit through which the solution may be seen. The edge of the slit may be graduated by liters with white paint to show the amount of solution remaining in the bottle. Clean the inside thoroughly with soap and water. Rinse with tap water. Give a final rinsing with distilled water and dry before using.

A waste receptacle for the titrated samples is necessary. The best type is a wide-mouth, 5-gallon bottle or carboy. This bottle should be secured on the deck beside the titration table. The precipitate of silver chloride which is collected in the bottle is removed and dried after the bottle gets about two-thirds full. The method for drying is given in section 13–34. From time to time, the excess water can be decanted from the bottle. If the water becomes red in the bottle add a little sea water to it. It is recommended that when running titrations keep a funnel in the mouth of the bottle. This will make it easier to pour waste into the bottle and will prevent the magnet used in stirring from being dumped accidentally into the bottle.

13–25 Preparing the Indicator Solution.—Potassium chromate (K_2CrO_4) is used as the indicator in determining the end point of the titration. This solution is made by dissolving 8 grams of chemically pure potassium chromate in 100 ml. of distilled water. This solution is kept in a 125-ml. dropping bottle that has been cleaned with acid-dichromate cleaning solution, rinsed with distilled water, and dried.

13–26 Preparing the Silver Nitrate Solution.—The silver nitrate solution is made by dissolving 37.11 grams of silver nitrate in 1 liter of distilled water. It has been found that the best results are obtained by making up larger batches of solution than 1-liter amounts. It is easier to make a correct solution when making a 10-liter batch than a 1-liter batch because the smaller the amount the greater the chance of error. One drop spilled would make a difference to 1 liter but only one-tenth as much difference to 10 liters.

As a triple beam balance can be used only ashore or when the ship is in port, it is recommended that the silver nitrate needed for a cruise be weighed out ashore and sealed in small clean glass jars. For 10-liter batches of solution, weigh out 371.1 grams per jar.

To mix a 10-liter batch, first open a silver nitrate jar and carefully pour all the crystals into a clean 800- or 1,000-ml. beaker. Add distilled water to the beaker by pouring it first into the jar and then into the beaker. Repeat this until the beaker is about three-fourths full. This will insure that all silver nitrate is removed from the jar. Stir with a glass rod until the crystals are dissolved, then divide the solution roughly equally between two 2,000-ml. volumetric flasks. Add distilled water to each flask (pouring it from the same beaker) up to the graduation mark; then pour each into the black silver nitrate bottle. Allow the flasks to drain well. The solution must be colorless. If it is cloudy or turns whitish, it is contaminated and must be discarded and all glassware thoroughly cleaned before using again. Refill both flasks to the graduation marks with distilled water and a third time with 1 flask until a total of 10 liters of solution is made up. Shake the bottle *vigorously* for at least 5 minutes before returning the bottle to its rack. Shake the bottle vigorously for 5 minutes before each series, or day's work, of titrations is started. *Never* start a series of titrations without shaking the silver nitrate.

If the silver nitrate is to be weighed out directly for making up the solution first, place a 800- or 1,000-ml. beaker on the triple beam balance, weigh it carefully to the nearest 0.1 gram, then add 371.1 grams to the beaker weight on the scale. Add silver nitrate crystals until balance is again obtained. Now add distilled water until the beaker is three-fourths full and dissolve the crystals. Make up to 10 liters by adding distilled water as described above.

Silver nitrate is a very poisonous compound, both internally and externally. Upon weighing out this chemical on the balance, frequently tiny crystals are spilled onto the laboratory bench. Therefore, the bench should always be wiped carefully with a cloth soaked in sea water and then with one soaked in fresh water. Anyone handling the equipment or chemical should wash their hands thoroughly in salt water and again in fresh water afterward.

The adjustment of the silver nitrate solution to bring its strength within the range of Knudsen's Hydrographical Tables of 1901 and instructions for the use of these tables are given in section 13–30.

13–27 Standard Sea Water.—To insure worldwide uniformity in chlorinity and salinity determinations, the International Council for the Exploration of the Sea prepared a universal reference, *Eau de Mer Normale*, under the direction of Professor Martin Knudsen in 1902. A new primary standard, prepared in 1937 and having a chlorinity of 19.381 ‰, is used to determine the chlorinities of all batches of standard sea water. Standard sea water is the basis for all chlorinity titrations and is the standard used to establish the concentration of the silver nitrate solution before and during a series of titrations. Its chlorinity has been determined with great exactness, and it is produced only by the Association d'Oceanographie Physique, Depot d'Eau Normale, Charlottenlund, Danemark. It is put up in flame-sealed glass vials containing about 200 ml. of water. The chlorinity to three decimal places is given on the label of each vial. Standard sea water is expensive and so must be used conservatively.

Before the standard sea water can be used, it must be transferred to a sea water sample bottle. The bottle should be an old one, or one that is well-leached, and provided with a good rubber gasket. The bottle must be *absolutely clean and dry*. To transfer the standard sea water to the bottle, scratch a small nick in the tapered tip of one neck of the vial and then, with a sharp rap of the glass-file, knock off the tip end of the neck. Shake about 20 ml. of the standard sea water into the prepared sample bottle. Stopper the bottle and shake it vigorously. Pour this rinse water out over the stopper. Repeat this rinsing operation once more. Now scratch a nick on the closed end and insert the open end into the bottle. Give the scratched tip a sharp rap to break it off and the standard sea water will drain freely into the bottle. Stopper the sample bottle at once to prevent evaporation. Do not open the bottle except when actually drawing a sample. Label the bottle, indicating the chlorinity of the vial just emptied and the date.

When a new vial must be opened, do not pour it into a bottle already containing standard sea water but take another water sample bottle, thoroughly clean and dry it and fill as described above.

13–28 Drawing the Sample With the Automatic Pipette.—Drawing the sample for analysis whether it is standard sea water or an unknown sea water sample, is carried out in precisely the same manner. Unless otherwise directed, this technique should never vary. Before any titrations are started all solutions, samples, and apparatus must have remained in the laboratory long enough to have come to the same temperature. This should be at least 6 hours and preferably 12.

The 15-ml. Knudsen automatic pipette must be rinsed twice with the sample water to be analyzed before the measured sample is drawn. To do this, turn on the salt water tap to which the aspirator is attached, insert the tip of the pipette into the sample bottle and turn the stopcock to the fill position. Fill the pipette and lower the sample bottle to allow thorough rinsing by the suction applied. Refill the pipette and, by turning the stopcock to vent position, drain the sample water into a beaker. Discard this water into the waste carboy. Draw a 15-ml. amount from the sample bottle, turn stopcock to off position and wipe the tube of the pipette with a paper wiper after withdrawing the bottle (fig. 13–3).

This will be the first sample to be titrated. Drain the water into a clean 100-ml. beaker, containing a plastic covered magnet. Immediately after the pipette stops draining, there will be about three-fourths of an inch of water remaining in the delivery tip. A few seconds after the last drop has fallen, bring the beaker up to the pipette tip and barely touch the tip to the surface of the liquid. Do not, under any circumstance, try to force more liquid from the pipette for as long as this procedure is followed each and every time, the results will be consistent.

The beaker should be washed thoroughly before the first titration and dried with a clean cloth. Once the titrations are started, however, it is not necessary to reclean the beakers after every run. The silver chloride remaining stuck to the sides of the beaker after a titration is chemically neutral. If one overruns the end point the beaker must be recleaned. Never use a beaker in which the sample has exceeded the end point without either (*a*) cleaning the beaker or (*b*) adding a little sea water to the sample and titrating again to the end point before discarding both the sample and the burette reading.

It is important when drawing samples to remember to always follow the same routine of *draw—wipe—drain—always rinse twice.*

Add exactly *six* drops of the potassium chromate indicator solution to the liquid in the beaker.

13–29 Titrating the Sample With the Automatic Burette.—Analysing the sample by titration, whether it is standard sea water or an unknown sea water sample, is carried out in precisely the same manner. Unless otherwise directed, this technique should never vary. Once the chemist has established his routine, every analysis should be carried out in exactly the same way. The overall time to run titrations of water of nearly the same chlorinity should be approximately the same. Good results will not be obtained if 2 analyses of the same sea water sample take 1 and 2 minutes respectively to run. The titration time for each should be within a few seconds of one another.

Figure 13–3. Drawing the salinity sample with the pipette.

To fill the burette with silver nitrate solution, first close the delivery stopcock, then turn the leveling stopcock at the top of the burette to the closed position. Now open the filling stopcock at the bottom of the burette and press the rubber bulb connected to the silver nitrate bottle. The solution will flow into the burette until a state of equilibrium is reached. Turn the top stopcock to the overflow position and allow the burette to fill. After the burette has filled and some silver nitrate has spilled into the overflow flask, close the filling stopcock at the bottom. Turn the leveling stopcock to the vent position. The burette is now automatically zeroed and is ready for running the titration.

Inspect the burette carefully for presence of any air bubbles. If air bubbles are present, drain the burette by opening the delivery stopcock and refill carefully until they are removed. Before the first titrations are run each day or after the solution has stood for more than a short time in the burette exposed to light, always drain completely and refill the burette at least twice.

To run the titration, place the beaker containing the covered magnet and 15-ml. sample with indicator solution on the magnetic stirrer beneath the delivery tip of the burette. Turn on the magnetic stirrer at a low speed that will not cause splattering. Open the delivery stopcock wide until the silver nitrate solution drains to the base of the burette bulb, and then proceed with caution. Increase the speed of the magnetic stirrer in order to maintain uniform stirring as the volume of solution increases in the beaker. This speed must be great enough to prevent formation of curds in the precipitate of silver chloride yet it must never be great enough to cause splattering of the sample up the sides of the beaker. A speed that is just short of that which will cause splattering is considered best.

Once the silver-nitrate solution leaves the bulb and starts down the graduated bore of the burette, the chemist must not again look at the level of the solution until the end point has been reached and the reading is to be made. He must pay strict attention to the color of the sample and the rate of delivery. Watching the burette scale during the period of titration is considered poor practice.

As the silver nitrate solution is added the liquid in the beaker will change in color from lemon yellow to yellow and will show rapidly increasing tints of tomato red. As the red tint increases, reduce the speed of delivery to a drop at a time until the entire sample becomes a peach color. At this point, called the first rough color change, close the delivery stopcock (the stirrer continuously running), and observe the color for 20 seconds. The color in the beaker should return to a pale yellow. Now add, drop by drop, silver nitrate until the liquid in the beaker again begins to produce tints of tomato red with each drop. This usually takes only a few drops. Now reduce the addition of solution to half drops by turning the stopcock very carefully and then closing it as a tiny droplet appears. Transfer the droplet to the sample with the tip of the stirring rod. Keep repeating this until the liquid turns to a solid peach or dirty orange color throughout without being really orange or even red. The liquid must retain this color for 30 seconds of vigorous stirring. This is the final color change or end point. The solution when examined for transparency is not opaque but rather clear. *Without losing any time, take the reading of the burette scale.* Shut off the stirrer (fig. 13–4).

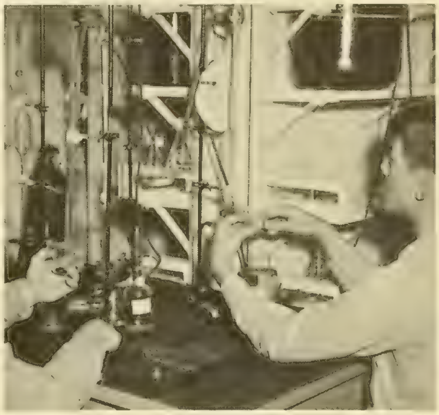

Figure 13–4. Titrating the sample with the Knudsen burette.

While reading the burette, it is convenient to hold a piece of stiff white cardboard directly behind the burette. The bore of the burette then appears to be divided into two parts horizontally; one dark and the other light. As a result, the meniscus can be easily seen and quickly read. The true meniscus is that line of the concave surface of the solution when the observer's eye is level with the top surface of the solution. The dark line is found slightly lower than the uppermost line of solution. Read the graduation of the bottom part of this dark arc. Make the reading immediately and repeat it aloud, then record it on the log sheet described in chapter 14.

Remove the magnet from the beaker with a magnetized pickup rod and pour the titrated sample into the waste jar. Once the titrations are started, however, it is not necessary to reclean the beaker after each titration unless the titration has run over the end point. With a proper end point the silver chloride remaining stuck to the sides of the beaker after the sample has been poured out should be chemically neutral and the beaker may be reused for the next sample as is.

When the end point had been exceeded, 1 or 2 methods must be followed before the beaker can be used for further titrations. One method is to add a drop or two of sea water to the sample—enough to again turn the sample to pale yellow. Then continue the titration to the end point to neutralize the solution. Do not take a burette reading for this. The sample may then be discarded. The second method and the one to use in the event the exceeded end-point sample has been discarded before carrying out the above method, is to wash the beaker with tap water, rinse with distilled water, and dry thoroughly before again using it for titrations.

When running sea water sample titrations a minimum of two titrations of each sample must be made. The burette readings of each titration must be within 0.02 to be acceptable. Whenever the readings have a difference greater than 0.02, a third or, if necessary, more titration must be run until 2 readings are obtained within the prescribed limits. When making the initial standard sea water titrations, a minimum of 3 titrations must be made for each station. Single standard sea water titrations, if they agree with the original, are made for every sixth sea water sample.

A summary of important points to be remembered when drawing and titrating follows:

1. Always keep the equipment spotlessly clean.
2. Always shake the silver nitrate solution bottle thoroughly for 5 minutes before running each station.
3. Always rinse the pipette twice with water to be analyzed before drawing the measured sample.
4. Be sure all solutions, samples and instruments are at the same temperature.
5. Titrate all sea water samples and standard sea water in an absolutely identical manner.
6. Be sure each titration lasts the same length of time.
7. Have the color of each end point identical for all samples.
8. Read the burette immediately after the end point has been reached.
9. Run at least 2 titrations for each sample and be sure they are within 0.02 of each other.

13–30 Standardization and Adjustment of the Silver Nitrate Solution.—Before the titrations of sea water samples are run to determine chlorinity, the silver nitrate solution must be standardized to learn its exact concentration in parts per thousand ($^{\circ}/_{\circ\circ}$). Also in order to carry out the calculations required to determine chlorinity, this concentration must fall within $-0.150^{\circ}/_{\circ\circ}$ to $0.145^{\circ}/_{\circ\circ}$ of the chlorinity of standard sea water. The latter is usually about $19.380^{\circ}/_{\circ\circ}$, the exact chlorinity always being given on the label of each vial. It is important to keep the silver nitrate concentration within the limits of the Hydrographical tables, usually referred to as Knudsen's tables, to find a correction value k necessary for the calculations given below.

Standardization is the process of determining the difference between the concentration of the silver nitrate solution (A) and the chlorinity of the standard sea water (N) which is exactly known. The difference is called alpha (α). Standardization is expressed by the following formula:

$$(N)-(A)=\alpha.$$

For example:

Chlorinity of standard sea water.	(N) = 19. 395
Burette reading of titration	(A) = 19. 37
Alpha	(α) = +. 025

also

Chlorinity of standard sea water.	(N) = 19. 395
Burette reading of titration	(A) = 19. 40
Alpha	(α) = −. 005

An average alpha is obtained from the three best titrations of the standard sea water. This average alpha is the value used to obtain the correction k from Knudsen's tables, which in turn is applied to the burette readings of the sea water samples to obtain chlorinity.

For example:

(N) −	(A) =	(α)
19. 395	19. 38	0. 015
19. 395	19. 36	. 035
19. 395	19. 37	. 025
		. 025 (average)

Or where alpha comes out negative:

(N) −	(A) =	(α)	
19. 395	19. 42	−0. 025	
19. 395	19. 42	− . 025	
19. 395	19. 47	− . 075	(poor run—discard)

19.395 19.42 — .025

— .025 (average)

In the event the standardization reveals that the solution is not within the limits of Knudsen's tables, then the solution must be adjusted. This adjustment is made by adding more silver nitrate crystals if the solution is too weak, i. e., shows a negative alpha lower than −0.150, or by adding distilled water if too strong, i. e., shows a positive alpha of more than 0.145.

To assist in making these adjustments, two linear graphs are shown in figures 13–5 and 13–6. The first graph shows the number of grams of silver nitrate to be added to each liter of solution when the titration reveals a negative alpha value below the limit given in the Knudsen tables. The second graph shows the number of milliliters of distilled water to be added to each liter of solution when the titration reveals a positive alpha value greater than the limit given in the Knudsen tables

Following are examples of both cases:

1. *Weak* solution with *negative* alpha. Assume that from the standardization the alpha is −0.199. Entering the graph in figure 13–5 with this value it is found that 0.380 gram of silver nitrate per liter of solution must be added. Looking at the graduations on the black-painted silver nitrate solution bottle it is seen that there are about 11.0 liters of solution. Therefore: 11.0 liters times 0.380 gram gives a total of 4.18 grams of $AgNO_3$ that must be added to the solution ($11.0 \times 0.380 = 4.18$). Dissolve this silver nitrate in a few ml., say 50, of distilled water, add it to the bottle and shake the solution thoroughly before repeating the standardization.

2. *Strong* solution with *positive* alpha. Assume that from the standardization the alpha is 0.186. Entering the graph in figure 13–6 with this value it is found that 9.4 ml. of distilled water must be added per liter of solution. It is found that there are 12.5 liters of solution. Therefore, 12.5 l×9.4 ml.=117.5 ml. of distilled water that must be added to the silver nitrate solution. Shake the solution thoroughly before repeating the standardization.

13–31 Calculations for Chlorinity and Salinity.—It is essential that all standardizations and titrations of sea water samples be duly noted on a log sheet. Complete instructions for this are given in chapter 14. The log sheet used on U. S. Navy oceanographic surveys is oceanographic log sheet D (PRNC–NHO–1191). After the standardizations and titrations of the sea water samples have been made and the results recorded on the log sheet, first compute the average burette readings for each sample. The next step is to determine the correction *k* which must be applied algebraically to the average burette reading to obtain the chlorinity. This has been greatly simplified by the use of Knudsen's tables. Using the alpha determined by the standardization, enter Knudsen's tables; pages 23 through 34. Alpha is shown at the top of the tables. Under the given alpha (make sure that the sign + or − is correct) find the two figures between which each average burette reading lies. The correction *k* is given in the right-hand column with its proper sign. Determine *k* for each average burette reading and apply *k* algebraically to obtain the chlorinity.

Example: (*k* from Knudsen's tables)

Alpha is + 0.025

Average burette reading is	19.81
Correction *k* (p. 30) is	+.01
Chlorinity °/₀₀ is	19.82

Example:

Alpha is + 0.025

Average burette reading is	19.72
Correction *k* (p. 30) is	+.02
Chlorinity °/₀₀ is	19.74

If the average burette reading is the same as one in the alpha column of the tables then select the nearest even *k*.

Once the chlorinity has been determined, salinity in parts per thousand can be calculated by the formula:

$$S°/_{oo} = 0.03 + 1.805\ (Cl°/_{oo}).$$

A simpler and quicker method is by direct inspection of table 16 in part II, or by Knudsen's tables, pages 1 through 22. Enter either table directly with the chlorinity and obtain the salinity from the adjacent column on the right.

13–32 How To Secure the Apparatus After Completing the Titrations.—After the analyses of a station have been completed, or a day's work has been finished, the apparatus must be secured. The pipette and burette will last longer between cleanings if whenever they are not in use they are kept filled. Fill the pipette with sea water and the burette with silver nitrate, and check to see there are no air bubbles. Set the upper leveling stopcock of the burette to the overflow position. This will allow expansion of solution in the burette in the event of temperature change. Apply a pinchclamp to the tubing from the silver nitrate bottle. Place an empty beaker below the delivery stopcock of the burette to catch any leakage. Clean the table with sea water, and

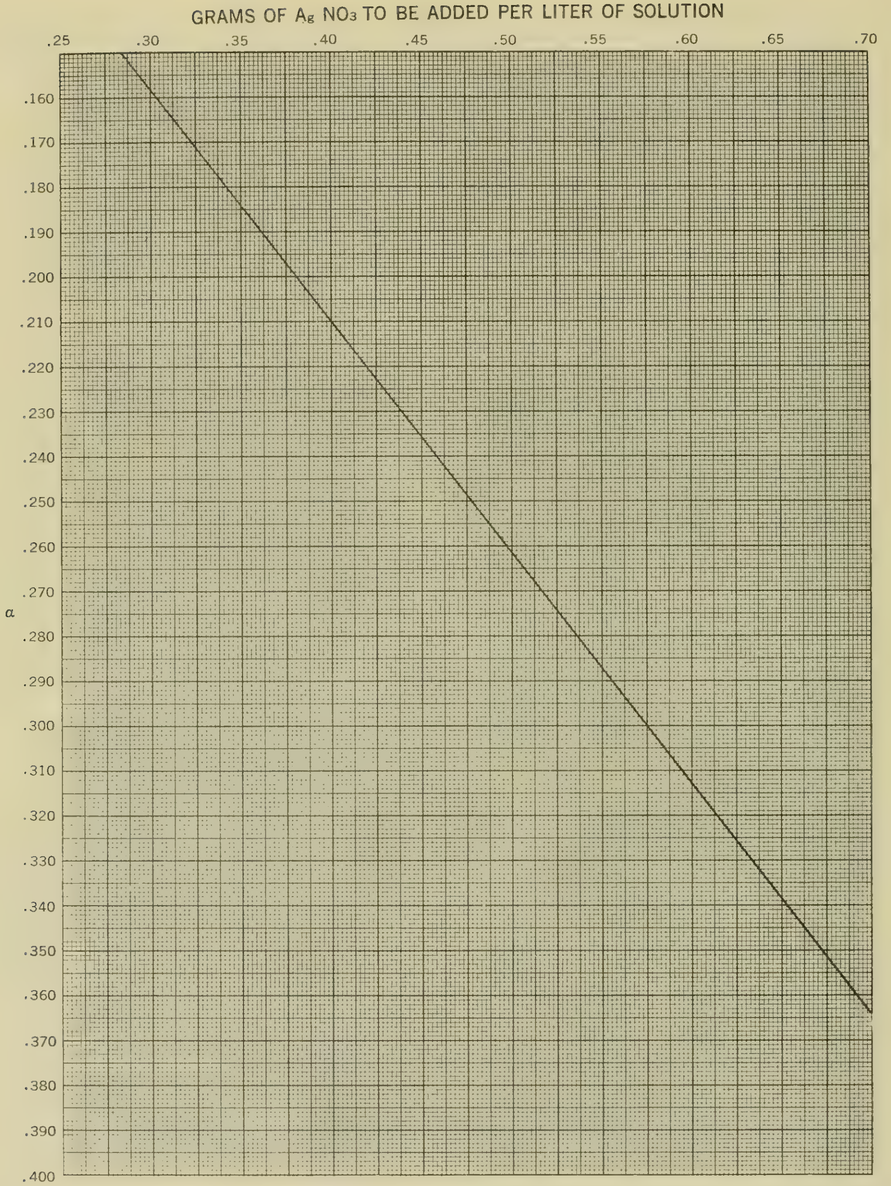

Figure 13-5. Grams of $AgNO_3$ to be added to the solution when alpha is negative.

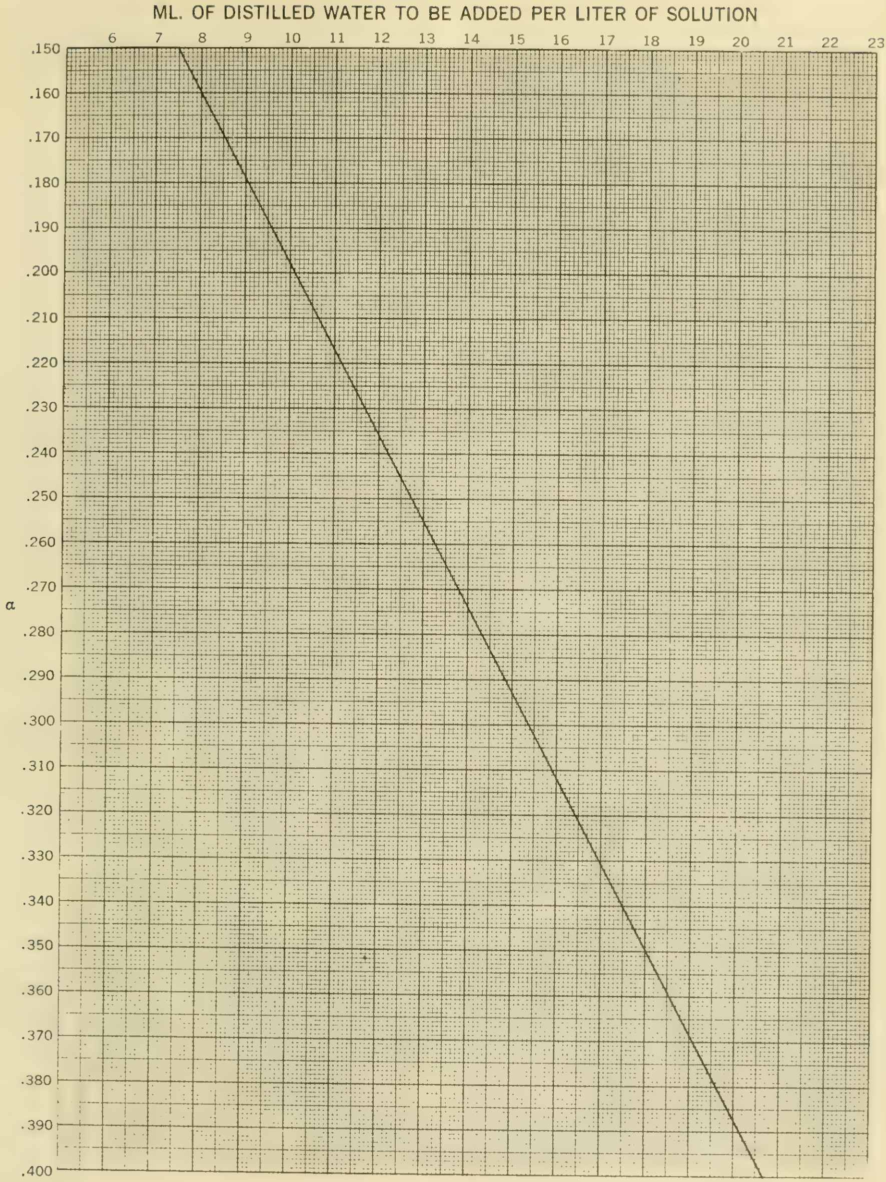

Figure 13–6. Ml. of distilled water to add to the solution when alpha is positive.

wash and dry all beakers, magnetic stirring bars, pickup, and stirring rods. Do not leave unwashed any apparatus that has been used.

13–33 Maintenance and Repair of Apparatus.—The Knudsen titration apparatus requires little maintenance except routine cleaning. The silver nitrate solution causes the rubber tubing to deteriorate after awhile, and small black particles will begin to get into the burette. The tubing should be replaced when there are indications of this. It is almost impossible to repair broken burettes or pipettes. Even when done by experienced glassblowers they must be recalibrated. It is better to use a new piece of apparatus.

13–34 Reclaiming the Silver Chloride.—After a period of time the waste jar will accumulate a considerable amount of silver chloride precipitate. This silver chloride contains a large amount of pure silver which can be reclaimed by smelting and refining companies. To prepare this material for shipment, the water should be decanted and the solids removed from the bottle. It may be placed in flat pans and dried in an oven. The dried material should be stowed in glass bottles. Care should be taken when handling as it will stain. Use of rubber gloves is recommended. U. S. Navy survey ships should return the bottled dried material to the Hydrographic Office.

13–35 A Method for Preparing Substandard Sea Water.—As the silver nitrate solution must be standardized after every sixth sea water sample, and to adjust the solution, a considerable amount of standard sea water is necessary. This water is expensive and sometimes difficult to obtain. To stretch use of standard sea water, some laboratories make use of substandard sea water in place of standard sea water. The advantage is that a large volume of sea water of known chlorinity can be made up, standardized against standard sea water, and used in the latter's place while running the routine analyses of sea water samples.

The easiest way to prepare substandard sea water is to collect several gallons of clear sea water in an area having higher chlorinity than standard sea water, for example—the Sargasso Sea, and diluting it to as near the chlorinity of standard sea water as possible. Filter the collected water at least twice through fine filter paper into clean well-leached brown glass bottles.

The substandard sea water should have a chlorinity as near 19.39 ‰ as possible. For example, assume that the Sargasso water to be diluted to astandard value of 19.39‰ has a present chlorinity of 19.60‰. Also assume that 8 liters has been collected and doubly filtered. To find how much distilled water to add to this Sargasso water, we set up the equation:

$$\frac{19.60}{19.39}=\frac{X}{8\times 1{,}000}$$

where:

19.60 is chlorinity of water to be diluted
19.39 is desired chlorinity
$8\times 1{,}000$ is volume of water in milliliters
X is volume of water after dilution.

Solving the equation, it is found that:

$$X=8{,}087 \text{ ml.}$$

Therefore 87 ml. of pure distilled water must be added to the 8 liters of Sargasso water in order that it will have a chlorinity of 19.39‰.

Having made up the substandard sea water, it must be well-mixed and the chlorinity again checked. Store it in 1-gallon brown glass bottles and stopper tightly. Label, date, and indicate the chlorinity on each bottle. The chlorinity value should be checked against standard sea water about once a week after thoroughly shaking the bottle. Note each of these checks on the label.

There are times when substandard water must be made up with water having chlorinity lower than 19.39‰. In this case, the water must have sodium chloride added to bring it to the required value. For example, assume that the water after filtering twice has a chlorinity of 19.30‰, and it is desired to bring it up to the required value. Again assume there are 8 liters of sample. How much sodium chloride must be added? The simplest, although not exact method, is to add the necessary salt in parts per thousand of salinity. Thus:

$$\begin{aligned} 19.39 \text{ Cl ‰} &= 35.03 \text{ S ‰} \\ 19.30 \text{ Cl ‰} &= \underline{34.87} \text{ S ‰} \\ &\ .16 \text{ grams/liter} \end{aligned}$$

As there are 8 liters of sea water to be brought up to approximately the standard chlorinity, then $8\times 0.16=1.28$ grams of sodium chloride must be added to the 8 liters of water. The resulting solution must be shaken vigorously for at least 5 minutes after the last of the salt has been dissolved in order to have a uniform concentration. Test and store it in the same manner as described above.

13–36 DETERMINATION OF DISSOLVED OXYGEN CONTENT OF SEA WATER.—The concentration of dissolved oxygen in sea water may vary from supersaturation near the surface, where photosynthetic activity by the phytoplankton is very high, to no oxygen in stagnant basins or deep fjords. The values, therefore, may be anything from 0 to 10 milliliters or more per liter of sea water.

The analysis for dissolved oxygen in sea water is important for numerous reasons: it aids in the interpretation of biological processes taking place in the ocean; it is finding increased use in studies of oceanic currents and mixing processes; and it is sometimes used as an index for detecting malfunctional sampling equipment and erroneous values.

13–37 The Winkler Method.—In waters which are relatively free of such substances as nitrites, ferrous salts, and organic matter, the Winkler method may be used for determining dissolved oxygen. These conditions are usually found in most areas of the open ocean. Thompson and Robinson (1939) describe modifications which should be applied to Winkler's original method (1888) in order to utilize the method for sea water determinations. In waters containing appreciable amounts of nitrites or ferrous salts, the Rideal-Stewart modifications of the Winkler method should be used. The Winkler method is not applicable to sea water containing hydrogen sulfide or other reducing substances which will react with iodide ions causing the liberation of free iodine. Such conditions usually are found only in stagnant basins, fjords, and certain estuaries. Additional methods of determining dissolved oxygen can be found in the bibliography at the end of part I.

While the chemical reactions involved in this analysis are rather complex and the complete reactions unknown, the analysis itself is not difficult to perform if the necessary precautions are taken in preparing the reagents, cleaning the glassware, and carrying out the treatment of the samples and the titrations.

The Winkler method requires that the sample be treated with an alkaline manganous solution while protected from oxygenation by air. A white precipitate of manganous hydroxide forms first:

$$Mn^{++}+2OH^- \rightarrow Mn(OH)_2.$$

This precipitate rapidly turns brown in the presence of dissolved oxygen, which reacts with the manganous hydroxide to form a tetravalent manganese compound:

$$2Mn(OH)_2+O_2 \rightarrow 2MnO(OH)_2.$$

When this solution is acidified to excess, in the presence of an iodide, iodine is released quantitatively; i. e., free iodine (more correctly, triodide ion) is liberated from the iodide which is equivalent to the amount of dissolved oxygen present in the sample:

$$MnO(OH)_2+4H^+ +3I^- \rightarrow Mn^{++}+I_3^- +3H_2O$$

This free iodine (or triodide ion) is titrated with a standardized solution of sodium thiosulfate:

$$I_2+I^- \rightleftharpoons I_3^-$$

$$I_3^- +2S_2O_3^{--} \rightarrow 3I^- +S_4O_6^{--}$$

13–38 Chemicals Required.—The following chemicals are required for dissolved oxygen titrations. The amounts in parentheses are those required to analyze 10 stations of 24 bottles each.

Chloroform, C. P., A. C. S., in 4-ounce bottle.

Hydrochloric Acid, Conc., 12N, specific gravity 1.19, C. P. (1 liter).

Manganese (ous) Chloride, C. P., in 1-pound bottle (400-gram bottle).

Sodium Hydroxide, pellets, C. P., in 1-pound bottle (360-gram bottle).

Sodium Thiosulfate, crystal, C. P., A. C. S., in 1-pound bottle (2 vials of 3.723 gms. each).

Sulfuric Acid, Conc., 36N, specific gravity 1.84, As and N_2 pure, A. C. S. (320 ml.).

Starch, potato, soluble, powder, C. P., in ¼-pound bottle (3-gram vial).

Paraffin.

Potassium Dichromate, fine crystal, C. P., in vials containing 4.9040 grams (1 vial).

Potassium Dichromate, fine crystal, C. P., in 1-pound bottle (32-gram bottle).

Potassium Iodide, crystal, C. P., low in iodates, in 1-pound bottle (150-gram bottle) (1 vial of 15 grams).

The various compounds required in this method must be free of oxidizing agents and every effort should be made to keep them from becoming contaminated. Extreme care should be exercised in purifying and recrystallizing the various salts, and especially in handling the hydrochloric acid. This acid is very poisonous; its fumes are extremely caustic, and it should be used only where good ventilation is available to draw off the fumes.

13–39 Apparatus Required.—In addition to that previously listed in sections 13–2 through 13–8, the following apparatus is required to carry out dissolved oxygen titrations by the Winkler method.

Bottle, Dropping, S. T., ground pipette, Pyrex, 125-ml. capacity.

Bottle, Amber glass, laboratory, metric capacity, narrow mouth with ground-in flat glass stopper. Capacity 250 ml., 1 liter, 2 liters.

Bottle, wide mouth, 3-gallon capacity.

Bottle, volatile liquid, ground-on glass cap, capacity 500 ml.

Burette, Schellbach, Automatic Zero, 3-way stopcock, capacity 25 ml., 50 ml.

Pipette, automatic, aba pipettor type capacity 2 ml.

Pipette, automatic, delivery, NORMAX, capacity 50 ml., 100 ml.

Pipette, Measuring, Mohr, EXAX, Blue Line No. 5, capacity 5 ml.

Pipette, transfer type, NORMAX, Pyrex capacity 1 ml., 5 ml., and 10 ml.

Reader, Burette meniscus.

13–40 Setting Up the Apparatus.—Numerous pipettes are required for the various steps in the Winkler method. A 10- and a 5-ml. pipette are required for the standardization of the sodium thiosulfate solution. A 50- or 100-ml. automatic volumetric pipette is required for drawing and measuring the treated sea water sample for titration. One- and two-ml. pipettes are required for the blank run and for the treatment of the sea water samples. All of the pipettes should be of at least EXAX quality, except for the transfer of potassium dichromate solution in the standardization procedure, where NORMAX quality is required.

The pipettes used on U. S. Navy surveys for delivery of the reagents required to treat the sea water samples are the automatic-measuring type, delivering 1 ml. each of manganous chloride and alkaline iodide, and 2 ml. of hydrochloric acid.

The burette used for the titration is a Schellbach automatic zeroing, 3-way stopcock, 25 or 50 ml. delivery capacity.

Before any of the pipettes and the burette are used they must be cleaned and the stopcocks lubricated in the manner described in sections 13–14 and 13–15. All other apparatus and glassware should be kept very clean. Washing with a good detergent soap and numerous rinses with fresh water usually will be adequate for most glassware.

The titration apparatus may be set up in much the same manner as that used for chlorinity analysis. The background behind the burette should be painted flat white and a fluorescent titration lamp should be rigged behind the burette.

Figures 13–7 and 13–8 show schematic arrangements for the automatic 50-ml. pipette and the burette. Clamp the glassware to the

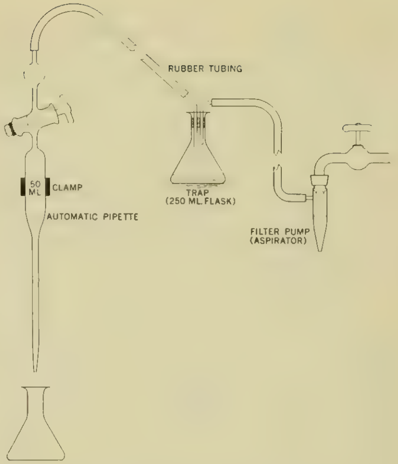

Table 13–7. Automatic pipette assembly.

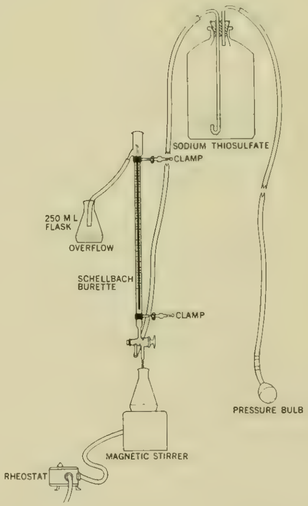

Figure 13–8. Automatic burette assembly.

support rods that are rigidly attached to the titration bench. Attach the filter pump, or aspirator, to the salt water tap and connect it to the pipette with rubber tubing. If a salt water tap is not available, a small electric vacuum pump of the portable laboratory type may be used in place of the aspirator.

Attach the magnetic stirrer below the burette. When it is being used, the top of the stirrer should be covered with a clean piece of white filter paper. This helps detect the end point color change, which is from blue to colorless in oxygen determinations.

Sea racks to hold three 500-ml. reagent bottles, the starch solution dropping bottle, the sample bottles and several Erlenmeyer flasks should be secured to the top of the table. Above them there should be a rack to hold the various small pipettes required for the normality determination and treatment of the sea water samples before titrating.

13–41 Reagent Storage Bottles.—The storage bottles for the various reagents used in this determination should be of adequate capacity to carry out the work over one complete leg of the cruise. Those required for the storage of the sodium thiosulfate and the sodium hydroxide-potassium iodide solutions must be either amber glass or bottles which have been painted black to protect the reagents from light. The sodium thiosulfate bottle should have a capacity of about 3 liters. A convenient size for the manganous chloride and alkaline iodide and the acid storage bottles is about 2 liters. The shelf bottles used for these solutions should be about 500 ml. capacity.

13–42 Manganous Chloride Solution.—The manganous chloride solution is prepared by dissolving 400 grams of manganous chloride ($MnCl_2.4H_2O$) in distilled water and making up to 1 liter. The manganous chloride must be free of ferric compounds.

13–43 Alkaline Iodide Solution.—Dissolve 360 grams of sodium hydroxide (NaOH) in 500 ml. of distilled water in a Pyrex beaker, and 150 grams of potassium iodide (KI) in 200 ml. of distilled water. Add the potassium iodide solution to the sodium hydroxide solution and dilute to 1 liter. Store this solution in an amber glass bottle with a *rubber stopper*. Because of freezing, ground glass stoppers are not recommended. It is important that the potassium iodide be free of periodate, as well as peroxide impurities. This solution must be kept out of contact with sunlight.

13–44 Starch Solution.—Dissolve 3 grams of soluble potato starch in a small amount of cold water and stir into 300 ml. of boiling water. Cover with a cover glass and boil vigorously for a few minutes. Allow the solution to cool, and pour off the supernatant liquid into a 125-ml. dropping bottle. Discard the residual portion. The period of stability of this indicator solution varies from a few days to several weeks depending upon local conditions. The addition of 2 or 3 drops of chloroform ($CHCl_3$) as a preservative will help keep the starch stable for a long time.

13–45 Potassium Iodide Solution.—A 15-percent solution of potassium iodide is prepared by dissolving 15 grams of C. P. grade potassium iodide in 100 ml. of distilled water. The potassium iodide should be free of oxidizing substances.

13–46 Potassium Dichromate Solution.—The stock solution of potassium dichromate must be made up ashore as it requires accurate weighing of chemicals with an analytical balance. Powder a small amount of C. P. grade potassium dichromate ($K_2Cr_2O_7$) in a mortar, place it in an oven at 130° C., and dry for 30 minutes; cool in a desiccator. Accurately weigh out on an analytical balance 4.9040 grams of the dried potassium dichromate. Dissolve this in distilled water and dilute to exactly 1 liter in a volumetric flask. After thoroughly mixing by placing a stopper in the flask and shaking vigorously, divide equally between two 500-ml. glass storage bottles. Seal with paraffin until needed. Open only one bottle at a time and reseal after use. This is the stock solution of 0.1 normality.

To make the standard solution, which is required for the standardization of the sodium thiosulfate solution, carefully measure out 50 ml. of the stock solution using a 50 ml. NORMAX delivery pipette. Dilute this solution to exactly 500 ml. in a volumetric flask. Transfer this solution to the storage bottle from which it will be used to standardize the sodium thiosulfate solution. The normality of the potassium dichromate solution will be exactly 0.0100 normal.

13–47 Sodium Thiosulfate Solution.—The sodium thiosulfate solution is used to titrate the sea water samples. To make it, dissolve 3.723 grams of sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) in 3 liters of distilled water that has been freshly boiled for about 10 minutes to expel carbon dioxide. The normality of this solution is approximately 0.005N. Store the solution in an amber glass bottle out of contact with the carbon dioxide of the air or direct sunlight. If an amber bottle is not available, then one painted in the same manner described in section 13–24 may be

350676 O—56——10

used. Add 5 or 6 drops of chloroform to retard bacterial action. This solution may be stable over a long period of time. It should be allowed to age for several days before using in order that the carbon dioxide which may be dissolved in the reagent water can be used up.

13–48 Normality Determination—The Blank Run.—The normality of the sodium thiosulfate solution must be determined before titrating a series of samples. A correction must be made if oxidizing substances are present in minute quantities in any of the reagents. In order to determine quantitatively the effect of these oxidizing substances on the titrations, a so-called blank run is made.

This is the first step toward determining the normality of the sodium thiosulfate solution. This blank run must be made each time a new batch of reagents is prepared. Each batch should be rechecked at least weekly or oftener, depending upon the degree of use, and the value entered in oceanographic log sheet C in the manner described in chapter 14. Carry out the blank run in the following way:

1. Carefully measure out 90 ml. of freshly boiled distilled water, in a 100 ml. graduate, and transfer it to an Erlenmeyer flask.
2. Add 2 ml. of concentrated hydrochloric acid (HCl).
3. Add 1 ml. of alkaline iodide reagent (NaOH–KI).
4. Add 1 ml. of manganous chloride reagent ($MnCl_2$).
5. After thoroughly mixing, add 1 ml. of the starch indicator solution.

If no blue color appears, the reagents are free of oxidizing substances. If a blue color appears, the approximate concentration of the oxidizing substances may be ascertained by titrating the solution with the sodium thiosulfate until it becomes colorless. The burette reading of the sodium thiosulfate is recorded on the log sheet. This is the value V_b.

The value of V_b should be less than 0.10 ml. If more than this is required to decolorize the solution, then it must be determined which reagent contains the oxidizing substances. When found the reagent must be purified or replaced with that which is pure.

If present, the oxidizing substance is most probably an iodate in the alkaline iodide solution. In such case it is well to make up a new solution using potassium iodide that has been purified by recrystallization. This is done by dissolving potassium iodide in water, then adding 2 ml. of sulfuric acid and concentrating the solution by boiling. Iodate reacts with iodite in the acid solution, and free iodine is removed from the solution by this process. The chemical reactions are:

$$IO_3^- + 8I^- + 6H^+ \rightarrow 3I_3^- + 3H_2O$$

$$I_3^- \rightleftharpoons I_2 + I^-.$$

Allow the solution to cool and then reheat over a low flame until the water is evaporated off. Recrystallization will take place as the water is driven off. This step may be carried out in a drying oven set at 105° C. This boiling and recrystallization should be carried out in a location relatively free of sunlight.

It is important that the hydrochloric acid used be chemically pure reagent grade and not contain impurities acting as oxidizing agents.

Should the manganous chloride contain an oxidizing agent in the form of a ferric ion, it can be removed by the method of recrystallization described in 13–17, the iron remaining in the mother liquid.

13–49 Normality Determination—Standardization of the Sodium Thiosulfate Solution.—As previously stated, the sodium thiosulfate is made stable by the addition of a few drops of chloroform. However, slight changes in normality may occur. It is therefore necessary to make at least one standardization run immediately before running the titrations for each station. If a number of stations are run at the same time, the standardization runs may be made at the start and again at the finish of the titrations, but care must be taken to see that each log sheet is completely filled out, showing the complete calculations for normality and all other necessary information.

The standardization of the sodium thiosulfate solution is carried out in the following manner:

1. Accurately pipette out 10 ml. of the potassium dichromate ($K_2Cr_2O_7$) standard of 0.0100 N. This should be done with a NORMAX 10-ml. volumetric pipette. Transfer to a 125-ml. Erlenmeyer flask.
2. Add 5 ml. of 15 percent potassium iodide (KI) solution.
3. Add 2 ml. of concentrated hydrochloric acid (HCl).
4. Titrate with sodium thiosulfate solution until the yellow color has almost disappeared.
5. Add 5 drops of starch indicator solution and titrate until the solution is just colorless. This titration should be reproducible within ±0.03 ml. Make at least three runs and average the best results.
6. Record the burette readings on the C-sheet as the values V_2.

7. Calculate the normality (N) of the sodium thiosulfate solution by means of the following formula:

$$N=\frac{V_1 \times N_1}{V_2-V_b}$$

where

N_1 = Normality of $K_2Cr_2O_7$ solution. This is always 0.0100.

V_1 = Milliliters of $K_2Cr_2O_7$ solution used. This is always 10.0 ml.

V_2 = Average milliliters of $Na_2S_2O_7$ required to decolorize sample. For example, assume 20.90 ml.

V_b = Average milliliters correction obtained from the blank run. For example, assume 0.07 ml.

therefore

$$N=\frac{10.0 \times 0.0100}{20.90-0.07}$$

$$N=\frac{0.1}{20.83}$$

$$N=0.0048$$

The normality of the sodium thiosulfate is used in determining the amount of dissolved oxygen content of the sea water samples from the burette readings of the titrations. The formula is shown in section 13–53.

13–50 Treating the Sea Water Sample.—Instructions for drawing the sea water samples for dissolved oxygen analysis are given in sections 2–26 and 2–28. These must be followed very carefully. Immediately after drawing the samples from the Nansen bottles, they must be taken to the laboratory and the following reagents introduced. Use an automatic pipette and introduce the reagents *well below* the surface of the sample:

1 ml. of manganous chloride ($MnCl_2 \cdot 4H_2O$) solution

1 ml. of the alkaline iodide (NaOH–KI) solution.

Replace the stopper and shake the sample thoroughly with a snapping motion of the wrist. Allow the precipitate to settle for a few minutes. Shake the sample a second time and allow the precipitate to settle again for at least ½ hour, but not longer than 6 hours.

The alkaline iodide solution precipitates manganous hydroxide which reacts with the dissolved oxygen. The precipitate settles to the bottom of the bottle. After sufficient time for this to occur (½ hour minimum to 6 hours' maximum), remove the stopper and with an automatic pipette add (well down in the sample) 2 ml. of concentrated hydrochloric acid (HCl). Replace the stopper and shake thoroughly until all the precipitate is dissolved. This is now the "treated sample" and is ready for titration.

The introduction of the reagents causes a liberation of part of the nitrogen dissolved in the sample of sea water. In addition, the acid may cause a small amount of carbon dioxide (CO_2) to be liberated. As a result, small bubbles of gas may occur in the sample after the precipitate has dissolved. This gas developed in the sample before titration only affects the results by diminishing the volume of the bottle's contents, and is of no importance as an aliquot (50-ml. or 100-ml. portion) of the sample is used for the titration.

13–51 Drawing the Sample With the Automatic Pipette.—Drawing the sample for analysis is carried out, for the most part, in the same manner as described in section 13–28. The exception to the method is that for rinsing. As the volume (50 to 100 ml.) of the sample to be titrated is considerably greater than that used for salinity, it is necessary to rinse the pipette with the sample only once before drawing the sample. Use only about 15 ml. for rinsing.

After rinsing draw the sample and transfer it to a clean 250-ml. Erlenmeyer flask.

13–52 Titrating the Sample With the Automatic Burette.—Analysing the sample by titration is carried out in precisely the same manner for every sample. Unless otherwise directed, this technique should never vary.

To fill the burette with sodium thiosulfate solution turn the three-way stopcock at the bottom of the Schellbach burette until the solution flows up the bore and overflows out the small spout into the drain cup at the top. Turn to off position and the self-zeroing burette is ready. It is well to fill and drain the burette twice before commencing titrations.

Insert a clean plastic-coated magnet in the flask and place it on the magnetic stirrer. Titrate with the standardized sodium thiosulfate solution until the yellow color of the sample has almost disappeared. Add six drops of starch indicator solution. This will produce a deep blue color. Continue titration drop by drop until the solution is just colorless. The sample is stirred constantly without splashing throughout the run (fig. 13–9).

The instant the sample becomes colorless, close the stopcock and immediately read the burette. Record the burette reading in milliliters on the C-sheet in the manner described in chapter 14.

Figure 13–9. Titrating the dissolved oxygen sample.

Drain the flask well and draw a second sample for titration. The second titration should be reproducible within ± 0.03 ml. If necessary, disregard poor runs and repeat with 50 ml. of sample.

At the end of the analyses, the Erlenmeyer flasks used should be washed with soap and water, rinsed, and finally rinsed with distilled water in preparation for the next station.

13–53 Calculations for Dissolved Oxygen.—The amount of dissolved oxygen expressed in milliliters per liter (ml./l.) is determined from the average of the burette readings of the two titrations of each sample by means of the following formula:

$$O_2 \text{ ml./l. } 56.45NV.$$

This formula is derived from the equation:

$$O_2\text{ml./l.}=\frac{B}{B-2}\times 5.6\times 10\times N\times V$$

where:

B=Volume of the sample bottle. This is 250 ml.

$B-2$=Volume of water in the sample bottle after addition of the first two reagents (1 ml. of $MnCl_2$ and 1 ml. of NaOH–KI).

5. 6=A constant representing ml. of oxygen equivalent to one ml. of normal sodium thiosulfate solution.

10=Number of ml. of potassium dichromate added.

N=Normality of the sodium thiosulfate solution.

V=Number of ml. of sodium thiosulfate required for the titration. This is the average burette reading.

thus:

$$O_2\text{ml./l.}=\frac{250}{250-2}\times 5.6\times 10\times N\times V$$

$$O_2\text{ml./l.}=\frac{250}{248}\times 56\ NV.$$

therefore:

$$O_2\text{ml./l.}=56.45NV$$

Another way of expressing this is:

$$O_2\text{ml./l.}=KV$$

where:

$K=56.45N$ for 100 ml. samples

and

$K=2(56.45)N$ or $112.9N$ for 50 ml. samples.

For example: let $N=0.0048$.

Therefore (for 50 ml. samples):

$$K=112.9(0.0048)$$

$$K=0.5419.$$

Once the value K has been determined, then the dissolved oxygen content is easily determined by multiplying each average burette reading (V) by K.

For example (if $V=9.28$):

$$O_2\text{ml./l.}=(0.5419)(9.28)$$

$$O_2\text{ml./l.}=5.03$$

13–54 Securing the Apparatus After Completing the Titrations.—After the analyses of a station have been completed, or a day's work has been finished, the apparatus must be secured. The pipette and the burette will stay clean longer if they are kept filled when not in use.

Rinse and fill the pipette with distilled water. Fill the burette with sodium thiosulfate solution and check to see that there are no air bubbles. Apply a pinchclamp to the tubing from the sodium thiosulfate solution bottle.

Clean the table, and wash and dry all beakers, flasks, magnetic stirring bars, and other glassware used.

13–55 Maintenance and Repair of Apparatus.—The Winkler titration apparatus requires little maintenance except for routine cleaning. The hydrochloric acid will cause rubber to deteriorate over an extended period, so if rubber stoppers are used they may have to be replaced infrequently. Rubber tubing should be replaced when there is evidence of cracking or wear.

CHAPTER 14

INSTRUCTIONS FOR RECORDING OCEANOGRAPHIC OBSERVATIONS, MEASUREMENTS, AND SAMPLES ON LOG SHEETS

14–1 GENERAL REMARKS.—Oceanographic observations, measurements, and samples obtained are recorded on special log sheets. The log sheets used by the U. S. Navy Hydrographic Office are included in this chapter, together with detailed descriptions of how the entries are to be made on each sheet. Certain data must be plotted on the graphs. The L–Z graph is discussed in chapter III, and the Oceanographic Station Plotting Sheet and the Temperature-Salinity Plot are discussed in chapter IV. These log sheets and graph sheets are listed below.

(*a*) Oceanographic log sheet A: Station and Thermometer Data, PRNC–NHO–1188.

(*b*) Oceanographic log sheet B: Bathythermograph Observations, PRNC–NHO–1189.

(*c*) Oceanographic log sheet C: Dissolved Oxygen Determination, PRNC–NHO–1190.

(*d*) Oceanographic log sheet D: Chlorinity and Salinity Determination, PRNC–NHO–1191.

(*e*) Oceanographic log sheet E: Station Summary, PRNC–NHO–1244.

(*f*) Oceanographic log sheet GEK 1: Electromagnetic Current Observations, PRNC–NHO–1336.

(*g*) Oceanographic log sheet GEK 2: Electromagnetic Current Computations, PRNC–NHO–1336a.

(*h*) Oceanographic log sheet L: Inshore Survey Station Sheet, PRNC–NHO–1364.

(*i*) Oceanographic log sheet M· Bottom Sediment Data, PRNC–NHO–1365.

(*j*) Shipboard Wave Observation Log, PRNC–NHO–1192.

(*k*) Ship and Aircraft Ice Log, H. O. Misc. No. 15,584.

(*l*) Oceanographic Station Plotting Sheet, H. O. Misc. No. 15,252–1.

(*m*) Temperature-Salinity Plot, H. O. Misc· No. 15,252–2.

(*n*) L–Z Graph, H. O. Misc. No. 15,252–3.

14–2 Obtaining Log Sheets.—The above listed log sheets and graphs may be obtained from the U. S. Navy Hydrographic Office, Washington 25, D. C., upon request. When requesting log sheets and graphs, include the complete title and number.

14–3 Station Folders.—Each oceanographic station usually requires the use of several log sheets and graphs. A convenient method of filing these sheets is to use a 9½- x 12-inch manila folder, using 1 folder for each station. In the left-hand corner of the folder, tab record the ship's name or code, cruise name or number, and the oceanographic station number. A station folder shown in figure 14–1, will usually include the following log sheets and graphs:

(*a*) Oceanographic log sheet A.

(*b*) Oceanographic log sheet C.

(*c*) Oceanographic log sheet D.

(*d*) Oceanographic log sheet E.

(*e*) An L − Z, or cosine (Z/L), graph for determining Accepted Depths. Millimeter graph paper is recommended.

(*f*) Oceanographic station plotting sheet, or an equivalent 10 x 10 to the ½-inch graph paper.

(*g*) Temperature—salinity plot, or an equivalent 10 x 10 to the ½-inch graph paper.

14–4 Pencils.—In order to insure a permanent record on the log sheets and graphs, a hard pencil, no softer than No. 3, should be used for recording all data, calculations, and graphs.

14–5 Codes and Tables.—All oceanographic codes and tables referred to in the following log sheet instructions are given in part II, unless otherwise indicated.

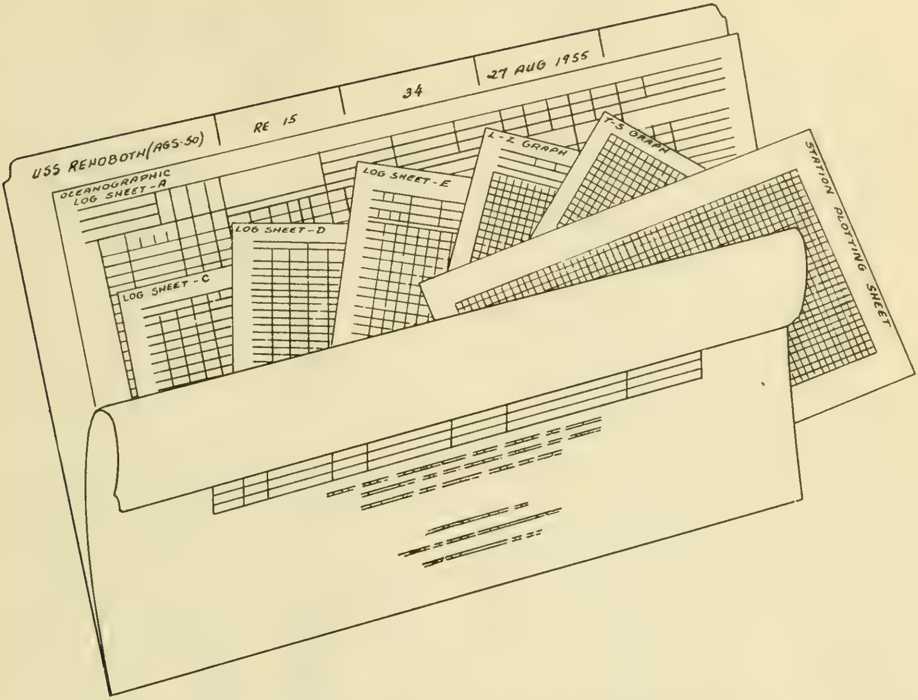

Figure 14–1. Oceanographic station folder with associated log sheets and graphs.

14–6 Log Sheet Entries.—The entries made on the log sheets are explained item by item and column by column. These explanations are, of necessity, brief. Where more detailed information is needed, it will usually be given in the chapter describing the operation of a particular instrument, analysis, or mathematical computation.

OCEANOGRAPHIC LOG SHEET A, PRNC–NHO–1188 (Rev. 7–53)

STATION AND THERMOMETER DATA

14–7 GENERAL REMARKS.—The A-sheet is the basic record of an oceanographic station. It is used to record the Nansen bottle observations, bottle numbers of the salinity and oxygen samples, temperature records and calculations, related meteorological and other observations taken while occupying an oceanographic station. The analyses and calculations of the station data are derived from the information recorded on this sheet. Extreme care must be taken when making all entries. Print all entries neatly. Study chapters 2 and 3 carefully before using this log sheet.

Since the A-sheet is used on deck while occupying a station, it is recommended that it be secured to a clipboard with rubber bands. Upon completion of all entries and calculations, the sheet should be filed in the manila station folder.

14–8 THE LOG SHEET.—A sample log sheet is shown in figure 14–2. Entries to be made under the log sheet headings are recorded as follows.

14–9 Cruise No.—The survey cruise number is assigned by the instructions for a specific cruise. On surveys conducted by U. S. Navy ships, a code prefixes the cruise number. This code is used to identify the ship on all log sheets, graphs, slides, records, and samples. For example, the 15th cruise of the U. S. S. *REHOBOTH* (AGS–50) is recorded as RE–15.

14–10 Station No.—Oceanographic stations are numbered consecutively as taken, starting with numeral one for the first station of each cruise. Thus, the complete identification for the 34th station of the 15th cruise of the U. S. S. *REHOBOTH* (AGS–50) is RE–15–34.

A station is any group of oceanographic observations made at the same, or virtually the same, time and geographic position. It usually consists of one or more Nansen bottle casts, plus possibly a bottom sample, Secchi disc readings, plankton samples, wave staff recordings, submarine photometer measurements, underwater photographs, microthermal depth measurements, current measurements, meteorological observations, etc.

14–11 Vessel.—Give the full name and number of the ship on each log sheet.

14–12 Date.—Record the day, month, and year. Use the Greenwich date of the starting time of the station. This is the time the first Nansen bottle is attached to the wire, as recorded in the Start column for the first cast.

14–13 Cast.—Any series of instruments, such as Nansen bottles, quantitative plankton samplers, current meters, etc. which are suspended at various depths along the oceanographic wire to obtain more or less simultaneous observations and samples is referred to as a cast. Two or more casts are usually required to obtain the desired data.

14–14 Wire Angle.—The wire angle is the angle between the oceanographic wire and the vertical. It is measured from the instrument platform when a cast is down. Just before the messenger is dropped to trip the Nansen bottles the angle is measured with a wire-angle indicator.

14–15 Greenwich Mean Time.—Record all times for each cast in Greenwich mean time (GMT) as follows:

(*a*) *Start* is the time the first Nansen bottle is placed on the oceanographic wire.

(*b*) *Down* is the time when the case is lowered to the desired wire depth and the winch is stopped.

(*c*) *Mess.* is the time when the messenger, which is placed on the wire to trip the first Nansen bottle, is dropped from the instrument platform. Allow a minimum of 6 minutes to elapse between the *down* time and the time the messenger trips the first bottle. This is to permit the reversing thermometers to come to temperature and the Nansen bottles to flush. The time required for a messenger to drop may be figured at 200 meters per minute for wire angles less than 35° and at 150 meters per minute for wire angles greater than 35°.

(*d*) *Up* is the time the last Nansen bottle is tripped and commence hauling in the cast.

(*e*) *In* is the time that the last Nansen bottle or instrument of the cast is removed from the wire.

14–16 Latitude and Longitude.—The position of the station is obtained from the adjusted ship's track on the smooth plotting sheets. The *Start* time of the first cast is used to determine the time of the position. Record latitude and longitude in degrees and minutes indicating north or south (N or S) and east or west (E or W), respectively

14–17 Sonic Depth.—Immediately after the ship has stopped on station obtain the sonic depth and record it in fathoms and meters. To convert fathoms to meters, refer to table 12. Check the depth before each cast. If the bottom is very irregular, frequent soundings while on station are recommended, especially when instruments may be near the bottom.

14–18 Max. Sample Depth.—The maximum sample depth is recorded with two digits. It is not entered until all values on the A-sheet are computed and recorded. It is obtained from the greatest bottle depth as shown in the *Accepted Depth* column and is given to the maximum 100 meters. For example, if the greatest *Accepted Depth* is 2153 meters, record it as 21; for 565, record 05; for 321, record 03.

14–19 Type of Bottom.—Whenever a bottom sediment sample or core is taken on station, the type of bottom is recorded using the code given in table 7. If no sample is obtained leave it blank.

14–20 Anemometer Ht. Above Sea.—For ships equipped with anemometers, record the

OCEANOGRAPHIC LOG SHEET-A
PRNC-NHO-1188 (REV. 7-53)

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

STATION AND THERMOMETER DATA
For use with H.O. Pub. No. 607

CRUISE NO	STATION NO	CAST	WIRE ANGLE	GREENWICH MEAN TIME START	DOWN	MESS	UP	IN
RE-15	34	FIRST	16°	1930	1952	1958	2004	2019
VESSEL: USS REHOBOTH (AGS-50)		SECOND	27°	2048	2115	2119	2131	2151
DATE: 27 AUGUST 1955		THIRD						

LATITUDE	MAX SAMPLE DEPTH	WIND DIR	WIND SPEED (Knots)	AIR TEMP. (°C) DRY	WET	SEA DIR	SEA AMT.	WATER COLOR (Forel)	COMPUTED BY
43° 30′ N	21	200°T.	12	21.7	21.1	21	1	10	BSRichmond

LONGITUDE	TYPE OF BOTTOM	WIND FORCE (Beaufort)	HUMIDITY	WEATHER	SWELL DIR	SWELL AMT	TRANSPARENCY	CHECKED BY
29° 39′ W	1		95 %	01	23	1	13	CWf

SONIC DEPTH	ANEMOMETER HT ABOVE SEA	BAROMETER (In MBS.)	CLOUDS TYPE	CLOUDS AMT	VISIBILITY	OBSERVERS
1280 FMS. 2341 M.	23 METERS	23	8	2	8	G. HAMMOND, S. W. Oliver

CAST	SERIAL NO.	SAMPLE BOTTLE NUMBER CL.	O2			METER WHEEL	WIRE DEPTH (L)	NANSEN BOTTLE NO.	LEFT THERMOMETER THERM. NO.	MAIN (T′)	AUX. (t)	V_0	I	C	T_w	RIGHT THERMOMETER THERM. NO.	MAIN (T′ OR T'_u)	AUX. (t OR t_u)	V_0	I	C	T_w OR T_u	AVERAGE T_w	DIFF. ($T_u - T_w$)	CORR.	THERMO-METRIC DEPTH (Z)	L − Z OR COSINE OBS.	USED	ACCEPTED DEPTH	REMARKS
						405																								
	844	4663	1			399	1	1	4524	21.35	21.0 / 20.8	101	.00	+.01	21.36	4365	21.36	20.9 / 20.9	102	.00	+.01	21.37	21.36					0	1	
	845	4718	2			390	10	2	4599	21.34	20.9 / 21.1	105	.00	+.01	21.35	4387	21.35	21.1 / 21.2	104	.00	.00	21.35	21.35					1	9	
	846	4307	3			380	20	3	4602	21.00	20.9 / 21.0	99	+.02	.00	21.02	4366	21.02	21.1 / 21.3	106	−.01	.00	21.01	21.02					1	19	
	847	4493	4			370	30	4	4689	20.92	21.1 / 21.0	104	.00	.00	20.92	4382	20.93	21.1 / 21.1	101	.00	.00	20.93	20.92					2	28	
	848	4656	5			360	40	5	4693	20.60	21.0 / 21.1	108	.00	−.01	20.59	4310	20.59	21.2 / 21.2	98	+.01	−.01	20.59	20.59					2	38	
	849	4299	6			350	50	6	4517	17.70	20.8 / 20.7	112	−.02	−.07	17.61	4326	17.66	21.1 / 20.9	100	+.01	−.06	17.61	17.61					3	47	
I	850	1502	7			325	75	7	4596	15.20	20.8 / 20.9	104	+.04	−.11	15.13	4519	15.23	20.8 / 20.5	102	.00	−.11	15.12	15.12					4	71	
	851	4757	8			300	100	8	4688	14.04	20.8 / 20.9	104	.00	−.13	13.91	4520	13.96	20.8 / 20.4	108	.00	−.14	13.82	13.86					5	95	
	852	4304	9			250	150	9	3487	12.78	20.8 / 20.7	99	.00	−.15	12.63	4523	12.76	21.0 / 20.3	101	.00	−.16	12.60	12.62					8	142	
	853	4331	10			200	200	11	4518	12.22	20.7 / 20.0	96	−.01	−.15	12.06	4720 U	14.70	20.3 / 20.3	99	−.01	−.15	14.54	12.06	2.48	−58	190	10	10	190	
	854	4653	11			100	300	12	4505	11.58	20.7 / 20.5	108	−.02	−.18	11.38	4719 U	15.24	20.2 / 20.2	108	−.03	−.18	15.03	11.38	3.65	−83	283	17	13	287	
	855	1497	12			0	400	13	4506	10.77	20.9 / 20.8	83	−.02	−.16	10.59	158 U	14.40	21.0 / 20.9	98	+.05	−.19	14.26	10.59	3.67	+18	385	15	15	385	
						2305																								
	856	4496	13			1800	500	6	4517	10.25	20.5 / 20.4	112	−.01	−.21	10.03	4326	10.22	20.7 / 20.5	100	.00	−.19	10.03	10.03					52	448	
	857	4494	14			1700	600	11	4518	9.33	20.9 / 20.2	96	−.01	−.20	9.12	4720 U	16.40	20.7 / 20.7	99	−.01	−.22	16.17	9.12	7.05	−167	538	62	62	538	
	858	4709	15			1500	800	7	4596	7.66	20.7 / 20.8	104	+.01	−.24	7.43	4519	7.67	20.7 / 20.4	102	.00	−.24	7.43	7.43					81	719	
II	859	4662	16			1300	1000	8	4688	6.29	20.8 / 20.9	104	.00	−.27	6.02	4520	6.28	20.9 / 20.5	108	+.01	−.28	6.01	6.02					99	901	
	860	4302	17			1100	1200	12	4505	5.51	20.5 / 20.3	108	−.02	−.28	5.21	4719 U	19.61	19.8 / 19.8	108	−.03	−.31	19.27	5.21	14.06	−320	1086	114	114	1086	
	861	4335	18			800	1500	9	3487	4.50	20.5 / 20.4	99	.00	−.28	4.22	4523	4.48	20.8 / 20.1	101	.00	−.29	4.19	4.20					131	1369	
	862	4301	19			300	2000	13	4506	3.93	20.5 / 20.4	83	−.01	−.24	3.68	158 U	21.76	20.7 / 20.6	98	+.03	−.33	21.46	3.68	17.78	+75	1853	147	147	1853	
	863	4711	20			0	2300	14	3491	3.71	20.5 / 20.6	98	−.02	−.28	3.41	210 U	23.14	20.8 / 20.7	122	−.06	−.41	22.67	3.41	19.26	+227	2153	147	147	2153	
	864	Phleger Core No. 17																												
	865	Half-Meter Plankton Tow No. 26																												
	866	Mid-water Trawl No. 5																												
	867	GEK run No. 32																												

NAVY-DPPO PRNC, WASH., D.C.

Figure 14-2. Oceanographic log sheet A

height of the anemometer cups above the waterline in meters.

14–21 Wind.—The direction from which the wind is blowing is recorded in degrees true. When the ship is equipped with an anemometer, record the wind speed in knots.

14–22 Wind Force (Beaufort).—When the ship is not equipped with an anemometer to determine the wind speed, estimate the wind force using Beaufort scale. Record the value using the code given in table 9.

14–23 Barometer (In MBS.).—The barometric pressure is recorded in millibars, using 2 digits, thus neglecting the 900 and 1,000 values. For barometers recording in inches of mercury, use table 11 to convert to millibars. For barometers recording in millimeters, use table 13.

14–24 Air Temp. °C.—The dry and wet bulb air temperatures are recorded in degrees and tenths Celsius (centigrade). To convert Fahrenheit to Celsius, refer to table 13.

14–25 Humidity.—Relative humidity is recorded in percent. To compute relative humidity refer to table 14.

14–26 Weather.—Record the state of the weather, using the 2-digit code given in table 1.

14–27 Clouds.—Record the significant cloud type by the single-digit code given in table 2. Indicate the amount of sky covered, using the single-digit code given in table 3.

14–28 Sea.—The direction from which the wind waves (seas) are coming is recorded in 2 digits, using the code given in table 8. The 2-digit code is 00 to 36, with 00 indicating calm and 36 indicating north; 99 indicating variable or unknown. Record the sea height, using the single-digit code given in table 5.

14–29 Swell.—The direction from which the predominant swells are coming is recorded in 2 digits, using the code given in table 8. Record the swell amount, using the single-digit code given in table 6.

14–30 Visibility.—Record the condition of the visibility, using the single-digit code given in table 4.

14–31 Water.—Record the color description of the water at each daylight station, using the Forel scale given by the 2-digit code in table 15.

The transparency of the water is determined by Secchi disc lowerings and is recorded in meters. If both white and black Secchi discs are used, record the reading of the white disc first and the black second.

14–32 Observers.—The name of the oceanographic observer in charge of the station is entered in the space provided. The name of the person making the thermometric calculations and the signature, or initials, of the oceanographer checking the work shall be entered in the spaces provided.

14–33 THE LOG SHEET COLUMNS.—Entries are made in the log sheet columns as follows.

14–34 Cast.—Number each cast of the station with a roman numeral, and enclose the corresponding serial numbers of that cast with brackets as shown in figure 14–2.

14–35 Serial No.—Each observation receives a serial number, commencing with 1, at the beginning of an oceanographic cruise. If numbers are omitted, make a note to that effect, otherwise the checker may think a data sheet or a series of observations is missing. These serial numbers are transferred to the serial number columns of the C-, D-, and E-sheets used for the station.

14–36 Sample Bottle Number.—Four columns are provided in which to record the numbers of the bottles used to hold the sea water samples drawn from the Nansen bottles. The first column is used for the chlorinity (C1) sample bottle numbers. The second column is used for the oxygen (0_2) sample bottle numbers. Two blank columns are used for other samples as needed. Record the chlorinity (C1) sample bottle numbers on both the A- and D-sheets, along with their corresponding serial numbers. In like manner, record the oxygen (0_2) sample bottle numbers on the C-sheet.

14–37 Meter Wheel.—Record in this column the reading of the meter wheel at which each Nansen bottle is placed on the wire. The number immediately above each cast in this column, as shown in figure 14–2, is the meter-wheel reading when the cast is down. These extra few meters allow for the distance between the point at which the Nansen bottles are attached to the wire and the waterline.

14–38 Wire Depth (L).—This column contains the depths in meters, measured along the wire from the sea surface, at which the Nansen bottles are spaced. It is the value L used in computing accepted depths.

14–39 Nansen Bottle No.—Enter here the number of the Nansen bottle, thermometer frame, or a designation of any other instrument used.

14–40 Left Thermometer and Right Thermometer Columns.—These 2 sets of 7 columns each are used to record the data of the protected and unprotected deep-sea reversing thermometers, which are mounted on the Nansen bottles, and the instructions for calculating the correct temperature readings are given in chapter 3. Only brief descriptions of the columns are given here.

14–41 LEFT THERMOMETER.

(*a*) *Therm. No.*—The thermometer number is the manufacturer's number and usually is found inside the reversing thermometer case on the metal band supporting the main and auxiliary thermometers. This number must be carefully recorded as it is the only means of identifying each thermometer.

(*b*) *Main* (T').—Record in this column the reading of the main thermometer. Allow sufficient time for the whole thermometer to come to air temperature before reading. The main temperature must be read to the nearest hundredth of a degree Celsius.

(*c*) *Aux.* (t).—Immediately after reading the main thermometer, the auxiliary thermometer must be read to the nearest tenth of a degree Celsius and the value recorded in this column. It is advisable to write the figures fairly small and close to the lower line in order to leave room to write the corrected reading above. The corrected reading (t) is obtained by applying the auxiliary index correction, given on the thermometer's calibration sheet, to the observed value.

(*d*) V_o.—The V_o is the volume of mercury below the 0° C. mark at the temperature of 0° C. in the reversed main thermometer, expressed in degrees. This value is obtained from the thermometer's calibration sheet.

(*e*) I.—I is the index correction for errors in the main thermometer scale. This value is obtained from the thermometer's calibration sheet. It is read for the temperature of reversal or as close thereto as the table of calibration will permit.

(*f*) C.—C is the correction for thermal expansion of the thermometer system after reversal. See chapter 3 for the formulas and methods for computing this value.

(*g*) T_w.—T_w is the corrected reading of the protected reversing thermometer. This value is obtained by adding algebraically the values given in the *Main*, *I*, and *C* columns.

14–42 RIGHT THERMOMETER.—Unprotected reversing thermometers are customarily placed on the right and are distinguished by placing the letter U after the manufacturer's number.

(*a*) *Therm. No.*—Same directions as for Left thermometer.

(*b*) *Main* (T' *or* T'_u).—Same directions as for the Left thermometer. T' is the symbol used in the correction formula for protected thermometers and T'_u is the symbol used in the correction formula for unprotected thermometers.

(*c*) *Aux.* (t *or* t_u).—Same directions as for the Left thermometer. The corrected reading (t) is used for the protected thermometers. The corrected reading (t_u) is used for unprotected thermometers.

(*d*) V_o.—Same directions as for the Left thermometer.

(*e*) I.—Same directions as for the Left thermometer.

(*f*) C.—Same directions as for the Left thermometer. See chapter 3 for the formulas and methods for computing this value. It is important to remember that protected and unprotected values are computed by different formulas.

(*g*) T_w *or* T_u.—T_u is the corrected reading of the unprotected reversing thermometer. T_w is the corrected reading of the protected reversing thermometer. Either value is obtained by adding algebraically the values in the *Main*, *I*, and *C* columns.

14–43 Average T_w.—When both right and left thermometers are protected the value recorded in this column is the average of the two corrected readings (T_w). When there is a single protected, or a protected paired with an unprotected, the corrected reading (T_w) given for the Left termometer is copied into this column. After completion of the depth calculations, these entries are copied on the E-sheet, into the column headed T_w °C., along with their corresponding serial numbers and accepted depths.

14–44 Diff. ($T_u - T_w$).—Entries are made in this column only where there are paired protected and unprotected thermometers. Each value entered here is the difference between the T_w and the corrected unprotected reading T_u in the preceding column.

14–45 Corr.—The correction value entered in this column is obtained from the depth anomaly (ΔZ) graph for the unprotected thermometer. Instructions for constructing and using ΔZ graphs are given in chapter 3. When ΔZ graphs are not used and the thermometric depths are determined by direct calculations, no entries need be made in this column.

14–46 Thermometric Depth (Z).—The Thermometric Depth (Z) is the algebraic sum of the 2 preceding columns times 100. It is the value, Z, used in determining the accepted depth by the L–Z method. Instructions for computing thermometric depths by formula are given in chapter 3.

14–47 *L–Z* or Cosine (*Z/L*).—The two columns under this heading are used to determine the accepted depths by either the *L–Z* or the cosine (*Z/L*) method. These methods are described in chapter 3. Indicate the method used by crossing out the other method.

(*a*) *Obs.*—In this column are recorded the *L–Z* or *Z/L* observed values. In the *L–Z* method, as shown in figure 14–2, the values recorded in this column are the differences between the Wire Depth (*L*) and the Thermometer Depth (*Z*). These values for the station are plotted on graph paper, as shown in figure 3–4, and curves drawn.

(*b*) *Used.*—In this column are recorded the *L–Z* or *Z/L* values interpolated from the curves constructed for all the bottles on one cast. These values are actually used to determine the accepted depths.

14–48 Accepted Depth.—The Accepted Depth is the best possible determination of the true depth of each Nansen bottle at the time of reversal. With the *L–Z* method, the accepted depth is obtained by subtracting the value listed in the preceding Used column from the Wire Depth (*L*). The values in this column are recorded on the E-sheet in the column headed Accepted Depth, along with their corresponding serial numbers and temperatures.

14–49 Remarks.—Record in the Remarks column any comments that may be useful in the analyses of data. Such items as thermometers malfunctioning, Nansen bottles failing to trip, unusual weather or sea conditions, etc., are very useful in later analyses.

14–50 ASSOCIATED OBSERVATIONS.—All other observations taken on the station should be recorded at the bottom of the A sheet. These would include bottom samples, biological specimens, transparency measurements, wave staff observations, etc.

OCEANOGRAPHIC LOG SHEET B, PRNC–NHO–1189 (Rev. 12–53)

BATHYTHERMOGRAPH OBSERVATIONS

14–51 GENERAL REMARKS.—The B-sheet is used to record all bathythermograph observations. General operating instructions are given in chapter 2.

14–52 Special Instructions.—During the course of a U. S. Navy survey, a great many bathythermograph observations are usually taken. Routine observations are made every hour and frequently observations are required as often as every 10 or 15 minutes. As special studies usually are made from these observations, the instructions given below for filling in the log sheet apply to U. S. Navy surveys.

14–53 The Term BT.—Through widespread usage the term BT has become the shortened name for bathythermograph. The term BT shall be used in these instructions.

14–54 THE LOG SHEET.—A sample log sheet is shown as figure 14–3. Print all entries accurately and neatly. Record complete information for every BT observation. Fill in every space. Do not use ditto marks.

14–55 The Log Sheet Headings.—Fill in the ship's name and number, the month, and the year at the top of the sheet. Write the cruise name and number above the space for Vessel. Number the log sheets consecutively above the space for Time Zone, as shown in figure 14–3. Use Greenwich mean time (GMT) for all BT observations. In the space marked Time Zone indicate the local time zone in which the ship is operating.

14–56 The Log Sheet Columns.—As soon as possible after each BT lowering the log sheet columns should be completed in accordance with the instructions given below.

14–57 Serial No.—Each observation receives a serial number commencing with numeral 1 for the first observation taken on the cruise and continuing consecutively. If numbers are omitted, make a note to that effect at the bottom of the log sheet; otherwise, the checker may think a data sheet or series of observations is missing.

14–58 Time.—Time is recorded in Greenwich mean time (GMT). Give the hour and minute at which the BT enters the water.

14–59 Date.—Record the day of the month only.

14–60 Latitude and Longitude.—Give the ship's position, in degrees and minutes, at the time the BT enters the water. Be sure to indicate whether latitude is N or S and longitude is E or W. Where these do not change on a log sheet, they may be entered once at the top of the columns, as shown in figure 14–3. These positions should be obtained from the adjusted ship's track as given on the smooth plotting sheets and not from the dead reckoning (DR) position. After the positions have been entered on the log sheets the positions and serial numbers of the BT observations are plotted in India ink, on H. O. 5050 Series Strategic Plotting Sheets. Give the ship's name and number, cruise name and number, beginning and ending dates of the cruise, and the sheet number on each sheet.

14–61 BT No.—The BT number is stamped on the nose of each instrument. As each BT has a different number, be sure to check this before each observation to make sure the proper instrument is being used. Record the BT number for each observation.

14–62 Depth.—Record the sonic sounding in fathoms for each observation. It is important to determine the depth just prior to making a BT lowering. More than one BT has been lost because the operator learned the hard way that there were only 25 fathoms when he thought there were 1,200 fathoms.

14–63 Speed.—Give the speed of the ship in knots for each observation. If the ship is lying to when an observation is made show the speed as zero.

14–64 Surf. Temp.—The surface temperature of the sea water is recorded in degrees and tenths Fahrenheit. Example: 53.4° F. After the temperature value, indicate whether it was obtained by a bucket sample (B) or by the engine room injection temperature (I). The bucket sample is recommended. Special bucket thermometers are supplied for U. S. Navy surveys by the Hydrographic Office. These are more accurate than the standard thermometers issued with the BT kits and are to be used in place of the latter.

14–65 Air Temp.—Record the dry bulb and wet bulb air temperatures in degrees and tenths Fahrenheit. Example: 57.3° F.

14–66 Barometer.—Record the barometric pressure in inches of mercury to hundredths of an inch. Example: 29.53.

14–67 Weather by Symbols.—Record the state of the weather at the time of the BT observation, using the code given in table 1.

14–68 Clouds.—Record the type of clouds present at the time of the BT observation, using the code given in table 2. Record the amount of cloud cover at the time of the BT observation, using the code given in table 3.

14–69 Visibility.—Record the condition of visibility at the time of the BT observation, using the code given in table 4.

14–70 Sea.—Record the height of the sea at the time of the BT observation, using the code given in table 5.

14–71 Wire Out.—Give the amount of wire paid out from the winch during a BT lowering. Use the maximum figure indicated by the winch counter. Although the counter actually records revolutions of the winch drum, it approximates the number of feet of wire paid out.

14–72 Sample Number.—If a sample of sea water is taken at the same time as the BT observation, record the sample bottle number in this space.

14–73 Observer's Initials.—The observer should initial the last column. If further remarks are required, make an asterisk (*) opposite the observer's initials and record the remarks on the back of the log sheet.

14–74 SHIPPING INSTRUCTIONS.—Upon completion of a cruise, carefully pack all slides, log sheets, and BT track charts, and mail them together to:

The Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C.
Attn: Code 5430

OCEANOGRAPHIC LOG SHEET C, PRNC–NHO–1190 (Rev. 12–53)

DISSOLVED OXYGEN DETERMINATION

14–75 GENERAL REMARKS.—The C-sheet is used for the chemical analyses and calculations involved in the determination of dissolved oxygen content of sea water samples by the Winkler method. Complete instructions for this method are given in chapter 13. Study those instructions carefully before attempting to use this log sheet.

14–76 THE LOG SHEET.—A sample log sheet is shown in figure 14–4. Print all entries accurately and neatly.

14–77 The Log Sheet Headings.—Fill in the ship's name and number, cruise name and number, and station number. The chemists name and the date of the analyses should be entered in the proper spaces. The name, or

OCEANOGRAPHIC LOG SHEET - B
PRNC-NHO-1189 (REV. 12-53)

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D. C.

BATHYTHERMOGRAPH OBSERVATIONS
FOR USE WITH H. O. PUB. NO. 606-C

VESSEL	CRUISE	MONTH	YEAR	TIME ZONE	SHEET NO.
USS REHOBOTH (AGS-50)	RE-15	AUGUST	1955	+5	1

SERIAL NO.	TIME G.M.T.	DATE	LATITUDE N	LONGITUDE W	BT NO.	DEPTH (Fathoms)	SPEED (Knots)	SURF. TEMP. DEGREES	SURF. TEMP. INJ. OR BKT.	WIND DIRECTION (True)	WIND FORCE KNOTS	AIR TEMP. DRY BULB	AIR TEMP. WET BULB	BAROMETER (Inches)	WEATHER (Tab. I)	CLOUDS TYPE (Tab. II)	CLOUDS COVER (Tab. III)	VISIBILITY (Tab. IV)	SEA (Tab. V)	WIRE OUT	SAMPLE NUMBER	OBSERVER'S INITIALS
1	0300	13	38°45'	74°30'	1591	13	12	75.6	B	178	13	77.2	76.0	29.92	2	8	9	7	2	220		BJB
2	0400	13	38°40'	74°15'	1591	23	12	75.5	B	170	18	76.2	75.7	29.92	1	8	7	7	2	200		BJB
3	0500	13	38°40'	74°01'	1591	27	12	75.3	B	201	21	75.6	75.3	29.90	1	8	6	7	3	300		BJB
4	0515	13	38°38'	73°56'	1591	75	12	75.2	B	201	21	75.6	75.1	29.90	2	8	6	7	3	500		WJ
5	0530	13	38°35'	73°52'	716	123	12	74.7	B	201	21	75.6	75.0	29.90	2	8	6	7	3/2	1000		WJ
6	0545	13	38°33'	73°49'	716	155	12	74.7	B	200	21	75.6	74.7	29.90	2	8	6	7	3	1200		WJ
7	0600	13	38°31'	73°47'	716	187	12	74.4	B	200	21	75.7	74.5	29.90	2	8	6	7	3	2000		WJ
8	0700	13	38°29'	73°45'	716	467	12	74.5	B	210	18	75.9	74.4	29.91	1	8	5	7	3	2000		SS
9	0800	13	38°27'	73°43'	716	610	12	74.4	B	210	17	76.3	74.5	29.91	2	8	5	7	2	2100		SS
10	0900	13	38°24'	73°41'	716	1120	12	74.2	B	210	15	77.1	74.4	29.92	2	8	5	7	2	2100		SS
—	0910	Stopped on station RE-15-1																				
11	0920	13	38°23'	73°41'	716	1150	0	74.3	B	210	12	77.5	74.3	29.92	3	8	6	7	2	900		SS
12	0940	13	38°23'	73°41'	1591	1150	0	74.2	B	210	12	77.6	74.3	29.92	2	8	6	7	2	450		SS
13	1000	13	38°23'	73°41	780A	1150	0	74.3	B	215	11	77.8	74.2	29.93	1	8	5	7	1	200		SS
—	1015	13	Underway from station RE-15-1																			
14	1100	13	38°21'	73°38'	716	1165	12.5	74.5	B	215	11	78.1	74.2	29.93	1	8	5	7	1	2100		KK

NAVY-DPPO PRNC, WASH., D.C.

350676 O—56 (Face p. 143)

Figure 14–3. Oceanographic log sheet B.

OCEANOGRAPHIC LOG SHEET - C
PRNC-NHO-1190 (REV. 12-53)

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D. C.

DISSOLVED OXYGEN DETERMINATION
For use with H. O. Pub. No. 607

VESSEL	CRUISE	STATION	CHEMIST	DATE ANALYZED	CHECKED BY
USS REHOBOTH (AGS-50)	RE-15	34	S. W. Oliver	27 Aug 1955	GEO. H. HAMMOND

SERIAL NUMBER	SAMPLE BOTTLE NUMBER	1ST BURETTE READING ml.	2ND BURETTE READING ml.	3RD BURETTE READING ml.	AVERAGE BURETTE READING V ml.	DISSOLVED OXYGEN O_2 ml/L	REMARKS
844	1	9.29	9.26		9.28	5.03	
845	2	9.30	9.29		9.30	5.04	
846	3	9.23	9.23		9.23	5.00	
847	4	9.38	9.36		9.37	5.08	
848	5	~~9.54~~	9.49	9.48	9.49	5.14	
849	6	10.62	10.64		10.63	5.76	
850	7	10.17	10.16		10.17	5.51	
851	8	9.61	9.64		9.63	5.22	
852	9	9.46	9.43		9.45	5.12	
853	10	9.36	9.35		9.36	5.07	
854	11	9.31	9.32		9.32	5.05	
855	12	9.01	9.00		9.01	4.88	
856	13	8.85	8.87		8.86	4.80	
857	14	8.17	8.17		8.17	4.43	
858	15	~~8.20~~	8.25	8.26	8.25	4.47	
859	16	9.26	9.26		9.26	5.02	
860	17	9.96	9.95		9.96	5.40	
861	18	10.69	10.71		10.70	5.80	
862	19	11.24	11.23		11.24	6.09	
863	20	11.13	11.16		11.15	6.04	

NORMALITY DETERMINATION

I BLANK RUN

V_b (1ST RUN) = 0.07
V_b (2ND RUN) = 0.08
V_b (3RD RUN) = 0.06
TOTAL = .0.21
V_b (AVERAGE) = 0.07

II STANDARDIZATION OF $Na_2S_2O_3$

V_2 (1ST RUN) = 20.88
V_2 (2ND RUN) = 20.92
V_2 (3RD RUN) = 20.90
TOTAL = 62.70
V_2 (AVERAGE) = 20.90

III NORMALITY OF $Na_2S_2O_3$

$N = \frac{0.1}{V_2 - V_b} = 0.0048$

CHECK VOLUME OF SAMPLES TITRATED

☐ 100 ml. ☑ 50 ml.

IV DISOLVED OXYGEN DETERMINATION

$O_2 = 56.45\ NV$

FOR 100 ml. SAMPLE:
$K = 56.45N =$

FOR 50 ml. SAMPLE:
$K = 112.9N = 0.5419$

$\therefore O_2 = KV$

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Figure 14-4. Oceanographic log sheet C.

initials, of the oceanographer checking the sheet will signify acceptance of the data as to accuracy and correctness.

14–78 The Log Sheet Columns.—The log sheet columns are completed in accordance with the instructions given below.

14–79 Serial Number.—The serial number is obtained from the serial number column of the A-sheet for the station being analyzed.

14–80 Sample Bottle Number.—The sample bottle numbers are obtained from the A-sheet. They are listed in the column headed 0_2, under Bottle Numbers. When copying these numbers from the A-sheet, be sure that they agree with the serial numbers, line for line.

14–81 1st Burette Reading ml.—Record in this column the burette reading for the first titration of a treated sea water sample. Readings are recorded in milliliters to two decimal places. Example: 22.92.

14–82 2nd Burette Reading ml.—Record in this column the burette reading for the second titration of a treated sea water sample. When titrating, the second sample should be not more than ± 0.03 ml. different from the first titration to be acceptable.

14–83 3rd Burette Reading ml.—The column for a third burette reading is used only when 50-ml. samples are being titrated. As the sea water sample bottles contain 250 ml., there is only enough sample to make two 100-ml. titrations. With 50-ml. samples the margin of error is twice as great as with the larger samples; therefore, if the first two titrations are not within 0.03 ml. of each other, a third or, if necessary, a fourth titration must be run. In the latter case, record the three best titrations.

14–84 Average Burette Reading V ml.—Average the values given in the first, second, and third burette reading columns and record the average value in this column. The average burette reading is the value V in the formula for determining the amount of dissolved oxygen, $O_2 = 56.45NV$.

14–85 Dissolved Oxygen O_2ml./l.—The amount of dissolved oxygen (O_2), expressed in milliliters per liter (ml./l.) of sea water, is recorded in this column. This value is derived from the formula $O_2 = 56.45NV$, where N = the normality of the sodium thiosulfate ($Na_2S_2O_3$) solution and V = the average milliliters of sodium thiosulfate solution used in the titration. The latter value is given in the Average Burette Reading column. As 56.45 and N remain the same for all samples run on 1 station (unless new solutions have to be made up during the runs), a constant (K) may be determined as follows:

For 100-ml. samples, $K = 56.45N$

For 50-ml. samples, $K = 2(56.45N)$.

Thus, when K is determined, the formula becomes $O_2 = KV$ and the amount of dissolved oxygen can be determined by multiplying K and each V in the Average Burette Reading column.

The dissolved oxygen values are recorded on the E-sheet in the O_2ml./l. column under Observed Values. Be sure the serial numbers for these values on the C- and the E-sheets are in agreement.

14–86 Remarks.—Record in the Remarks column any information that will aid persons analyzing the data after the cruise. If more than one normality determination must be made, use this column to record the data.

14–87 NORMALITY DETERMINATION.—The determination of the normality of the sodium thiosulfate solution must be made immediately before running the titrations of the sea water samples. Complete instructions for making the blank run and standardization are given in chapter 13. Study thoroughly those instructions before using this column.

I. *Blank Run.*—Make three blank runs to determine the value V_b and compute the average V_b.

II. *Standardization of $Na_2S_2O_3$.*—Make three standardization runs of the sodium thiosulfate solution to determine and compute the average V_2.

III. *Normality of $Na_2S_2O_3$.*—Compute the normality of the sodium thiosulfate solution by completing the formula N (normality) $= \frac{0.1}{V_2 - V_b}$ and recording the answer to at least three decimal places.

IV. *Dissolved Oxygen Determination.*—The formula for determining the dissolved oxygen content of each sample is: $O_2 = 56.45NV$; where N is the normality, obtained by III above, and V is the Average Burette Reading. A constant K can be determined as $K = 56.45N$ for 100-ml. samples and $K = 112.9N$ for 50-ml. samples. This factor K may then be multiplied by each value V, given in the Average Burette Reading column, to obtain the dissolved oxygen. The K-factor is recorded to at least three decimal places.

CHLORINITY AND SALINITY DETERMINATION

14–88 **GENERAL REMARKS.** The D-sheet is used for recording the chemical analyses and calculations involved in the determination of chlorinity and salinity of sea water samples by the Knudsen method. Complete instructions for this method are given in chapter 13. Study those instructions carefully before attempting to use this log sheet.

14–89 **THE LOG SHEET.**—A sample log sheet is shown in figure 14–5. Print all entries accurately and neatly.

14–90 **The Log Sheet Headings.**—Fill in the ship's name and number, cruise name and number, and station number. The chemist's name and the date of the analyses should be entered in the proper spaces. The name, or initials, of the oceanographer checking the sheet will signify acceptance of the data as to accuracy and correctness.

14–91 **The Log Sheet Columns.**—The log sheet columns are completed in accordance with the instructions given below.

14–92 **Serial Number.**—The serial number is obtained from the serial number column of the A-sheet for the station being analyzed.

14–93 **Sample Bottle Number.**—The sample bottle numbers are obtained from the A-sheet. They are listed in the column headed Cl under Bottle Numbers. When copying these numbers from the A-sheet be sure that they agree with the serial numbers, line for line.

14–94 **First Burette Reading.**—Record in this column the reading of the Knudsen burette for the first titration of each sea water sample. These values are given on the burette in double milliliters. They are recorded to two decimal places.

14–95 **Second Burette Reading.**—Record in this column, the reading of the Knudsen burette for the second titration of each sea water sample.

14–96 **Third Burette Reading.**—Record in this column, the reading of the Knudsen burette for the third titration of each sea water sample. This titration is necessary only when the first and second titrations differ by more than 0.02. If the third titration fails to agree within 0.02 of either of the first two, continue running titrations until two results are obtained that do agree within 0.02. Enter the value then obtained in the third burette reading column.

14–97 **Average Burette Reading.**—Average the readings of the first and second and/or third titrations, and record the average value in this column. If more than 2 titrations are made, average the 2 values that agree within 0.02.

14–98 ***k***—*k* is the correction needed to convert the average burette reading to chlorinity. *k* is given in the Hydrographical Tables of 1901, by Martin Knudsen. These tables are commonly referred to as Knudsen's Tables. *k* is shown on the right-hand side of pages 23 through 34 of these tables. To obtain the proper *k* enter the tables with the alpha value (α), as determined by the standardization of the silver nitrate solution. Select the column having the proper alpha value, making sure the correct sign ($\pm$) is used, and find the two figures between which the average burette reading of the water sample lies. Record *k* with its proper sign on the D-sheet. If the average burette reading is the same as the one in the alpha column of the tables, then select the nearest even *k*.

14–99 **Chlorinity °/₀₀.**—Record in this column the chlorinity of each sea water sample as expressed in parts per thousand (°/₀₀). This is the weight of chlorine, in grams, found in 1,000 grams of sea water. This value is obtained by adding algebraically the Average Burette Reading and the *k* value for each sample.

14–100 **Salinity °/₀₀.**—Record in this column the salinity of each sea water sample as expressed in parts per thousand and (°/₀₀). This is the total weight of salt, in grams, found in 1,000 grams of sea water. This value can be computed ($S°/_{oo}=0.03+1.805\times Cl°/_{oo}$) but may be obtained directly from table 16. Enter the table with the chlorinity ($Cl°/_{oo}$) and read the salinity ($S°/_{oo}$) directly from the adjacent column to the right. These values are then recorded on the E-sheet in the column headed Salinity °/₀₀, under Observed Values. Be sure values agree with the serial numbers on the E-sheet, line for line.

14–101 **Time.**—Record in this column the time that the last titration of each sea water sample was completed.

OCEANOGRAPHIC LOG SHEET-D
PRNC.NHO.1191 (Rev. 6-53)

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

CHLORINITY & SALINITY DETERMINATION
For use with H.O. Pub. No. 607

VESSEL	CRUISE	STATION	CHEMIST	DATE ANALYZED	CHECKED BY
USS REHOBOTH	RE-15	34	Wilson	29 AUG 1955	E.W. Johnson

SERIAL NUMBER	SAMPLE BOTTLE NUMBER	1st. BURETTE READING	2nd. BURETTE READING	3rd. BURETTE READING	AVERAGE BURETTE READING	k	CHLORINITY ‰	SALINITY ‰	TIME	STANDARDIZATION (N)-(A)=a: Cl‰ of STANDARD (N)	amt. of A_gNO_3 (A)	a	REMARKS
844	4663	19.82	19.80		19.81	+0.01	19.82	35.81		*19.395	19.38	+.015	
845	4718	19.79	19.80		19.79	.01	19.80	35.79		19.395	19.36	+.035	
846	4307	19.79	19.79		19.79	.01	19.80	35.77		19.395	19.37	+.025	
847	4493	19.78	19.78		19.78	.01	19.79	35.75			+	.025	
848	4656	19.78	19.80		19.79	.01	19.80	35.77					
849	4299	19.78	19.80		19.79	.01	19.80	35.77					
850	1502	19.79	19.79		19.79	.01	19.80	35.77		*19.395	19.37	+.025	
851	4757	19.75	19.76		19.76	.01	19.77	35.71					
852	4304	19.72	19.71		19.72	+0.02	19.74	35.66					
853	4331	19.69	19.70		19.70	.02	19.72	35.61					
854	4653	19.64	19.67	19.64	19.64	.02	19.66	35.53					
855	1497	19.58	19.57		19.58	.02	19.60	35.41					
856	4496	19.51	19.52		19.52	.02	19.54	35.30		*19.395	19.37	+.025	
857	4497	19.48	19.49		19.48	.02	19.50	35.25					
858	4709	19.45	19.43		19.44	.02	19.46	35.16					
859	4662	19.32	19.36	19.36	19.36	.02	19.38	35.01					
860	4302	19.34	19.34		19.34	.02	19.36	34.97					
861	4335	19.31	19.32		19.32	+0.03	19.35	34.96					
862	4301	19.31	19.31		19.31	.03	19.34	34.94		*19.395	19.36	+.015	
863	4711	19.31	19.31		19.31	.03	19.34	34.94		19.395	19.38	+.035	
											+	.025	

* RUN STANDARD

NAVY-DPPO PRNC, WASH., D.C.

Figure 14–5. Oceanographic log sheet D.

OCEANOGRAPHIC LOG SHEET-E
PRNC-NHO-1244 (REV. 4-54)

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D. C.

STATION SUMMARY
FOR USE WITH H.O. PUB. NO. 607

CRUISE	STATION	LATITUDE	MAX SAMPLE DEPTH	WIND DIR.	WIND SPEED (M./S.)	BAROMETER (In MBS.)	CLOUDS TYPE	CLOUDS AMT.	VISIBILITY	COMPUTED BY
RE-15	34	4330 N	21 M.	20	06	23	8	2	8	B S Richmond

VESSEL	LONGITUDE	LAYER DEPTH (Below Surf.)	WIND FORCE (Beaufort)	AIR TEMP. (°C.) DRY	AIR TEMP. (°C.) WET	SEA DIR.	SEA AMT	WATER COLOR (Forel)	CHECKED BY
USS REHOBOTH (AGS-50)	02939 W	10 M.		217	211	21	1	10	cwt.

DAY	MONTH	YEAR	G M T	SONIC DEPTH	TYPE OF BOTTOM	ANEMOMETER HT ABOVE SEA	HUMIDITY	WEATHER	SWELL DIR.	SWELL AMT.	TRANSPARENCY	APPROVED BY
27	08	955	20	2341 M.	1	23 METERS	95%	01	23	1	13	S. W. Oliver

OBSERVED VALUES

SERIAL NO.	ACCEPTED DEPTH	T °C.	SALINITY °/oo	σ_t	O_2 ML/L		
844	1	21.36	35.81	25.03	5.03		
845	9	21.35	35.79	25.02	5.04		
846	19	21.02	35.77	25.09	5.00		
847	28	20.92	35.75	25.10	5.08		
848	38	20.59	35.20	25.20	5.14		
849	47	17.61	35.77	25.97	5.76		
850	71	15.12	35.77	26.55	5.51		
851	95	13.86	35.71	26.78	5.22		
852	142	12.62	35.66	27.00	5.12		
853	190	12.06	35.61	27.06	5.07		
854	287	11.38	35.53	27.14	5.05		
855	385	10.59	35.41	27.17	4.88		
856	448	10.03	35.30	27.19	4.80		
857	538	9.12	35.25	27.31	4.43		
858	719	7.43	35.16	27.50	4.47		
859	901	6.02	35.01	27.57	5.02		
860	1086	5.21	34.97	27.63	5.40		
861	1369	4.20	34.96	27.74	5.80		
862	1853	3.68	34.94	27.79	6.09		
863	2153	3.41	34.94	27.81	6.04		

DYNAMIC CALCULATIONS

STD. DEPTH	T °C.	SALINITY °/oo	σ_t	δ	MEAN δ	ΔD	$\Sigma\Delta D$	O_2 ML/L		
0	21.36	35.81	25.03	293.8			....	5.03		
					294.0	.0294				
10	21.33	35.79	25.03	294.2			.0294	5.04		
					291.5	.0292				
20	21.01	35.76	25.09	288.8			.0586	5.01		
					287.6	.0288				
30	20.90	35.76	25.12	286.4			.0874	5.10		
					243.4	.0487				
50	17.35	35.77	26.03	200.4			.1361	5.70		
					173.6	.0434				
75	14.90	35.77	26.60	146.9			.1795	5.43		
					136.8	.0342				
100	13.70	35.71	26.82	126.6			.2137	5.20		
					117.7	.0589				
150	12.50	35.65	27.02	108.8			.2726	5.11		
					106.5	.0533				
200	11.98	35.60	27.08	104.1			.3259	5.06		
					102.8	.0514				
250	11.60	35.55	27.12	101.5			.3773	5.05		
					101.1	.0506				
300	11.25	35.51	27.14	100.7			.4279	5.04		
					100.3	.1003				
400	10.46	35.38	27.17	99.8			.5282	4.88		
					93.3	.0933				
500	9.46	35.26	27.26	92.6			.6215	4.60		
					86.9	.0869				
600	8.54	35.23	27.39	81.3			.7084	4.37		
					75.2	.1504				
800	6.80	35.08	27.53	69.1			.8588	4.64		
					66.1	.1322				
1000	5.60	34.98	27.60	63.0			.9910	5.24		
					58.2	.1164				
1200	4.67	34.96	27.70	53.4			1.1074	5.59		
					50.2	.1506				
1500	3.94	34.95	27.78	46.9			1.2580	5.95		
					47.3	.2365				
2000	3.50	34.94	27.80	47.6			1.4945	6.08		
2500										
3000										
4000										

350676 O—56 (Face p. 147)

Figure 14–6. Oceanographic log sheet E

14–102 STANDARDIZATION $(N)-(A)=\alpha$.—Standardization is the process of determining the difference between the concentration of the silver nitrate solution (A) which is used for titrating the sea water samples, and the chlorinity of a standard (N) which is exactly known. This difference is called alpha (α). It is used to determine the correction k that is applied to the Average Burette Reading to obtain chlorinity of the sea water samples. The formula used to determine alpha is: $(N)-(A)=\alpha$.

The standard (N) used is known as standard sea water. By international agreement, standard sea water is produced only by the Association d'Oceanographie Physique, Dépot d'Eau Normale, Charlottenlund slot, Charlottenlund, Danemark. This water is put up in flame-sealed glass tubes. Each tube contains approximately 200 ml. of water, and the exact chlorinity, to 3 decimal places, is given on the label of each tube.

Standardization titrations must be run before titrating the sea water samples. At least three titrations must be run for the first standardization of each station. Record these at the first asterisk (*) shown on the log sheet. At least one titration must be run at each of the other points indicated by the asterisks. As in all chlorinity titrations, these values must agree within 0.02.

14–103 Cl°/₀₀ of Standard (N).—Record the chlorinity of the standard sea water used for the standardization titrations. This should be given at each point indicated by asterisks.

14–104 Am't. of $AgNO_3(A)$.—Record in this column, the reading of the Knudsen burette for the amount of silver nitrate solution used to titrate each sample of standard sea water.

14–105 α.—Record in this column, the alpha (α) for each standardization titration. The alpha is determined by the formula $(N)-(A)=\alpha$. Compute the average alpha for each set of standardization titrations and record it in this column, as shown in figure 14–5.

14–106 Remarks.—Record in the Remarks column any information that will aid persons analyzing the data after the cruise.

OCEANOGRAPHIC LOG SHEET E, PRNC–NHO–1244 (Rev. 4–54)

STATION SUMMARY

14–107 GENERAL REMARKS.—The E-sheet is the sheet on which all data of a station are summarized. The sources of data recorded on this sheet are the A-, C-, and D-sheets. From the observed values recorded on this sheet, graphs are constructed and standard depth values derived. From the standard depth values, dynamic height anomalies are computed. The meteorological and associated data are coded from the A-sheet.

14–108 IBM Punch Cards.—The completed data shown on this log sheet are transferred to the F-sheet and thence onto IBM punch cards and processed at the U. S. Navy Hydrographic Office. The processes involved in transferring this data to punch cards are simplified when the data are coded directly on the log sheet. It is therefore necessary that the instructions given below be carefully followed, and all information be recorded properly. All tables referred to are given in part II.

14–109 The Log Sheet Headings.—The cruise name and number, station number, and name of the vessel are filled in as shown on the A-sheet. Fill in blanks requiringnumeralswith the designated number of digits as given in the following instructions (fig. 14–6).

14–110 Day.—Indicate the day of the month with two digits. If the station was occupied on the third, write 03.

14–111 Month.—Indicate the month with two digits. Thus if the station was occupied in August, write 08.

14–112 Year.—Indicate the year with the year's last three digits. Thus, for the year 1955, write 955.

14–113 GMT.—Indicate the Greenwich mean time of the station with two digits. This is the nearest hour as shown by the Start time of the first cast on the A-sheet. Thus, if the Start time is 1930, write 20.

14–114 Latitude.—Record the corrected latitude with four digits, followed by N or S to indicate north or south. Thus, latitude 43°30′ north is written 4330N.

14–115 Longitude.—Record the corrected longitude with five digits, followed with E or W to indicate east or west. Thus, longitude 29°39′ west is written 02930W.

14–116 Sonic Depth.—Record the depth of water, in meters, with four digits. See table 12 for conversion of fathoms to meters.

14–117 Max. Sample Depth.—The maximum sample depth is recorded with two digits. This is the greatest Nansen bottle depth as shown in the Accepted Depth column of the A- and E-sheets. It is recorded to the maximum 100 meters. Thus, if the greatest Accepted Depth is 2,153 meters, record it as a maximum sample depth of 21.

14–118 Layer Depth (Below Surf.).—The layer depth of the thermocline below the surface is recorded in meters with three digits. Layer depth of the thermocline is defined as the depth from the surface to the top of a sharp negative gradient or, in the case of a positive gradient, the depth of maximum temperature. The layer depth is obtained from the plotted temperature graph. (See sec. 14–141 Plotting Observed Values on Graphs, following.)

14–119 Type of Bottom.—The type of bottom sediment obtained on station by means of corer, snapper, or other device, is recorded with one digit using the code given in table 7. If no sample is taken, leave it blank.

14–120 Wind.—The direction from which the wind is blowing is recorded with two digits using the code given in table 8. The 2-digit code is 00 to 36, with 00 indicating calm and 36 indicating north; 99 indicating variable or unknown. Thus, if the wind is from 200° T., record it as 20. Wind speed is recorded in meters per second using two digits. To convert from knots to meters per second, refer to table 10A. Round the value obtained from table 10A to the nearest even whole number. Thus, if the wind speed is 12 knots, the table indicates a speed of 06.2 meters per second. Write the value as 06.

14–121 Wind Force (Beaufort).—If the ship is not equipped with an anemometer to determine the wind speed, estimate the wind force using the Beaufort scale. Record the value with 2 digits using the code given in table 9. When there is no anemometer, do not record speed in meters per second, as outlined above, but only by wind-force code.

14–122 Anemometer Height Above Sea.—For ships equipped with anemometers, record the height of the anemometer cups above the waterline, in meters, using two digits.

14–123 Barometer (In mb.).—The barometric pressure is recorded in millibars, using two digits. Thus, neglect the 900 or 1,000 values. For barometers recording in inches of mercury, use table 11A to convert to millibars. For barometers recording in millimeters, use table 11B to convert to millibars.

14–124 Air Temp. (° C.).—The dry and wet bulb air temperatures are recorded in degrees and tenths Celsius (centigrade) using three digits. Thus, if an air temperature is 21.7° C. write it as 217. For ships equipped with only Fahrenheit thermometers, use table 13A to convert to Celsius.

14–125 Humidity.—Relative humidity is recorded in percent, using two digits. If relative humidity is 100 percent write as 99. To compute relative humidity, refer to table 14.

14–126 Weather.—Record the state of the weather, using the 2-digit code given in table 1.

14–127 Clouds.—Record the significant cloud type, using the single-digit code given in table 2. Indicate the amount of sky covered using, the single-digit code given in table 3.

14–128 Sea.—The direction from which the wind waves (seas) are coming is recorded in 2 digits, using the code given in table 8. The 2-digit code is 00 to 36 with 00 indicating calm and 36 indicating north. Record the sea amount, using the single-digit code given in table 5.

14–129 Swell.—The direction from which the predominant swells are coming is recorded in 2 digits, using the code given in table 8. Record the swell amount using the single-digit code given in table 6.

14–130 Visibility.—Record the condition of visibility, using the single-digit code given in table 4.

14–131 Water.—Record the color description of the water, at each daylight station, using the Forel scale as given by the 2-digit code in table 15. The transparency of the water, as determined in meters by Secchi discs, is recorded in two digits. If both white and black Secchi discs are used, record the reading of the white disc first and the black second, separating the two figures with a dash.

14–132 OBSERVED VALUES COLUMNS.—The Observed Values columns are filled in as follows.

14–133 Serial No.—The serial numbers are obtained from the Serial No. column of the A-sheet.

14–134 Accepted Depth.—The accepted depths are obtained from the Accepted Depth column of the A-sheet. Be sure that they agree with their corresponding serial numbers, line for line.

14–135 T_w°C.—The temperature of the water, in degrees and hundredths Celsius, is obtained from the Average T_w°C. column of the A-sheet. Be sure that they agree with their corresponding serial numbers, line for line.

14–136 Salinity °/₀₀.—The salinity of the water, in parts per thousand, is obtained from the column of the same heading on the D-sheet. Be sure that they agree with their corresponding serial numbers, line for line.

14–137 *σt*.—This value is called sigma *t* (*σt*). It represents, in abbreviated form, the density of the water samples at atmospheric pressure as determined by the temperature and salinity of each sample. It may be determined in several ways: from table 17, or from the tables in H. O. Pub. No. 614, Processing Oceanographic Data, or in H. O. Pub. No. 615, Tables for Sea Water Density. Another method is by use of nomographs such as H. O. Misc. 15530–1 through 15530–6, Nomographs for Determination of Density from Salinity and Temperature of Sea Water. This set of 6 nomographs covers salinity ranges from 0 °/₀₀ to 42 °/₀₀. A sample is shown in figure 14–7.

14–138 Determining *σt*.—The *σt* is determined from the nomograph by laying a straightedge across the given temperature (21.33° C.) on the right and the given salinity (35.79°/₀₀) on the left, and reading the desired density (25.03) from the *σt* column that is marked with the same symbol (a square in this example) as the temperature column used. Density (*σt*) is always recorded on the log sheet to two decimal places.

14–139 O_2 ml/l.—The amount of dissolved oxygen, in milliliters per liter, is obtained from the column of the same heading in the C-sheet. Be sure that the values agree with their corresponding serial numbers, line for line.

14–140 Blank Columns.—Two blank columns are provided for recording any other observed values that may be determined from the sea water samples. These may include pH, phosphates, silicates, nitrates, etc. Indicate in the column head the type of determination recorded and the units used. Example: SiO_2, mg–A/L.

14–141 PLOTTING OBSERVED VALUES ON GRAPHS.—After the Observed Values have been recorded on the log sheet, they are plotted against depth in meters on graph paper. H. O. Misc. 12,252–A, Oceanographic Station Plotting Sheet, provides for plotting temperatures, salinities, densities, and dissolved oxygen values against the accepted depths. In the event the ranges of the station's Observed Values exceed those given on this sheet, any good graph paper, of the scale of 10 x 10 to the ½ inch, may be used. Detailed instructions for plotting graphs are given in chapter 4.

14–142 Std. Depth.—By international agreement, certain specified depths, in meters below the surface, were selected and designated as Standard Depths. All physical oceanographic values are adjusted to these standard depths. The standard depths are: surface, 10, 20, 30, 50, 75, 100, 150, 200 (250), 300, 400, 500, 600, (700), 800, 1,000, 1,200, 1,500, 2,000, 2,500, 3,000, 4,000, and thereafter every 1,000 meters to the bottom. The depths in parentheses are optional.

14–143 *T°C*.—From the graph constructed with the Observed Values, read the temperature for each standard depth and record the value in this column.

14–144 Salinity °/₀₀.—From the graph constructed with the Observed Values, read the salinity for each standard depth and record the value in this column.

14–145 *σt*.—From the graph constructed with the Observed Values, read the *σt* for each standard depth and record the value in this column. As each density is determined, check the value by taking the standard depth temperature and salinity and obtain the density by table or nomograph as was done for the Observed Values for density. This value should agree with the density as determined by the plotted graph. Thus, if any Observed Value is incorrectly plotted, or standard depth value misread, the error may be caught.

14–146 DYNAMIC CALCULATIONS COLUMNS.—The dynamic calculations columns are used for the determination of dynamic height anomalies. The dynamic height anomalies are used for computing oceanic currents.

14–147 *δ*.—This column is used for recording the value of the Specific Volume Anomaly. The Specific Volume Anomaly is determined, for this log sheet, by means of nomographs. Another method, using tables, is given in H. O. Pub. No. 614, "Processing Oceanographic Data." The nomographs used with this log sheet are: H. O. Misc. 15,078—A & B. Pressure Correction to Specific Volume Anomaly, and H. O. Misc. 15,078–1 through 12, Specific Volume Anomaly Diagrams.

14–148 HOW TO USE THE SPECIFIC VOLUME ANOMALY DIAGRAMS.—To find the Specific Volume Anomaly (*δ*) the depth, temperature, and salinity must be known. In these instructions, the following values are used for the example:

Depth: 2,000 meters.
T° C.: 3.50.
S°/₀₀: 34.94.
Find: *δ*.

350676 O—56——11

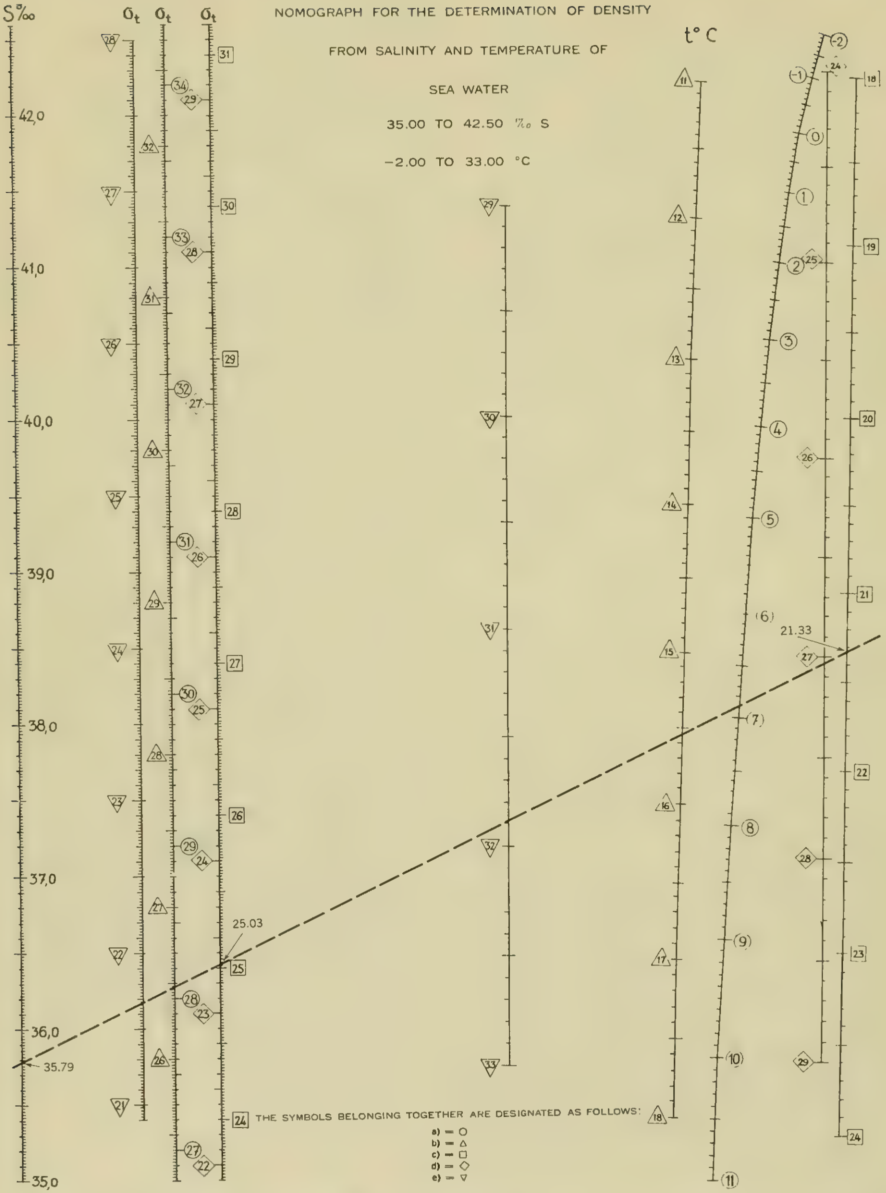

Figure 14–7. H. O. Misc. 15530–6, nomograph for the determination of density from salinity and temperature of sea water.

OCEANOGRAPHIC LOG SHEET - GEK I
PRNC-NHO-1336 (Rev. 7-53)

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

ELECTROMAGNETIC CURRENT OBSERVATIONS
For use with H.O. Pub. No. 607

VESSEL	SURFACE GEOMAGNETIC ELECTRO-KINETOGRAPH NO.	CHECKED BY	
USS REHOBOTH (AGS-50)	GEK MOD. V	G. HAMMOND	*Specify algebraic signs and units of all measurements. The more distant electrode should be connected to the positive input terminal. Consult H.O. Chart No. 1702 for local value of H_z and set recorder scale to value of nearest standard isodynamic line.*
CRUISE		DATE CHECKED	
RE-15		29 AUGUST 1955	

GEK SERIAL NO.	DATE *(Day, Month, Year)*	HOUR *(GMT)*	VERTICAL MAGNETIC INTENSITY *(Milliorsteds)* STAND. I	LOCAL II	WAVE SIGNAL SUPP. *(C-Units)*	INITIAL BASE-COURSE DIR. (°T) III	SIG. (cm./sec.) IV	FIRST FIX-COURSE DIR. (°T) V	SIG. (cm./sec.) VI	SECOND FIX-COURSE DIR. (°T) VII	SIG. (cm./sec.) VIII	RESUMED BASE-COURSE DIR. (°T) IX	SIG. (cm./sec.) X	DEPTH OF WATER (~~m.~~, fm.)	POSITION OF CURRENT FIX LATITUDE (N.S.)	LONGITUDE (E.W.)	SHIP'S AVERAGE SPEED (Knots, ~~m/sec.~~)	OBS. INIT.
1	13 AUG 55	0354	.5	.52	0	138	$\overline{5}$	228	$\overline{75}$	048	$\overline{50}$	138	−1	1480	39° 06' N	71° 15' W	13.5	AB
2	13 AUG 55	1647	.5	.51	0	030	30	120	$\overline{122}$	300	60	030	32	2550	37° 22' N	70° 27' W	13.5	AB
3	14 AUG 55	0245	.5	.51	0	050	$\overline{15}$	140	$\overline{153}$	320	145	050	$\overline{15}$	2590	35° 11' N	70° 15' W	13.5	WHL
4	14 AUG 55	1246	.5	.51	0	180	45	270	53	090	41	180	51	2500	35° 58' N	70° 11' W	13.5	AB
5	15 AUG 55	0046	.5	.51	0	015	75	105	$\overline{65}$	285	85	015	40	2550	36° 13' N	70° 06' W	13.5	RLW
6	26 AUG 55	1044	.5	.51	4	090	$\overline{20}$	180	$\overline{85}$	000	122	090	$\overline{25}$	2450	44° 27' N	30° 16' W	13.5	AB
7	26 AUG 55	1345	.5	.49	4	010	25	100	38	280	$\overline{10}$	010	17	2550	44° 27' N	30° 25' W	13.5	WHL
8	27 AUG 55	1420	.5	.48	8	034	$\overline{147}$	124	$\overline{157}$	304	$\overline{149}$	034	$\overline{149}$	1350	43° 58' N	29° 42' W	12.0	AB

350676 O—56 (Face p. 151)

NAVY-DPPO PRNC, WASH., D.C.

Figure 14–8. Oceanographic log sheet GEK 1.

(*a*) *Step 1.*—Using a pair of dividers, enter Sheet A (H. O. Misc. 15,078–A, Pressure Correction to Specific Volume Anomaly), on the vertical line for depth (2,000 meters), placing one point of the dividers on the 35.00 ‰ salinity line and the other point on the 0° C. temperature line. These two lines are parallel.

(*b*) *Step 2.*—Next, without changing the spacing of the dividers, move them up the 2,000-meter line until the lower point is at the given salinity (34.94). The upper point now will be slightly above the 0° C. line.

(*c*) *Step 3.*—Pivot the dividers on the upper point, swinging the lower point around to the 2,000-meter line and placing it on the given temperature (3.50°). The space between the points is the total correction for temperature, pressure, and salinity for the unknown Specific Volume Anomaly (δ).

(*d*) *Step 4.*—Select the Specific Volume Anomaly diagram having the proper combination of temperature and salinity. In this case, it is Sheet 9 (H. O. Misc. 15,078–9).

(*e*) *Step 5.*—Without changing the correction spacing of the dividers, enter the sheet at the given salinity (34.94) and move up that vertical line until the lower point of the dividers is at the given temperature (3.50°).

(*f*) *Step 6.*—With the lower point of the dividers at the intersection of the given temperature and salinity, place the upper point along the vertical salinity line and read the Specific Volume Anomaly (δ) along the nearest horizontal line. In this case, the reading is +47.

(*g*) *Step 7.*—Record this value in the δ column of the log sheet for the 2,000-meter depth. The above steps must be repeated for each standard depth of the station.

14–149 Mean δ.—The mean value of the Specific Volume Anomaly, δ, between each two successive depths, is computed from the values given in the δ column, and recorded in this column.

14–150 ΔD.—The ΔD is the anomaly of dynamic depth for each layer in dynamic meters. This is obtained by multiplying the Mean δ by the difference in standard depth between the successive samples. The latter value is called the pressure interval.

NOTE.—The values recorded in the δ and Mean δ columns are abbreviated. The actual value for +47, in the above example, is 0.00047. Thus, the correct ΔD, to 4 decimal places, is obtained as follows: ΔD= 0.00001 (Mean δ) (pressure interval).

14–151 $\Sigma\Delta D$.—This column contains the cumulative sum of the anomalies of dynamic depth of the layers above, as given in the ΔD column. The $\Sigma\Delta D$ for the surface is always 0.0000 and is printed so in the first line of the column.

Record the first value from the ΔD column on the second line of the $\Sigma\Delta D$ column; add the second value in the ΔD column to this and record the sum on the third line of the $\Sigma\Delta D$ column. Continue adding successive ΔD values to this cumulative sum on down the column.

14–152 O_2**ml./l.**—From the graph constructed with the Observed Values, read the dissolved oxygen content for each standard depth and record the value in this column.

14–153 Blank Columns.—The two blank columns are provided to record the values, at standard depths, of any observations which may be given in the blank columns under Observed Values.

OCEANOGRAPHIC LOG SHEET GEK 1, PRNC–NHO–1336 (Rev. 7–53)

ELECTROMAGNETIC CURRENT OBSERVATIONS

14–154 GENERAL REMARKS.—The GEK-1 sheet is used to record surface current data obtained with the Geomagnetic Electrokinetograph (GEK). Instructions for operating the GEK are given in chapter 9. Study those instructions carefully before using this log sheet.

14–155 THE LOG SHEET.—A sample log sheet is shown in figure 14–8. Print all entries accurately and neatly.

14–156 The Log Sheet Headings.—Fill in the ship's name and number, cruise name and number, and the GEK instrument number in the proper spaces.

14–157 The Log Sheet Columns.—The log sheet columns are filled in accordance with instructions given below. One line is used for each current fix.

14–158 GEK Serial No.—Record the consecutive number for each current fix, commencing with the numeral 1 for the first fix of each cruise.

14–159 Date.—Give the day, month, and year. Abbreviate the month by using the first three letters. Use the last two digits of the year. The change of date is determined by Greenwich mean time (GMT).

14–160 Hour.—Record the hour and minute for the beginning of the current fix; i. e., the start of the 4-minute run on the initial base course. Use Greenwich mean time (GMT).

14–161 Vertical Magnetic Intensity.—The vertical magnetic intensity is the value of the nearest standard isodynamic line as indicated by H. O. Chart 1702, The Vertical Intensity of the Earth's Magnetic Force, for the approximate position of the current fix.

(*a*) *Stand.* (I).—The H_z dial setting of the GEK at the time of the current fix is recorded in this column.

(*b*) *Local.* (II).—The standard isodynamic value for the position of the current fix is recorded in this column. Record this value to the nearest 0.005 oersted.

14–162 Wave Signal Supp.—The wave signal suppression is the record of the total amount (in C units) of wave supression in use during the current fix. This is indicated by the setting of the filter resistance dial on the GEK. This value is also recorded on the GEK recorder chart.

14–163 Initial Base Course.—The initial base course is that course the ship is steering prior to the first course change of the current fix. The direction (III) is recorded in degrees true. The signal (IV) is recorded in centimeters per second and is obtained from the trace on the GEK recorder chart during the four minutes prior to the first course change.

14–164 First Fix Course.—The direction (V) of the first fix course is the first course change from the base course. It is 90° to the right, or left, of the base course. Record the time of the course change on the GEK recorder chart. The signal (VI) is that indicated by the trace.

14–165 Second Fix Course.—The direction (VII) of the second fix course is the second course change from the base course. It is 180° from the first fix course, with the turn being made in the direction of the base course. Record the time of the course change on the GEK recorder chart. The signal (VIII) is that indicated by the trace.

14–166 Resumed Base Course.—The direction (IX) of the resumed base course is the same as the initial base course. It is 90° to the right, or left, of the second fix course. The signal (X) is that indicated by the trace during the first 4 minutes after the electrodes have steadied on the base course.

14–167 Depth of Water.—Record in fathoms the sonic depth of the water at the time of the current fix.

14–168 Position of Current Fix.—Record the corrected ship's position for the time at the beginning of the current fix. Latitude and longitude are recorded in degrees and minutes. Be sure to indicate whether N or S latitude and E or W longitude.

14–169 Ship's Average Speed.—Record the ship's average speed, in knots, during the current fix.

14–170 Observer's Initials.—The observer logging the current fix should initial both the log sheet and the GEK recorder chart.

14–171 Remarks.—Use a whole line, or lines, under the current fix data to note any remarks that may be of help in later analysis of the data.

OCEANOGRAPHIC LOG SHEET GEK 2, PRNC–NHO–1336a (Rev. 6–54)

ELECTROMAGNETIC CURRENT COMPUTATIONS

14–172 GENERAL REMARKS.—The GEK-2 sheet is used to record computations from surface current data given on the GEK-1 sheet. Instructions for operating the GEK are given in chapter 9. Study those instructions carefully before using this log sheet.

14–173 THE LOG SHEET.—A sample log sheet is shown in figure 14–9. Print all entries accurately and neatly.

14–174 The Log Sheet Headings.—Fill in the ship's name and number, cruise name and number, and the GEK instrument number in the proper spaces.

14–175 The Log Sheet Columns.—The log sheet columns are filled in accordance with instructions given below. One line is used for each current fix.

14–176 GEK Serial No.—Obtain the GEK serial number from the corresponding line on oceanographic log sheet GEK 1.

14–177 Greenwich Mean Time.—Obtain the Greenwich mean time for the day, month, and hour from the corresponding line on the GEK-1 sheet.

14–178 Position of Current Fix.—Obtain in the corrected latitude and longitude from the corresponding line on GEK-1 sheet.

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OCEANOGRAPHIC LOG SHEET - GEK2
PRNC-NHO-1336A (REV. 6-54)

ELECTROMAGNETIC CURRENT COMPUTATIONS
For use with H.O. Pub. No. 607

VESSEL	CRUISE	YEAR	COMPUTED BY	DATE	CHECKED BY	DATE
USS REHOBOTH (AGS-50)	RE-15	1955	S. W. Oliver	29 Aug. 55	GEO. HAMMOND	30 AUG. 55

GEK SERIAL NO.	GREENWICH MEAN TIME			POSITION OF CURRENT FIX		ZERO POINT	AVERAGE BASE-COURSE SIGNAL		AVERAGE FIX-COURSE SIGNAL		RESULTANT SIGNAL VECTOR		CORRECTION TO STANDARD ISODYNAMIC LINE	CURRENT VELOCITY		
	DAY	MONTH	HOUR	LATITUDE	LONGITUDE		MAG.	DIR.	MAG.	DIR.	MAG.	DIR.		SPEED		DIR.
				(N or S)	(E or W)	Cm./Sec. (XI)	Cm./Sec. (XII)	(°T) (XIII)	Cm./Sec. (XIV)	(°T) (XV)	Cm./Sec. (XVI)	(°T) (XVII)	(Multiplier) (XVIII)	Cm./Sec. (XIX)	(Knots) (XX)	(°T) (XXI)
1	13	8	04	39°06'N	71°15'W	$\overline{62}$	59	138	12	048	60	126	1.00	60	1.17	216
2	13	8	17	37°22'N	70°27'W	$\overline{31}$	62	030	91	300	111	334	1.02	113	2.20	064
3	14	8	03	36°51'N	70°35'W	$\overline{4}$	11	230	149	320	149	316	1.02	152	2.95	046
4	14	8	13	35°54'N	70°11'W	47	1	000	4	270	4	282	1.02	4	0.08	012
5	15	8	01	36°14'N	70°06'W	10	47	015	75	285	90	318	1.02	92	1.79	048
6	26	8	11	44°41'N	30°16'W	18	40	270	104	000	112	339	1.02	114	2.21	069
7	26	8	14	44°27'N	30°21'W	14	7	010	24	100	25	081	1.06	26	0.51	171
8	27	8	14	43°58'N	29°42'W	$\overline{153}$	5	034	4	304	6	355	1.08	6	0.12	085

EQUATIONS

For (I) through (X) see Log Sheet - GEK 1.

XI = ½ (VI + VIII)

Y = ½ (IV + X) − XI

XII = |Y|

XIII = III if Y ≥ 0
or = III ± 180° if Y ≤ 0

XIV = |VI − XI|

XV = V if VI ≥ VIII
or = VII if VI ≤ VIII

*XVI = $\sqrt{XII^2 + XIV^2}$

*tanA = XIV/XII

*XVII = XIII + A
If XIII + 90° = XV
or
*XVII = XIII − A
if XIII − 90° = XV

**May be computed on Mark 3a Plotting Board*

XVIII = 1.04 x I/II

XIX = XVIII x XVI

XX = .0194 x XIX

XXI = XVII + 90°
if II > 0
or
XXI = XVII − 90°
if II < 0

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Figure 14–9. Oceanographic log sheet GEK 2.

OCEANOGRAPHIC LOG SHEET – L
PRNC-NHO-1364 (NEW 8-52)

HYDROGRAPHIC OFFICE

VESSEL	DATE	LATITUDE	OBSERVERS	STATION NO.
YF-876	27 March 1955	28°50'30" N	D. Tidrick	A 47 e

AREA	TIME	TIME ZONE	LONGITUDE	COMPUTED BY	CHECKED BY
Gulf Coast	0930	+6	89°25'50" W	C. S. Janifer	W. R. Seeber

SERIAL NUMBER	NANSEN NO.	WIRE DEPTH	WIRE ∠	THERM. NO.	T	t	t^1	V_0	I	ΔT	T_c	SAL.	σt	SECCHI DISC BLACK	SECCHI DISC WHITE	REMARKS
113	3	0	5°	28013	28.3	29.1						34.2		9'	23'	
				28027	28.3	29.0										
114	9	26'		42-070	27.9	29.2						34.1				
				43-196	28.0	29.1										
115	13	48'		28030	27.5	29.0						28.9				
				28033	27.5	29.0										

REMARKS	WIND			WAVES								
				SEA					SWELL			
	DIR. dd	SPEED ff	ELEV. E	SEA S	HEIGHT H_wH_w	PERIOD P_wP_w	LENGTH $L_wL_wL_w$	DIRECTION d_wd_w	HEIGHT H_wH_w	PERIOD P_wP_w	LENGTH $L_wL_wL_w$	DIRECTION d_wd_w
	090	02	1	2	02	03	060	22	09	12	030	18

dd OR d_wd_w DIRECTION

00-Calm	20-SSW
02-NNE	23-SW
05-NE	25-WSW
07-ENE	27-W
09-E	29-WNW
11-ESE	32-NW
14-SE	34-NNW
16-SSE	36-N
18-S	

E – ELEVATION OF ANEMOMETER

0 - 0 - 9 feet
1 - 10 - 19 Feet
2 - 20 - 29 feet
3 - 30 - 39 feet
4 - 40 - 49 feet
5 - 50 - 69 feet
6 - 70 - 89 feet
7 - 90 - 130 feet
8 - Above 130 feet
9 - Reported in Beaufort Scale

H_wH_w – HEIGHT

(Height of the Significant Wind, Waves or Swell)

Report height in feet using two figures. For example, a 5-foot wave is reported as 05.

P_wP_w – PERIOD

(Period of the Significant Wind, Waves or Swell)

Report period in seconds using two figures. For example, a 6-second wave is reported as 06.

$L_wL_wL_w$ – LENGTH

(Length of the Significant Wind, Waves, or Swell)

Report length to nearest 10 feet, using three figures, with final zero omitted. For example, a 50-foot wave length is reported 005, a 210-foot wave length is reported 021, etc.
If observations are made to nearest foot, drop final figure if less than 5, and add one to 10's figure if 5 or more. For example, a 63-foot wave length is reported 006, a 155-foot wave length is reported 016, etc.

ff – WIND SPEED

Report speed in knots using two figures. Use the Beaufort Scale below when no anemometer is available.

		BEAUFORT
Calm	Less than 1 knot	00
Light airs	1-3	01
Light breeze	4-6	02
Gentle breeze	7-10	03
Moderate breeze	11-16	04
Fresh breeze	17-21	05
Strong breeze	22-27	06
Moderate gale	28-33	07
Fresh gale	34-40	08
Strong gale	41-47	09
Whole gale	48-55	10
Storm	56-63	11
Hurricane	64 and above	12

S – SEA CONDITION

0 - Calm
1 - Smooth
2 - Slight
3 - Moderate
4 - Rough
5 - Very Rough
6 - High
7 - Very High
8 - Mountainous
9 - Confused

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350676 O—56 (Face p. 153)

Figure 14–10. Oceanographic log sheet L.

14–179 Zero Point (XI).—The zero point is determined by averaging the sum of columns VI and VIII of GEK-1 sheet.

14–180 Average Base-Course Signal Magnitude (XII).—This quantity is determined by first computing the auxiliary quantity Y, which is one-half the sum of columns IV and X minus column XI. Y of course may be a negative number. XII is the absolute (positive numerical) value of Y.

14–181 Average Base-Course Signal Direction (XIII).—This quantity is the same as that in column III, if Y (section 14–180) is positive or zero. If Y is negative or zero, then it becomes column III $\pm 180°$ (whichever leads to an angle between 0° and 360°).

14–182 Average Fix-Course Signal Magnitude (XIV).—This quantity is determined by subtracting column XI from column VI and taking the absolute (the positive numerical) value of the result.

14–183 Average Fix-Course Signal Direction (XV).—This quantity (1) is the same as column V if column VI is algebraically greater than or equal to column VIII; or (2) it is the same as column VII if column VI is algebraically less than or equal to column VIII. *Remember that* -5 *is less than* -2, *and that* -2 *is greater than* -5.

14–184 Resultant Signal Vector Magnitude (XVI).—This quantity is the positive square root of the sum of the squares of the Average Base-Course Signal Magnitude (XII) and the Average Fix-Course Signal Magnitude (XIV).

14–185 Resultant Signal Vector Direction (XVII).—The auxiliary angle A must first be determined. Divide the Average Fix-Course Signal Magnitude (XII) by the Average Base-Course Signal Magnitude (XIV). The result is the tangent of A. From a tangent table tabulated in 1-degree increments (3-decimal accuracy is adequate) find the angle A, to the nearest degree, whose tangent is the above quotient. Angle A is added to the Average Base-Course Signal Direction (XIII) if column XV is 90° greater than column XIII. Angle A is subtracted from XIII if column XV is 90° less than XIII. This value is the resultant signal vector direction (XVII).

14–186 Alternate Method for Determining the Resultant Signal Vector Direction.—The average base and fix course vectors may be plotted on a Mark 3A Plotting Board or on any vector plotting paper, and the resultant signal vector determined graphically by the completion of the parallelogram method.

14–187 Correction to Standard Isodynamic Line (XVIII).—This quantity is 1.04 multiplied by the quotient of the Standard Vertical Magnetic Intensity (I) divided by the Local Magnetic Intensity (II), which are given on GEK-1 sheet.

14–188 Current Velocity Speed in cm./sec. (XIX).—This is the Correction to Standard Isodynamic Line (XVIII) multiplied by the Resultant Signal Vector Magnitude (XVI).

14–189 Current Velocity Speed in Knots (XX).—To obtain the current velocity in knots, multiply the Current Velocity Speed in cm./sec. (XIX) by 0.0194.

14–190 Current Velocity Direction (XXI).—To obtain the current velocity direction in degrees true, add 90° to the Resultant Signal Vector Direction (XVII) when in the northern magnetic hemisphere. Subtract 90° from the Resultant Signal Vector Direction when in the southern magnetic hemisphere.

OCEANOGRAPHIC LOG SHEET L, PRNC–NHO–1364 (New 8–52)

INSHORE SURVEY STATION SHEET

14–191 GENERAL REMARKS.—The L-sheet is used only for special inshore area surveys. It is a station log sheet for temperature, salinity, density, wind, sea and swell, and Secchi disc observations. This log sheet, combines some of the features of the A-, D-, and E-sheets, and the Shipboard Wave Observation Log. It is used only when instructions for a cruise specifically so state.

14–192 THE LOG SHEET.—A sample log sheet is shown in figure 14–10. Print all entries accurately and neatly.

14–193 The Log Sheet Headings.—Entries in the log sheet headings are made as given below.

14–194 Vessel.—Give the name and number of the ship on each sheet.

14–195 Area.—Give the name of the area under investigation; e. g. Nantucket Sound, Raritan Bay, etc.

14–196 Date.—Enter the day, month, and year.

14–197 Time.—Enter the hour and minute for the start of the station. Use local time and indicate the time zone.

14–198 Latitude and Longitude.—Record the latitude and longitude in degrees, minutes, and seconds. Indicate whether north or south, east or west. Record at the start of the station.

14–199 Station Number.—A number shall be used to designate each station. Start with 1 and number consecutively. Do not use letter designations. Enter the number in the space designated Station No.

For those special stations that will be occupied every day, week, or month, or at any other series of regular intervals, assign a number the first time the station is occupied and retain that number. For all succeeding regular observations, the number shall have a letter suffix without an intervening hyphen, i. e., 10A. If a special station in such a series should be occupied by chance and not at the regular established time, assign a new number instead of adding a letter to the series.

14–200 Observers.—Enter the name of the oceanographic observer in this space.

14–201 Depth.—Obtain the depth of the water from the sonic sounder at the time of the first Nansen bottle cast and enter it in the first line of the Remarks column. Record the depth in feet.

14–202 THE LOG SHEET COLUMNS.—The log sheet columns are completed in accordance with the instructions given below.

14–203 Serial Number.—The serial number is composed of the station number followed by a number indicating the depth of the Nansen bottle or thermometer frame in feet. The number shall be separated by a hyphen, i. e., 12–0, 12–3, etc. For the special stations, the serial number is similar, i. e., 11A–0, 11A–6, etc.

14–204 Nansen Bottle Number.—Record in this column the number of each Nansen bottle or thermometer frame used during each cast.

14–205 Wire Depth.—Enter the depths in feet measured along the wire from the sea surface to the depth of each bottle.

14–206 Wire Angle.—Determine the angle of the wire from the vertical immediately after the messenger is dropped to trip the bottles or frames.

14–207 Therm. No.—The thermometer number is the manufacturer's serial number usually found inside the reversing thermometer case on the metal band supporting the main and auxiliary thermometers. This number must be recorded carefully as it is the only means of identifying each thermometer. When reading the thermometers, check carefully to ensure that the thermometers on the Nansen bottle or frames agree in number with those listed on the log sheet.

14–208 T.—The readings of the *main* thermometers are recorded in degrees and hundreths.

14–209 t.—The readings of the auxiliary thermometers are recorded in degrees and tenths.

14–210 t′.—Record the corrected readings of the auxiliary thermometers. The corrections applied to the readings (t) are obtained from the thermometer calibration sheets.

14–211 V_0.—The V_0 is the volume of mercury below the 0° C. mark at 0° C. in the reversed main thermometer, expressed in degrees. This value is obtained from the thermometer calibration sheets.

14–212 I.—The index correction for errors in the main thermometer scale is obtained from the thermometer calibration sheet. It is read for the temperature of reversal, or as close thereto as the table of calibration will permit.

14–213 ΔT.—The correction for the thermal expansion of the thermometer system after reversal is computed from the formulas and methods discussed in chapter 3. This value is the same as C, as defined in chapter 3.

14–214 Tc.—The corrected reading of the protected reversing thermometer is obtained by adding algebraically the values given in the T, I, and ΔT columns.

14–215 Sal.—The salinity of the water, in parts per thousand, is obtained from the D-sheet.

14–216 σt.—This value gives, in abbreviated form, the density of the water samples at atmospheric pressure. See sections 14–137 and 14–138 for more detailed instructions.

14–217 Secchi Disc.—There are two colums under this heading, one for black and one for white Secchi Disc observations. Lower each disc until it is barely visible, note the depth, then lower until out of sight. Raise the disc until it is again visible, and note the depths. Record the mean of the two depths, in feet, in the column for each disc. See chapter 12.

14–218 Wind and Waves.—Record the data for wind and waves using the codes given at

OCEANOGRAPHIC LOG SHEET - M
BOTTOM SEDIMENT DATA
PRNC-NHO-1365 (NEW 8-52)

HYDROGRAPHIC OFFICE

VESSEL	CRUISE		CHECKED BY	DATE CHECKED
USS REHOBOTH (AGS-50)	RE-15	1955	A.W. Anderson	30 Aug. 55

SERIAL NO.	DATE	SAMPLE POSITION		DEPTH (Fathoms)	WEIGHT OF SAMPLER	APPROX. PENE-TRATION	LENGTH OF TUBE	LENGTH OF CORE	FIELD DESCRIPTION	REMARKS (Unusual conditions, cohesiveness, dented cutter, free fall, stat. no., trigger core no., date extruded, disposition, etc.)	OBS. INIT.
		LATITUDE	LONGITUDE								
798	20 Aug	40°25'N	17°26'W	2600	1200#	20 FT.	22 FT.	17'3"	Ewing Core No. 3	12 ft. free fall	BJC
827	22 Aug	40°27'N	18°57'W	3400	125#	15 IN.	18 IN.	10 IN	Underwater Camera No. 12	gray ooze	KC
845	26 Aug	41°15'N	22°27'W	1782	80#	2 FT.	2 FT.	1'8"	Phleger Core No. 16	gray white	WB
864	27 Aug	43°30'N	29°39'W	1280	80#	3'2"	4 FT.	2'6"	Phleger Core No. 17	light brown	WB

Use more than one line per sample if necessary.

NAVY-DPPO PRNC, WASH., D.C.

Figure 14–11. Oceanographic log sheet M.

the bottom of the log sheet. In reporting the directions of sea and swell, be sure to indicate the direction from which the waves are coming. Make the observations as soon as possible while on station. Space is provided for remarks; enter here whether waves are long- or short-crested and note any reflecting waves, confusion, or glassy surface of the sea. For complete instructions see H. O. Pub. No. 606–e, Sea and Swell Observations.

OCEANOGRAPHIC LOG SHEET M, PRNC–NHO–1365
(New 8–52)

BOTTOM SEDIMENT DATA

14–219 GENERAL REMARKS.—The M-sheet is used to record all types of bottom sediment samples obtained during a cruise. This sheet may be used for any type of bottom sampling device. Indicate the type of instrument used in the Remarks column. Instructions for operating several types of bottom sampling instruments are given in chapter 6. Study those instructions carefully before using this log sheet.

14–220 THE LOG SHEETS.—A sample log sheet is shown in figure 14–11. Print all entries accurately and neatly.

14–221 The Log Sheet Headings.—Fill in the ship's name and number, and cruise name and number in the proper spaces.

14–222 The Log Sheet Columns.—The log sheet columns are completed in accordance with the instructions given below. Use more than one line per sample if necessary. If there is not enough space for remarks, etc., write them across the columns using one or more lines.

14–223 Serial No.—Record the designated serial number for each sample as taken.

14–224 Date.—Record the day and month. Record the hour and minute the sample is obtained on the same line above the date. Use Greenwich mean time to determine the time and date.

14–225 Sample Position.—Record the corrected ship's position for the time the sample is obtained. Latitude and longitude are recorded in degrees and minutes unless greater accuracy is required for special area surveys. Indicate whether N or S latitude and E or W longitude.

14–226 Depth.—Record the depth in fathoms at the time the sample is obtained.

14–227 Weight of Sampler.—Indicate the weight of the sampler used in pounds.

14–228 Approximate Penetration.—This column is used when samples are obtained with coring devices. Penetration of the corer is measured in feet and inches. As soon as the corer is secured on deck, measure the amount of sediment retained on the outside of the coring tube from the end of the cutting edge to the top of the visible sediment.

14–229 Length of Tube.—This column is used when samples are obtained with coring devices. For corers with plastic liners the length of the tube is the length of the liner plus the cutting edge. For Ewing piston corers, it is the length measured from cutting edge to top of core tube. Record the length in feet and inches.

14–230 Length of Core.—Measure the length of the core obtained from the cutting edge to the top of the sediment. Record the length in feet and inches.

14–231 Field Description.—Enter a field description of the sample when required. Description of materials, stratification, coarseness, and colors are desired. When color is given, it should be obtained from comparison with the Rock-Color Chart of the Geological Society of America.

14–232 Remarks.—Enter in the Remarks column any pertinent information necessary for future identification of the sample. Give the station number; type of instrument used; length of free fall; condition of cutting edge; date extruded; type of container used for disposition of sample from cutting edge and core catcher, scoopfish, snapper, dredge, etc. Whenever a core is extruded, record the date of extrusion and give the number of the box in which the core is stored.

14–233 Observer's Initials.—The initials of the person concerned with obtaining and preparing the sample should be entered in this column.

SHIPBOARD WAVE OBSERVATION LOG, PRNC–NHO–1192 (REV. 12–51)

14–234 GENERAL REMARKS.—The Shipboard Wave Observation Log is used to record visual sea and swell observations at sea. Complete instructions for using this log sheet are given in H. O. Pub. No. 606–e, Sea and Swell Observations.

14–235 THE LOG SHEET.—A sample log sheet is shown in figure 14–12.

SHIP ICE LOG, H. O. MISC. 15584 (REV. 1–55)

14–236 GENERAL REMARKS.—The Ship Ice Log is used to code visual ice observations by shipboard observers. Complete instructions for using this log sheet are given in H. O. Pub. No. 606–d, Ice Observations.

14–237 THE LOG SHEET.—A sample log sheet is shown in figure 14–13.

SHIPBOARD WAVE OBSERVATION LOG
PRNC-NHO-1192 (Rev. 12-51)

Refer to H.O. Pub. No. 606e for instructions in use of this form.

SHIP

Return to: U.S. Navy Hydrographic Office
Division of Oceanography, Code 40
Washington 25, D. C.

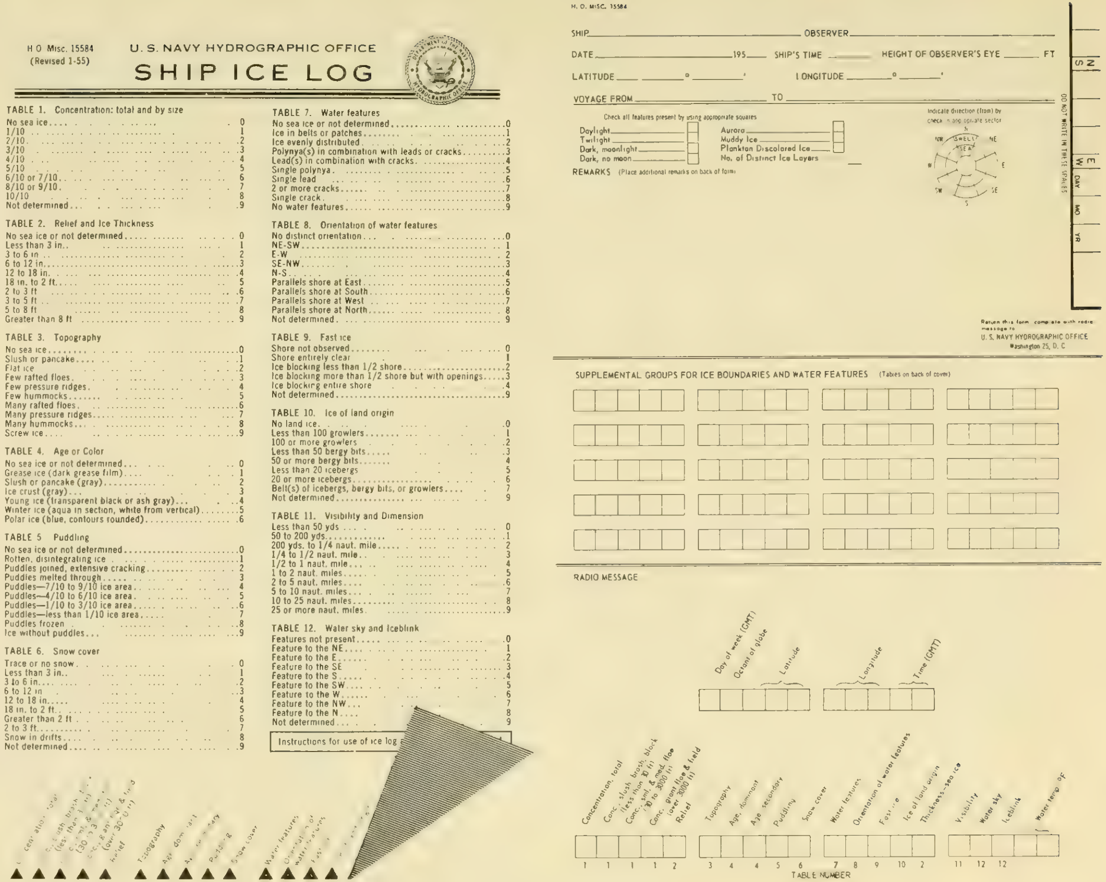
LOCATION							WIND			WIND WAVES (SEA)					SWELL					SWELL					REMARKS	OBS. INITIAL
MO.	DAY	YR.	OCT.	LAT.	LONG.	TIME	DIR.	SPEED	ELEV.	SEA	DIR.	HEIGHT	PERIOD	LENGTH		DIR.	HEIGHT	PERIOD	LENGTH		DIR.	HEIGHT	PERIOD	LENGTH		
MM	dd	yy	Q	$L_aL_aL_a$	$L_oL_oL_o$	GG	dd	ff	E	S	d_wd_w	H_wH_w	P_wP_w	$L_wL_wL_w$	X	d_wd_w	H_wH_w	P_wP_w	$L_wL_wL_w$	X	d_wd_w	H_wH_w	P_wP_w	$L_wL_wL_w$		

See reverse side for explanation of columns.

NAVY-DPPO PRNC, WASH., D.C.

Figure 14–12. Shipboard wave observation log.

350676 O—56 (Face p. 156)



H O Misc. 15584
(Revised 1-55)

U. S. NAVY HYDROGRAPHIC OFFICE

SHIP ICE LOG

TABLE 1. Concentration: total and by size	
No sea ice	0
1/10	1
2/10	2
3/10	3
4/10	4
5/10	5
6/10 or 7/10	6
8/10 or 9/10	7
10/10	8
Not determined	9

TABLE 2. Relief and Ice Thickness	
No sea ice or not determined	0
Less than 3 in.	1
3 to 6 in	2
6 to 12 in	3
12 to 18 in	4
18 in. to 2 ft	5
2 to 3 ft	6
3 to 5 ft	7
5 to 8 ft	8
Greater than 8 ft	9

TABLE 3. Topography	
No sea ice	0
Slush or pancake	1
Flat ice	2
Few rafted floes	3
Few pressure ridges	4
Few hummocks	5
Many rafted floes	6
Many pressure ridges	7
Many hummocks	8
Screw ice	9

TABLE 4. Age or Color	
No sea ice or not determined	0
Grease ice (dark grease film)	1
Slush or pancake (gray)	2
Ice crust (gray)	3
Young ice (transparent black or ash gray)	4
Winter ice (aqua in section, white from vertical)	5
Polar ice (blue, contours rounded)	6

TABLE 5 Puddling	
No sea ice or not determined	0
Rotten, disintegrating ice	1
Puddles joined, extensive cracking	2
Puddles melted through	3
Puddles—7/10 to 9/10 ice area	4
Puddles—4/10 to 6/10 ice area	5
Puddles—1/10 to 3/10 ice area	6
Puddles—less than 1/10 ice area	7
Puddles frozen	8
Ice without puddles	9

TABLE 6. Snow cover	
Trace or no snow	0
Less than 3 in.	1
3 to 6 in	2
6 to 12 in	3
12 to 18 in	4
18 in. to 2 ft	5
Greater than 2 ft	6
2 to 3 ft	7
Snow in drifts	8
Not determined	9

TABLE 7. Water features	
No sea ice or not determined	0
Ice in belts or patches	1
Ice evenly distributed	2
Polynya(s) in combination with leads or cracks	3
Lead(s) in combination with cracks	4
Single polynya	5
Single lead	6
2 or more cracks	7
Single crack	8
No water features	9

TABLE 8. Orientation of water features	
No distinct orientation	0
NE-SW	1
E-W	2
SE-NW	3
N-S	4
Parallels shore at East	5
Parallels shore at South	6
Parallels shore at West	7
Parallels shore at North	8
Not determined	9

TABLE 9. Fast ice	
Shore not observed	0
Shore entirely clear	1
Ice blocking less than 1/2 shore	2
Ice blocking more than 1/2 shore but with openings	3
Ice blocking entire shore	4
Not determined	9

TABLE 10. Ice of land origin	
No land ice	0
Less than 100 growlers	1
100 or more growlers	2
Less than 50 bergy bits	3
50 or more bergy bits	4
Less than 20 icebergs	5
20 or more icebergs	6
Belt(s) of icebergs, bergy bits, or growlers	7
Not determined	9

TABLE 11. Visibility and Dimension	
Less than 50 yds	0
50 to 200 yds	1
200 yds. to 1/4 naut. mile	2
1/4 to 1/2 naut. mile	3
1/2 to 1 naut. mile	4
1 to 2 naut. miles	5
2 to 5 naut. miles	6
5 to 10 naut. miles	7
10 to 25 naut. miles	8
25 or more naut. miles	9

TABLE 12. Water sky and Iceblink	
Features not present	0
Feature to the NE	1
Feature to the E	2
Feature to the SE	3
Feature to the S	4
Feature to the SW	5
Feature to the W	6
Feature to the NW	7
Feature to the N	8
Not determined	9

Instructions for use of ice log

H. O. MISC. 15584

SHIP ________ OBSERVER ________

DATE ________ 195__ SHIP'S TIME ____ HEIGHT OF OBSERVER'S EYE ____ FT

LATITUDE ____ ° ____ ' LONGITUDE ____ ° ____ '

VOYAGE FROM ________ TO ________

Check all features present by using appropriate squares

Daylight ____ ☐ Aurora ____ ☐
Twilight ____ ☐ Muddy Ice ____ ☐
Dark, moonlight ____ ☐ Plankton Discolored Ice ____ ☐
Dark, no moon ____ ☐ No. of Distinct Ice Layers ____

Indicate direction (from) by check in appropriate sector

N NE E SE S SW W NW SWELL SEA

REMARKS (Place additional remarks on back of form)

N S | E W | DAY | MO | YR

DO NOT WRITE IN THESE SPACES

Return this form complete with radio message to
U. S. NAVY HYDROGRAPHIC OFFICE
Washington 25, D. C.

SUPPLEMENTAL GROUPS FOR ICE BOUNDARIES AND WATER FEATURES (Tables on back of cover)

RADIO MESSAGE

Day of week (GMT), Octant of globe, Latitude, Longitude, Time (GMT)

Concentration, total; Conc. slush, brash, block (less than 30 ft); Conc. sml. & med. floe (30 to 3000 ft); Conc. giant floe & field (over 3000 ft); Relief; Topography; Age, dominant; Age secondary; Puddling; Snow cover; Water features; Orientation of water features; Fast ice; Ice of land origin; Thickness—sea ice; Visibility; Water sky; Iceblink; Water temp. or

1 1 1 1 2 | 3 4 4 5 6 | 7 8 9 10 2 | 11 12 12

TABLE NUMBER

Figure 14–13. Ship ice log.

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APPENDIX A

A–1 NOTES ON MALFUNCTIONAL BEHAVIOR AND ITS CORRECTION IN DEEP-SEA REVERSING THERMOMETERS.—The following notes on malfunctional behavior and its correction in deep-sea reversing thermometers (Whitney, 1952) are given here in the entirety.

A–2 Introduction.—In the course of working with and calibrating some 400 deep-sea reversing thermometers of various types and manufacture during the past year or so, opportunity has been afforded to study the different types of malfunctions occurring in reversing thermometers, and to investigate various corrective measures to restore proper functioning. It is thought that the results of this investigation may be of interest and assistance to oceanographic personnel who have occasion to work with these instruments.

Malfunctions, which may be described as failure of the mercury column of the main thermometer to break correctly at reversal, are a source of annoyance to observers. When the mercury thread breaks very near but not at the correct breaking point, a false reading occurs which is not readily detectable as such, and may result in false information being entered on the station data sheets.

A–3 Types of Malfunctions.—There may be considered to be four basic types of malfunctions, as follows:

1. The mercury breaks either on the stem or reservoir side of the appendix or constriction; if on the reservoir side or in the throat of the reservoir, the mercury runs out of the appendix or entirely clears the constriction.
2. The mercury breaks on the reservoir side of the appendix or constriction or in the throat of the reservoir; some mercury remains (sticks) in the appendix or in the constriction.
3. The mercury column does not break at all at reversal, but runs down filling the entire capillary system, leaving a visible bubble in the reservoir.
4. The mercury column neither moves nor breaks at reversal unless or until the instrument is jarred, sometimes quite solidly, which jarring will usually cause the instrument to function incorrectly in 1 of the 3 ways described above.

A–4 Definitions.—To insure clarity, the terms which will be used in this discussion are here defined.

Reservoir: The usually cylindroid glass portion of the thermometer which holds the principal body of mercury. The reservoir is at the bottom when the instrument is in its upright position.

Bulb: The small expansion chamber at the opposite end of the thermometer from the reservoir, which is at the top when the instrument is in its upright position.

Upright: That vertical position of the instrument in which the zero point of the main thermometer is near the top of the instrument. To right is to move the instrument to the upright position.

Reversed: That vertical position of the instrument in which the zero point of the main thermometer is near the bottom of the instrument. (The thermometer is always read in the reversed position.) To reverse is to move the instrument to the reversed position.

Appendix: The small branch, or dead-arm, off the main capillary channel near the reservoir. The mercury is supposed to break on reversal at the junction of the appendix with the capillary.

Constriction (sometimes referred to as the collar button from its general appearance): A type of breakoff point made by pinching the capillary together while plastic to deform it and reduce its nominal diameter. In this discussion, unless reference to this particular type of construction is specifically intended, the word appendix will be broadly used in connection with either type of breakoff point.

Pigtail: The 360° turn, or equivalent thereof, as an S shape, between the appendix and stem which acts as a trap for any mercury extruding from beyond the appendix as the result of a temperature rise after reversal.

Capillary: The bore of the thermometer from reservoir to bulb, in which the mercury moves.

Stem: The straight, graduated section of the thermometer.

Throat of the bulb: The point at which the straight capillary diameter of the stem begins to open out to form the bulb.

Throat of the reservoir: That portion of the capillary from the reservoir to the appendix.

Tap: To jar from below with the hand or against some object.

Manipulation: The entire procedure or series of procedures used to remove bubbles from within the mercury column.

Drain: The flowing back of the mercury from the bulb upon righting the thermometer after reversal, to rejoin the main body of mercury in the reservoir and contiguous capillary section.

Flood: The type of malfunction described as No. 3 above.

Correct breaking point: The one and only point at which the mercury column is supposed always to break at reversal. This is the junction of the appendix with the main capillary channel, in thermometers having a true appendix (fig. A–1a). In thermometers made with a constriction or "collar-button," the correct breaking point will be either at the stem end of the constriction, or at the narrowest part of the channel in the constriction, depending upon the exact shape of the deformed area (figs. A–1b and A–1c).

A–5 Causes of Malfunctions.—Certain instruments are more prone to malfunction than others, and the instruments of one manufacturer may, in general, give more trouble in this respect than those of another. There are found in use occasionally reversing thermometers which are basically defective due to the conformation of the appendix or constriction and/or the adjacent capillary, which exhibit the characteristic of breaking at either one of two distinct points in entirely random sequence. These points are generally very close together, so that the temperature difference indicated between a correct and an incorrect break is very small, from a few hundredths of a degree to half a degree. Such an instrument may be considered to be permanently malfunctional.

The usual cause of intermittent malfunction in a reversing thermometer is the presence of gas (a bubble) within the mercury column somewhere in the capillary system. Normally, whatever gas is present in the thermometer is, and should be, above the mercury column when the instrument is in an upright position. On occasion, however, as the result of transporting or rough handling of the instrument in its reversed position, such gas, or part of it, moves up through the mercury column, and wherever it settles, will generally cause separation of the mercury at that point when the attitude of the thermometer is again changed.

When a malfunction occurs as the result of a bubble, and the mercury breaks at some other point than the correct breaking point, manipulation must be undertaken to move the bubble from wherever it happens to be out to the end of the bulb, so that it will be above the mercury when the instrument is in the upright position. This process is well and adequately described in the Richter & Wiese pamphlet "Über die Funktion der Umkippthermometer sowie die Beseitigung von Störungen," a translation of which will be found in the appendix hereto. There are a few refinements to the Richter & Wiese basic technique, however, which may be of interest, as they tend to facilitate manipulation.

A–6 Heating Medium.—Instead of a small flame, hot water, preferably running, up to 50° or 60° C. is safer and quicker to use for warming the thermometer when required during manipulation. It should, of course, be applied fairly slowly so that the temperature change is not too sudden.

A–7 Rejoining Mercury Separated in the Bulb.—When a bubble has been moved up into the lower or middle part of the bulb, particularly if the bubble is of any size, the final stage of the manipulation (knocking off of globules of mercury in the bulb) can, in the case of a great many instruments, be more quickly, easily, and safely accomplished in the following manner:

There being a portion of mercury in the outer end of the bulb, with gas between it and the column of mercury entering the bulb from the stem, hold the thermometer nearly horizontal and allow the two sections of mercury to come very slowly together. When the two sections of mercury meet, joining will begin at the bottom side, and the bubble will be squeezed out to the top wall of the bulb (fig. A–1d). Now, if the thermometer is slowly partially righted, the mercury in the bulb will probably begin to separate at the point where the bubble was, the separation starting at the top side. As the two sections move apart, the cohesiveness of the mercury will cause a certain amount of the outer portion to be drawn along with the inner portion retreating into the stem, while the bubbles move toward the outer end of the bulb (fig. A–1e). Relatively few repetitions of this action will move the bubble entirely out to the end of the bulb, where it is desired to be.

It should be noted that this method will not work with all instruments, and it may be necessary to resort to the Richter & Wiese method, but it is worth trying at the beginning. The nearer the trapped gas is to the outer end of

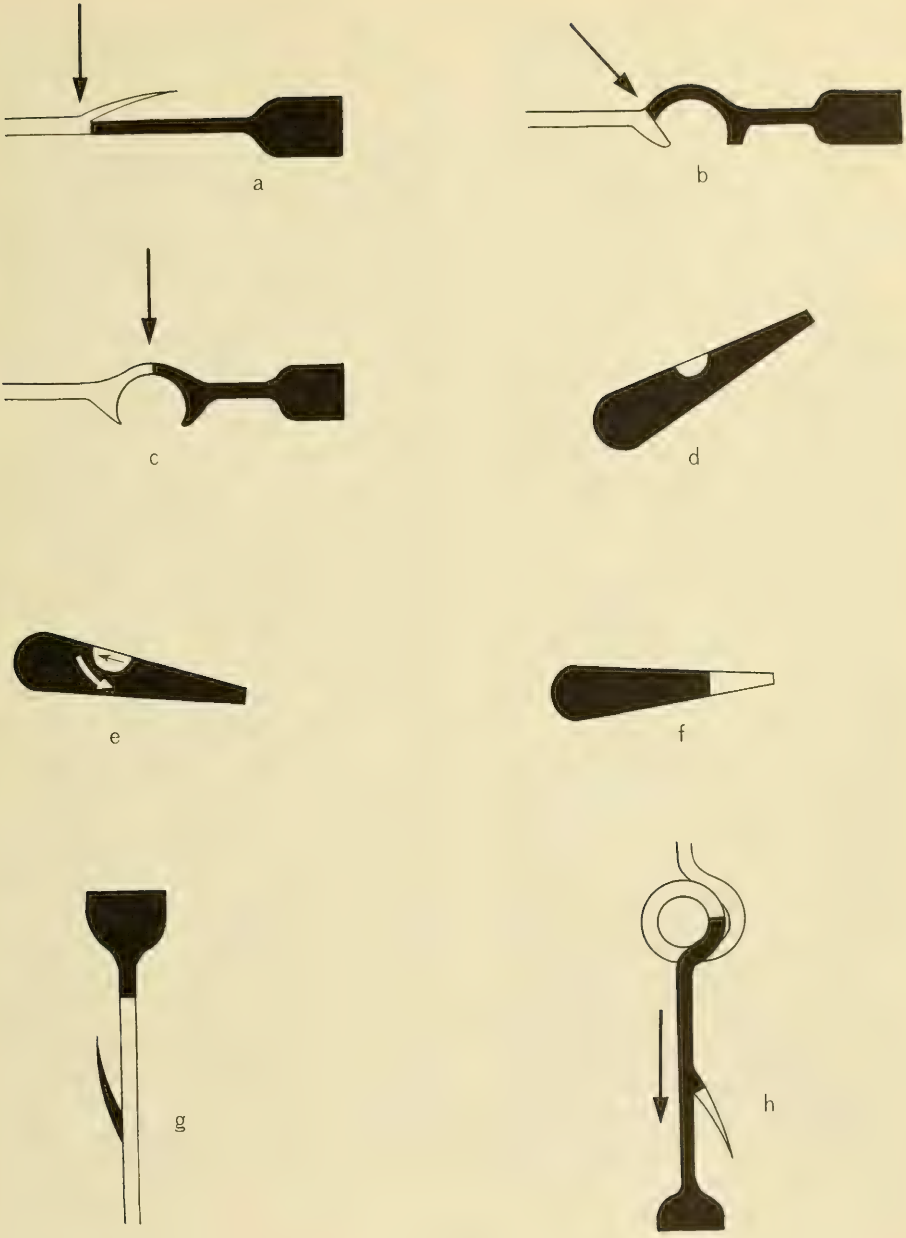

Figure A–1.

the bulb, the more likely is the above-described method to be usable. Certain internal shapes of the bulb cavity do not usually lend themselves to this method, particularly that in which the logitudinal section of the cavity is substantially a double ogive, largest diameter in the middle and coming to a point at the closed end.

A–8 Excessive Gas in Thermometer.—It has been noted that thermometers may occasionally contain too much gas, so that when most of the gas is at the outer end of the bulb (where it is supposed to be) and manipulation is attempted, the gas tends to move the outer portion of the mercury inward, joining it prematurely to the portion extending into the bulb from the stem. Under these conditions, the mercury will not again separate at the point of joining. In such case it is impossible to complete the manipulation, but experience tends to indicate that with such an instrument, a bubble trapped against the wall of the bulb near the middle will probably not cause any trouble, and in time may even work its way out to the end of the bulb where it belongs.

A few cases have been noted in which there was so much gas present in the thermometer that at temperatures near zero, the weight of the mercury broken off at reversal was insufficient to overcome the pressure of the gas in the end of the bulb. The result was that the mercury did not completely fill the bulb, consequently read high on the scale, and a visible bubble existed in the end of the bulb. Such behavior would not be classed as a malfunction, even though a false indication of the temperature resulted, since the mercury column broke correctly at reversal. It should rather be considered to be a defect in the thermometer, which can only be corrected by unsealing the capillary system and further evacuating it.

A–9 Flooding.—Flooding frequently appears to be due to gas being present in the reservoir. The following technique has been used with some degree of success to restore normal functioning, *provided that the mercury is not jammed or stuck in the appendix*:

First, reverse the thermometer at any temperature, but bring it to a horizontal position before the mercury has entirely filled the bulb, leaving roughly one-fifth of the bulb's volume void. Then, holding the thermometer very firmly by the reservoir end, snap it sharply as one might a clinical thermometer, returning it instantly to a horizontal position. The object of this is to forcibly cause the mercury to separate in the throat of the bulb, so that a large mass of mercury is driven to the outer end of the bulb, leaving a small void at the inner end of the bulb near the throat (fig. A–1f). This mass of mercury will generally hang or stick in the outer end of the bulb when the instrument is carefully righted; if it will not do so, but runs down into the stem to rejoin the main body of mercury, the method cannot be used. Now very carefully right the thermometer and very gently place the thermometer upright in an insulated container with some broken pieces of dry ice. It will be noted at this time, that the end of the column of mercury contiguous to the reservoir is probably somewhere in the lower part of the pigtail. *It is necessary to notice* that the mercury in this area is continuous from the reservior outward, so that the contraction of the mercury in the reservoir as it is chilled can draw the mercury from the pigtail into the reservoir (fig. A–1g). If the mercury is not continuous, it may be necessary to tap the instrument very gently to cause the mercury in the capillary to run down by the appendix or constriction and join with that in the reservoir. Too severe tapping may permanently damage the appendix, or cause the mass of mercury suspended in the bulb to run down, so great care should be used. Let the thermometer remain in the dry ice for 10 minutes or so until the mercury has contracted to its freezing point, at which time it is hoped that all the mercury (except the portion suspended in the bulb) will be inside the reservoir, with any gas which may have been trapped there above it. Now remove the thermometer from the dry ice and allow it to warm up, still holding it upright. Heat should not be applied with anything warmer than the hand until the instrument has warmed to the point at which the condensate on the outside does not freeze, then warm water may be used. After heating to perhaps 50° C., the end of the column of mercury contiguous to the reservoir will probably be somewhere in the middle or upper part of the pigtail, presumably with any gas that may have been trapped in the reservoir above (ahead of) it. Thereafter proceed with the standard manipulation to move the bubble to the outer end of the bulb. This procedure may not be effective at once, and in the event that the first attempt does not restore normal functioning, several more attempts should be made before abandoning the instrument as hopeless.

A single case has been noted in which an unprotected thermometer functioned normally and satisfactorily during scale correction tests at atmospheric pressure, but when reversed under a pressure of 100 kg/cm^2 consistently flooded. This may be presumed to have been due to a deformation of the appendix by the pressure, causing the mercury to stick in the appendix, as no visible defect or bubble could be detected, and in spite of repeated attempts to correct the difficulty by manipulation, the instrument persisted in its behavior; normal atmosphere, malfunctional at 100 kg/cm^2. Such a case is, of course, very unusual, and not typical of a difficulty to be encountered at sea, as the eccentricity would presumably have been discovered in the testing laboratory and the instrument disqualified from use.

A–10 Mercury Stuck in Appendix.—Sometimes, at reversal, the mercury column may break behind the appendix in the throat of the reservoir, so that the moving column breaks away from the mercury in the appendix, leaving some mercury stuck there (fig. A–1h). This is most apt to be due to a physical defect in the appendix, possibly the result of rough handling or jarring, which causes the mercury to become wedged in the appendix. Under these conditions, the bond between the appendix wall and the mercury is stronger than the cohesive bond of the mercury itself at the junction of the appendix with the main capillary channel. At reversal, the weight of the mercury column suspended from the reservoir may either cause flooding or a separation of the mercury column in the throat of the reservoir.

In the case of thermometers in which the mercury is stuck in the appendix, the mercury column is very likely not to break at all at reversal unless or until the instrument is jarred or tapped, and then, of course, to break incorrectly or flood. Tapping or jarring with the instrument in a reversed position is undesirable as it tends to work gas up into (within) the mercury column, thereby inducing other types of malfunctions and complicating the situation.

At least one manufacturer of reversing thermometers claims that they can sometimes correct a faulty appendix of this nature by heating, the exact method not being specified, but no examples of such repairs have been observed to note the degree of success achieved by this alleged cure, and no shipboard method of corrective treatment has been discovered.

A–11 Failure To Drain.—Failure to drain spontaneously upon righting is not truly a malfunction, in that it does not affect the ability of the instrument to give accurate temperature information. However, it is annoying and time-consuming at sea, as instruments exhibiting this undesirable characteristic have to be examined carefully at each station to make sure they have drained before lowering, and in severe cases, the instruments may even have to be removed from the rack to cause draining.

Failure to drain spontaneously is more apt to occur when a short column of mercury extends into the stem capillary from the bulb. Contributing causes may be: not enough gas in the outer end of the bulb (therefore gas in the stem); a rough inner surface of the bulb; the shape of the bulb cavity; or too small a capillary diameter in the stem.

Occasionally, a separation of the mercury may take place in the throat of the bulb, leaving the bulb full of mercury which refuses to drain. This mercury cannot be rejoined to the main body of mercury either by knocking off globules of mercury (because there is no space into which to knock them) or by the method described herein above. The corrective treatment for this condition as described by Richter & Wiese may or may not be effective, and is somewhat limited in its application. The treatment described below has been used with considerable success to rejoin the mercury in some very stubborn cases of separations in the throat of the bulb. It is essentially the same as the standard manipulation procedure given by Richter & Wiese for eliminating bubbles near the appendix, except that the cooling and heating cycles are in reverse sequence.

When the bulb is full of separated mercury which refuses to drain, hold the thermometer horizontal (mercury still separated) and chill the bulb end in ice water until the auxiliary thermometer shows that main bulb is near zero in temperature. Now quickly reverse the thermometer, allowing the mercury in the stem and pigtail to run down and join the mercury in the bulb. Note: Since a large part of the mercury normally present in the stem and pigtail is lodged in the bulb, it will be necessary in the beginning to heat the reservoir to about 50° C. with the instrument upright, in order to get enough mercury beyond the appendix to break off; thereafter, this broken-off section of mercury should be kept free in the stem and pigtail, and not allowed to run back into the reservoir.

Now, with the thermometer reversed, heat the bulb to about 50° C. or so, then quickly right the thermometer, tap very lightly if necessary to cause the mercury to separate at the bubble in the throat of the bulb, and instantly return the thermometer to a substantially horizontal position so that the free portion

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of the mercury in the stem and pigtail will not rejoin the mercury in the reservoir. By this sequence of treatment, the bubble will have been moved outward a little toward the end of the bulb. After repeating this cycle a number of times, the bubble will have been moved far enough into the bulb so that a small globule of mercury can be knocked off of the mass remaining in the bulb, and manipulation completed in the usual manner.

It should be noted that under the above conditions, tapping the thermometer in the upright position is not apt to do any damage, as there is no mercury present in or near the appendix which might injure the appendix. This is because the cooling down of the reservoir after heating to 50° C. will have withdrawn the mercury in the throat of the reservoir back into the reservoir, and all of the mercury outside of the reservoir will be either stuck in the bulb or free-running in the stem and pigtail at the instant of tapping. From this, it may be concluded that in some cases, draining may be induced merely by tapping, without danger to the thermometer, if the reservoir is heated to about 50° C., with the instrument in the upright position, the instrument then reversed and allowed to cool so that the appendix area is void of mercury, and then quickly righted and tapped before any mercury has had time to flow back into the appendix area.

In the case of protected thermometers, the chilling and heating sequence outlined above is necessarily very slow, as the blanket of air between the jacket and the bulb of the thermometer must also be cooled and warmed. When treating unprotected thermometers, it is advantageous to remove the thermometer from its jacket.

A–12 Mercury Does Not Separate at Bubble During Manipulation.—There may be encountered, from time to time, an instrument which frequently or consistently malfunctions in the manner described as No. 1 at the beginning of this discussion, in which the cause of the malfunction is obviously a bubble appearing near the appendix, but which, after the first heating and cooling cycle, refuses to separate again at the point where the bubble is located. Such an instrument, when violently reversed as described by Ritcher & Wiese, will break correctly, instead of at the bubble, and the tail end of the mercury broken off at reversal will run down by the point at which the bubble was trapped. When the instrument is again righted, the leading end of the mercury column returning to the reservoir will pick up the bubble and carry it toward the reservoir. The bubble will then come to rest where the descending column joins the mercury extending from the reservoir, probably somewhere in the throat. At the next reversal, the mercury will probably break again at the bubble, producing another malfunction.

The difficulty in such a case would appear to be inherent in the construction of the thermometer. The factors involved are apparently the diameters of the capillary in the appendix area and in the pigtail area in relation to a bubble of a given size, and possibly also the location of the bubble in the capillary. For example, a bubble present in a part of the capillary where the diameter is relatively small might reduce the sectional area of the mercury thread at that point sufficiently to induce separation at the bubble rather than at the correct breaking point when the thermometer is reversed. However, when the same size of bubble is trapped against the capillary wall where the capillary diameter is relatively large, as in parts of the pigtail, the sectional area of the mercury thread is only very slightly reduced at the bubble. The mercury is therefore sufficiently cohesive at that point to resist separation, and separation takes place instead at the correct breaking point upon reversal. In all cases, the fundamental force which causes separation is the gravitational pull of the suspended column of mercury. This will vary depending on the size of the mass of mercury suspended below the bubble, in other words on the location of the bubble. Cases have been noted in which, during manipulation, a bubble could be moved through at least two heating and chilling cycles, more than halfway through the pigtail, but on the next attempted cycle, the amount of mercury beyond (below) the appendix at reversal was great enough in relation to the amount suspended beyond the bubble to cause the cohesive bond of the mercury to be broken at the correct breaking point rather than at the bubble, with the result that manipulation could not be completed. In cases where this difficulty arises, patient and careful procedure may determine just how far the bubble can be moved before separation at reversal reverts to the correct breaking point, and successful, complete manipulation may eventually be achieved.

When such difficulty in completing manipulation occurs, it is particularly important to observe the exact manner of holding the thermometer for a snap reversal as described by Richter & Wiese, that is, holding it firmly in such a manner that, as nearly as possible, the center around which the thermometer is rotated when reversed is at the bubble. When thus reversed with as sudden a motion as is practicable, the centrifugal force of the rotation tends to move the mercury on the stem side of the bubble out toward the bulb, and to hold the mercury on the reservoir side of the bubble tight in the reservoir, inhibiting a separation at the correct breaking point. It is helpful also if the direction of the rotation (clockwise or counterclockwise) is controlled in relation to the direction of flow or movement of the mercury column as it separates. If the direction of movement of the mercury in the pigtail as it separates at the bubble will be clockwise, the rotation of the instrument should be counterclockwise, and vice versa. This will take advantage of any inertia of that part of the mercury which is on the stem side of the bubble, and may assist in inducing separation at the bubble.

A–13 Appendix.—*The Operation of the Richter and Wiese Reversible Thermometer and the Elimination of Disturbances* (translated from the booklet by Richter and Wiese, Berlin).

I. *Operation*

The visible breaking point makes possible an accurate check of the operation of the thermometers. One is therefore in a position to test the thermometer at any time with regard to its functioning. This is of special importance after the instrument has been transported.

If the thermometer is in good order, the mercury in the capillary and in the reservoir should not be broken at any point while in an upright position (reservoir down), i. e., the small quantity of air actually present in the capillary must be above the mercury in the bulb of the thermometer. If one now reverses the thermometer (reservoir up) the mercury thread must, if functioning normally, break at the point A (fig. A–2b). If one examines the point A with the help of a magnifying glass while reversing the instrument, very slowly, one will see distinctly that the mercury commences to run out of the dead arm (fig. A–2a) and then breaks at the point where the dead arm and the capillary meet (fig. A–2b). During this test it is important that the instrument be as nearly as possible in equilibrium with the temperature of the surrounding medium, in order that the mercury may not rise or fall at the moment of observation and thus render impossible an accurate observation of the breaking procedure. For this reason, the touching by hand of the reservoir during the observation should be avoided as much as possible.[1]

The quantity of mercury broken off corresponds to the actual temperature existing at the moment of breaking. If one turns the instrument back again after the breaking (reservoir down), the separated mercury should run out easily from the bulb and should combine with the mercury in the reservoir.[2]

II. *Disturbances*

As a result of careless handling during transportation or during temperature measurements, or after a long period of storage (in a horizontal position) the mercury may fail to form a continuous thread.

a. Mercury remaining in the bulb (fig. A–2c)

In many cases it will be sufficient to reverse the thermometer, a movement which cuases the mercury to run and to combine with the mercury remaining in the bulb. If while again uprighting the thermometer (reservoir down) the mercury runs down as a continuous thread, the instrument is in order; but if the mercury continues to break as at first, it is a sure sign that an air bubble is present, perhaps visible with a magnifying glass, which prevents the two portions of mercury from being joined. The air bubble must, in that case be forced upwards, above the mercury to the top of the bulb.

The following method should be employed:

The thermometer is held with the right hand at the bottom of the reservoir; with the instrument in a horizontal position, one taps the other end, viz., the bulb, lightly on the palm of the left hand in order to separate a few globules of mercury which should lie free in the bulb (fig. A–2d).

Now one reverses the thermometer and allows the mercury to run forward in order to take up the globules; the bulb, however, should not be filled, only the globules should be picked up.

This manipulation must be repeated several times, while additional globules are being shaken off, until all the mercury will be joined together.

The thermometer should not be tapped while in an upright position (with the reservoir down) in such a manner as to allow the separated mercury to run down, because in that case the air bubbles would simply travel downward, let

[1] Note difference between "reservoir" and "bulb."

[2] It will often be necessary to tap the instrument lightly in an upright position against the under side of a wooden surface, in case the mercury should not thus run easily out of the bulb.

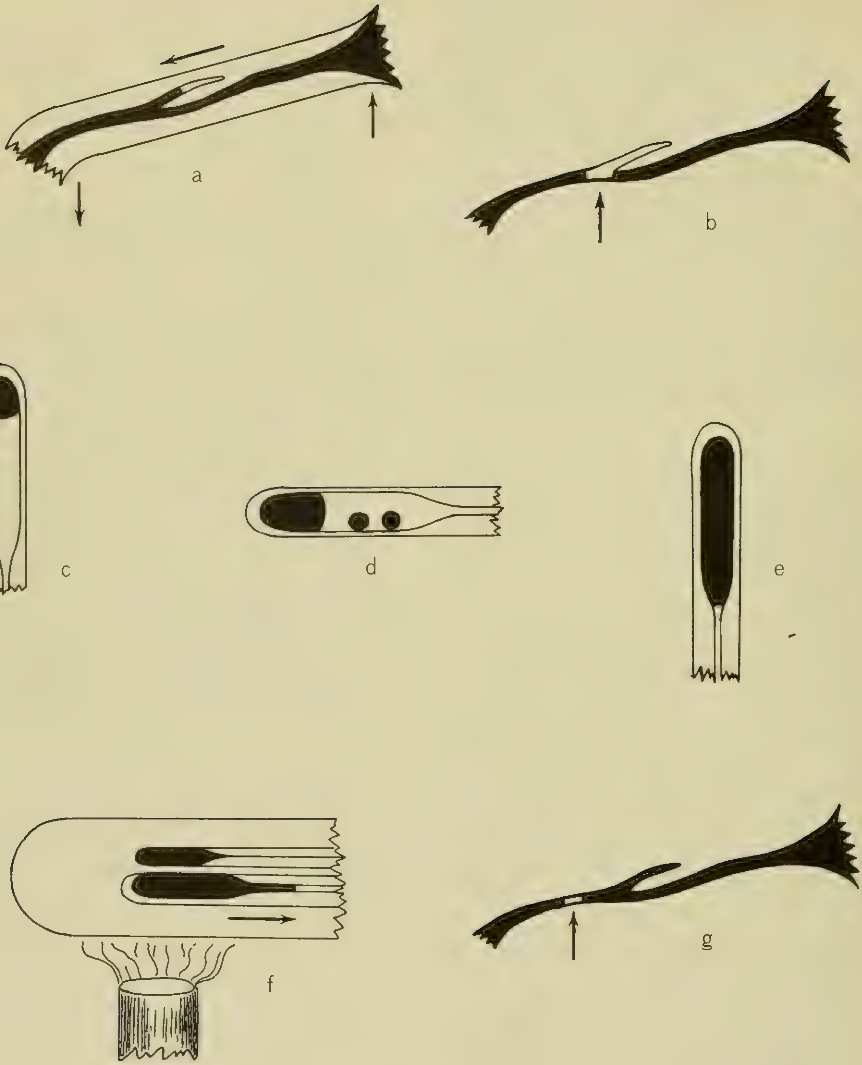


Figure A–2.

alone that by such shocking the weight of the mercury thread which presses on the narrow point (at A) will cause the small fissures in the narrow capillary part of the dead arm and entirely ruin the thermometer.

b. The bulb is completely filled with mercury (fig. A–2e)

With a Bunsen or alcohol flame one heats very carefully the glass jacket surrounding the bulb. The mercury in the bulb should expand and enter the capillary (fig. A–2e). Of course the heating has to be done very carefully, preferably with the thermometer in a horizontal position, continuously rotated, and withdrawn frequently from the flame in order to prevent a too sudden and one-sided heating which might cause the jacket to break.

The auxiliary thermometer naturally rises also, and one must take care lest some mercury in the bulb of the auxiliary thermometer becomes separated or that the heat becomes too great. Later, placing the thermometer reversed in ice will indicate the position of the zero point.

During the heating process one raises the thermometer frequently with the reservoir downward and examines whether the mercury has already expanded sufficiently and whether it runs down into the capillary. Naturally the air bubble will thus be pushed downward, and it will be necessary to force it back to the bulb and above the mercury. In many cases (where air bubbles are present) a check of the breaking point will indicate that the mercury breaks correctly, since the air bubble is perhaps too small and consequently has no effect on the breaking point; but it is advisable to follow the method outlined for removing the air bubbles. It is very possible that the mercury will break at another point, perhaps below point A. In that case an adjustment is obviously necessary.

c. The thermometer breaks incorrectly, i. e., the mercury separates at a place other than point A (fig. A–2g).

In the case of careless handling of the instruments, especially during a long transportation, it is quite possible that air bubbles will travel from the bulb downward (see also *b*). They must again be brought above the mercury in the bulb.

The following manipulation is necessary:

The thermometer is placed in an upright position and cooled, preferably in ice water, during which the mercury must be continuous. If one now reverses the thermometer, it will be of some advantage to take hold of the instrument at the point where the loop is situated and with a little jerk, to turn it around its axis in order to break up the mercury at the point where the air bubble is located (look up fig. A–2g), because it should then be possible to push it forward during the subsequent heating of the reservoir. It is immaterial whether the mercury also breaks at the regular breaking point. After the mercury has run into the bulb, one tilts the thermometer into a horizontal position, and heats very slowly and carefully the reservoir of the thermometer by a very small flame (up to about 60° C.).

The rising mercury now pushes the air bubble forward, the greater the previous cooling, the farther the air bubble will be pushed on; it will be of advantage if now it be located at the end of the loop or at the beginning of the capillary. One now places the thermometer quickly in an upright position in order to allow the mercury to run out of the bulb, joining the mercury below, thus all of the mercury in an upright position forms now again a coherent quantity.

Now another cooling in ice will take place, the thermometer will be caught again at the loop, then will be turned around its axis with a jerk in order to cause the mercury to break at the point to which the air bubble has been pushed.

The subsequent heating need only be slight; if the mercury rises up to the lower end of the bulb, the air bubble has been pushed to that point. One now combines the mercury again in the bulb and finally cools down the thermometer, while in an upright position, preferably to below 0° C. in order to make sure that all the air bubbles are located *above* the mercury.

The indicated manipulations are to be performed with several stages of interruptions, the principal point, however, is that the air bubble is always to be pushed forward *successively*.

III. *The keeping and handling of the instruments*

Of course a very careful handling of the instruments is imperative in order to avoid disturbances in their perfect functioning. The thermometers must be shipped in an upright position or at least in a half horizontal position and should also be stored in this manner, and should be especially protected from jolts or shocks. An accurate test must consider the following points.

1. Observe whether the mercury at an upright position forms a continuous thread, i. e., that the mercury is not separated and that there are no globules of mercury in the bulb.

2. Check the breaking point with a magnifying glass. This check is especially important after transportation or long storage.

3. From time to time a zero-point test should be made in order to determine casual variations of the freezing point.

4. If some defect of the instrument has been discovered and according to our directions has been corrected, we recommend for absolute safety with regard to perfect functioning, the check of the freezing point mentioned under "3."

5. When the reversing thermometer is in a reversing frame or is mounted on a water sampler, do not permit this to be tripped in the air, as the thermometer can be damaged by the hard impact.

Safe function of reversing thermometers is only assured in water.

IV. *Ice-point determinations*

The undertaking of an ice-point test is from time to time necessary in order to establish random changes of the instruments. These tests become especially important if a thermometer in disorder has been successfully repaired. The following description gives a reliable ice-point determination to within 0.015° C.

The thermometer will be stood up in finely shaved, pounded, melting ice up to the beginning of the graduations. Air space surrounding the reservoir is to be guarded against; the ice should therefore be stirred from time to time. A standard thermometer for the ice point, graduated in $\frac{1}{50}$° or $\frac{1}{100}$° C. is recommended in order to establish an exact zero point of the ice.

A one-fourth hour rest of the thermometer suffices. Then the thermometer will be reversed with the ice chamber and extracted. In this reversed position it is again placed into the ice and the main and auxiliary thermometers are read off after one-half hour. In the ice-point reading, it is necessary that the thermometer be lifted and shaken in the ice to avoid adhesion of the mercury in the capillary; especially with a narrow capillary ($\frac{1}{20}$° and $\frac{1}{50}$° C.) and such with a widening above zero, it is important to ascertain the accurate level while tapping.

For repeated ice-point determinations of a large number it is recommended that one supply oneself with a special apparatus consisting of a reversible, double-walled and insolated cylinderlike ice bath. The ice-point determination of the D. A. E. showed an individual curve of ice point changes for each instrument, so that for exact investigations extending over a long time this test cannot be ignored.

APPENDIX B

B–1 A METHOD FOR DETERMINING PRESSURE COEFFICIENTS OF UNPROTECTED REVERSING THERMOMETERS AT SEA.—The pressure coefficients (Q) of unprotected thermometers must be known in order to calculate thermometric depths. Ordinarily these Q-factors are determined by carefully controlled tests conducted at the Bureau of Standards or at one of the oceanographic laboratories. Occasionally new thermometers must be put to use before Q-factors have been determined. In such cases the Q-factors can be determined at sea provided there are one or more unprotected thermometers with known Q-factors available to use with those that are unknown.

For purposes of illustration assume that there are three unprotected thermometers with known Q-factors available and that it is desired to determine the Q-factors for four other thermometers at 1,000, 2,000, and 3,000 meters. This is carried out as follows:

1. Using five Nansen bottles, place the 3 unprotected thermometers of known Q-factors in the top, center and bottom bottles of the cast. Pair with these the best available protected thermometers. On the bottles between these, place the 2 pairs of unknown unprotected thermometers.
2. Space the Nansen bottles on the wire 10 meters apart and lower the top of the cast to 1,000 meters. It is desirable to do this at a time when wire angles are slight. Allow 10 minutes for the thermometers to come to temperature before reversal. Allow ample time for all bottles to reverse then recover the cast.
3. Take an oxygen sample from each bottle. The oxygen determination serves as a quick check on the validity of the reversing of each bottle. Discard the remaining water. The oxygen values should be checked against the normal figure for the depth, if known.
4. When the thermometers have come to equilibrium at air temperature, it is best to have two or more persons with experience in reading thermometers make separate readings.
5. Repeat items 2, 3, and 4.
6. Repeat items 2, 3, and 4, but send the bottles to 2,000 meters for 2 casts.
7. Repeat items 2, 3, and 4, but send the bottles to 3,000 meters for 2 casts, if the range of the thermometers permit.
8. Correct the readings for the paired protected and unprotected thermometers in the top, center, and bottom bottles and compute their thermometric depth. Prepare an L–Z graph and determine the accepted depths for each cast. By interpolation, determine the accepted depths for the remaining bottles.
9. Plot the values of T_w against depth and construct a curve through the points. From this graph the temperatures, for the bottles without protected thermometers, are read off and used to correct the readings of the unknown unprotected thermometers, thus T_u is determined for them.
10. From 8. and 9. above, the values for $T_u - T_w$ and Z (using the accepted depth) are established. ρ_m for each depth may be determined from figure 3–3 or from table 17. The pressure coefficient, Q, at each depth is calculated for the unknown, unprotected thermometers by applying the above values in the following formula, where all values are defined in section 3–10:

$$Q = \frac{T_u - T_w}{\rho_m Z}$$

11. Although the Q for a given thermometer may be different for the 1,000-, 2,000-, and 3,000-meter depths, the Q for each cast at the same depth must agree to 1×10^{-5} (to 1 unit at the fifth decimal place) to be considered valid. If such agreement is not made, then additional casts should be made to obtain further comparisons.

PART II

OCEANOGRAPHIC CODES AND TABLES

Table 1.—WEATHER STATE CODE

00–49. No precipitation at the ship at the time of observation.

00–19. No precipitation, fog, duststorm, sandstorm, or drifting snow at the ship at the time of observation or during the preceding hour, except for 09.

00	Cloud development not observed or not observable.	*No hydrometeors except clouds.*
01	Clouds generally dissolving or becoming less developed.	
02	State of sky on the whole unchanged.	*Characteristic change of the state of sky during past hour.*
03	Clouds generally forming or developing.	
04	Visibility reduced by smoke, e. g., veldt or forest fires, industrial smoke, or volcanic ashes.	*Haze, dust, sand, or smoke.*
05	Dry haze.	
06	Widespread dust in suspension in the air, not raised by wind at or near the ship at the time of observation.	
07	Dust or sand raised by wind at or near the ship at the time of observation, but no well developed dust devil(s), and no duststorm or sandstorm seen.	
08	Well-developed dust devil(s) seen at or near the ship within last hour, but no duststorm or sandstorm.	
09	Duststorm or sandstorm within sight of the ship or at the ship during the last hour.	
10	Light fog (visibility 1,100 yards or more).	
11	Patches of.	*Shallow fog at the ship not deeper than about 33 feet.*
12	More or less continuous.	
13	Lightning visible, no thunder heard.	
14	Precipitation within sight, but not reaching surface at the ship.	
15	Precipitation within sight, reaching surface, but distant (i. e., estimated to be more than 3 miles from the ship).	
16	Precipitation within sight, reaching surface, near to but not at the ship.	
17	Thunder heard, but no precipitation at the ship.	
18	Squall(s).	*Within sight during the last hour.*
19	Funnel cloud(s) (tornado or water-spout).	

20–29. Precipitation, fog or thunderstorm at the ship during the preceding hour but NOT at the time of observation.

20	Drizzle (not freezing).	*Not falling as showers.*
21	Rain (not freezing).	
22	Snow.	
23	Rain and snow.	
24	Freezing drizzle or freezing rain.	
25	Shower(s) of rain.	
26	Shower(s) of snow, or of rain and snow.	
27	Shower(s) of hail or of hail and rain.	
28	Fog.	
29	Thunderstorm (with or without precipitation).	

30–39. Duststorm, sandstorm, or drifting snow.

30	Slight or moderate duststorm or sandstorm.	*Has decreased during preceding hour.*
31	Slight or moderate duststorm or sandstorm.	*No appreciable change during preceding hour.*
32	Slight or moderate duststorm or sandstorm.	*Has increased during preceding hour.*
33	Severe duststorm or sandstorm.	*Has decreased during preceding hour.*

34	Severe duststorm or sandstorm.	*No appreciable change during preceding hour.*
35	Severe duststorm or sandstorm.	*Has increased during preceding hour.*
36	Slight or moderate drifting snow.	*Generally low.*
37	Heavy drifting snow.	
38	Slight or moderate drifting snow.	*Generally high.*
39	Heavy drifting snow.	

40–49. Fog at the time of observation.

40	Fog at a distance at the time of observation, but not at the ship during the last hour, the fog extending to a level above that of the observer.	
41	Fog in patches.	
42	Fog, sky discernible.	*Has become thinner during preceding hour.*
43	Fog, sky not discernible.	
44	Fog, sky discernible.	*No appreciable change during preceding hour.*
45	Fog, sky not discernible.	
46	Fog, sky discernible.	*Has begun or has become thicker during preceding hour.*
47	Fog, sky not discernible.	
48	Fog, depositing rime, sky discernible.	
49	Fog, depositing rime, sky not discernible.	

50–99. Precipitation at the ship at the time of observation.

50–59. Drizzle at time of observation.

50	Drizzle, not freezing, intermittent.	*Slight at time of observation.*
51	Drizzle, not freezing, continuous.	
52	Drizzle, not freezing, intermittent.	*Moderate at time of observation.*
53	Drizzle, not freezing, continuous.	
54	Drizzle, not freezing, intermittent.	*Thick at time of observation.*
55	Drizzle, not freezing, continuous.	
56	Drizzle, freezing, slight.	
57	Drizzle, freezing, moderate or thick.	
58	Drizzle and rain, slight.	
59	Drizzle and rain, moderate or heavy.	

60–69. Rain at time of observation.

60	Rain, not freezing, intermittent.	*Slight at time of observation.*
61	Rain, not freezing, continuous.	
62	Rain, not freezing, intermittent.	*Moderate at time of observation.*
63	Rain, not freezing, continuous.	
64	Rain, not freezing, intermittent.	*Heavy at time of observation.*
65	Rain, not freezing, continuous.	
66	Rain, freezing, slight.	
67	Rain, freezing, moderate or heavy.	
68	Rain or drizzle and snow, slight.	
69	Rain or drizzle and snow, moderate or heavy.	

70–79. Solid precipitation not in showers at time of observation.

70	Intermittent fall of snow flakes.	*Slight at time of observation.*
71	Continuous fall of snow flakes.	
72	Intermittent fall of snow flakes.	*Moderate at time of observation.*
73	Continuous fall of snow flakes.	
74	Intermittent fall of snow flakes.	*Heavy at time of observation.*
75	Continuous fall of snow flakes.	
76	Ice needles (with or without fog).	
77	Granular snow (with or without fog).	
78	Isolated starlike snow crystals (with or without fog).	
79	Ice pellets.	

80–99. Showery precipitation, or precipitation with current or recent thunderstorm.

80	Rain shower(s), slight.	
81	Rain shower(s), moderate or heavy.	
82	Rain shower(s), violent.	
83	Shower(s) of rain and snow mixed, slight.	
84	Shower(s) of rain and snow mixed, moderate or heavy.	
85	Snow shower(s), slight.	
86	Snow shower(s), moderate or heavy.	
87	Shower(s) of soft or small hail with or without rain, or rain and snow, slight.	
88	Shower(s) of soft or small hail with or without rain, or rain and snow mixed, moderate or heavy.	
89	Shower(s) of hail with or without rain, or rain and snow mixed, not associated with thunder, slight.	
90	Shower(s) of hail, with or without rain, or rain and snow mixed, not associated with thunder, moderate or heavy.	
91	Slight rain at time of observation.	*Thunderstorm during preceding hour but not at time of observation.*
92	Moderate or heavy rain at time of observation.	
93	Slight snow, or rain and snow mixed, or hail* at time of observation.	
94	Moderate or heavy snow, or rain and snow mixed, or hail* at time of observation.	

* Hail, small hail, soft hail.

95 Thunderstorm, slight or moderate, without hail* but with rain and/or snow at time of observation. 96 Thunderstorm, slight or moderate, with hail* at time of observation.	*Thunderstorm at time of observation.*	97 Thunderstorm, heavy, without hail* but with rain and/or snow at time of observation. 98 Thunderstorm combined with duststorm or sandstorm at time of observation. 99 Thunderstorm, heavy, with hail* at time of observation.

*Hail, small hail, soft hail.

Table 2.—CLOUD TYPE CODE

Code	*Cloud type*	*Code*	*Cloud type*
0	Stratus or Fractostratus (St or Fs).	5	Altostratus (As).
1	Cirrus (Ci).	6	Stratocumulus (Sc).
2	Cirrostratus (Cs).	7	Nimbostratus (Ns).
3	Cirrocumulus (Cc).	8	Cumulus or Fractocumulus (Cu or Fc).
4	Altocumulus (Ac).	9	Cumulonimbus (Cb).

Use code for SIGNIFICANT cloud layer.

CLOUD TYPES

Compiled by the U. S. Weather Bureau to aid in the interpretation and coding of cloud observations.

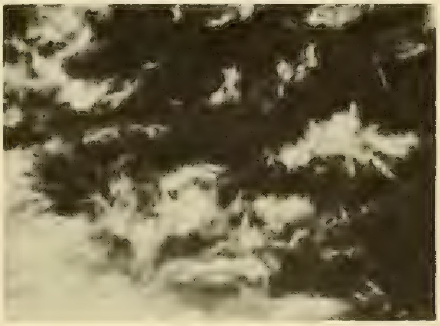
Family "A" High Clouds: Cirrus (Ci), Cirrocumulus (Cc). Mean lower level, 6,000 meters, 20,000 feet.

CODE 1 CIRRUS →

(NOTE.—*Further illustrations and descriptions of clouds are contained in U. S. Weather Bureau Circular S, Second Edition, "Manual of Cloud Forms and Codes for States of the Sky." This publication may be obtained by cooperating marine observers at U. S. Weather Bureau Port Offices and Marine Centers.*)

CODE 1 CIRRUS →

H1: Filaments or strands of cirrus scattered and not increasing (often "Mares' Tails").



← CIRRUS Code 1

H2: Dense cirrus in patches or twisted sheaves usually not increasing; possibly but not certainly the remains of the upper part of cumulonimbus.

← CIRRUS Code 1

H3: Cirrus, often anvil-shaped; either the remains of the upper portions of cumulonimbus or part of a distant cumulonimbus, the rest of which is not visible.

(See notes on L9 for coding requirements when cumulonimbus is present.)

← CIRRUS Code 1

H4: Cirrus (often hook-shaped) gradually spreading over the sky and usually thickening as a whole.

The essential characteristic is the gradual spreading over the sky.

Note that these clouds must extend to the horizon from which they are advancing, where owing to the effect of perspective they may assume the appearance of cirrostratus.

Codes 1 & 2 CIRRUS & CIRROSTRATUS →

H5: Cirrus and cirrostratus, often in bands converging toward the horizon; or cirrostratus alone; in either case gradually spreading over the sky and usually thickening as a whole, but the continuous layer not reaching 45° altitude.

When cirrus is present, the angular altitude refers to the leading edge of the cirrostratus layer.

Codes 1 & 2 CIRRUS & CIRROSTRATUS →

H6: Cirrus and cirrostratus often in bands converging toward the horizon; or cirrostratus alone; in either case gradually spreading over the sky and usually thickening as a whole, and the continuous layer exceeding 45° altitude.

When cirrus is present, the angular altitude refers to the leading edge of the cirrostratus layer.

Code 2 CIRROSTRATUS →

H7: Cirrostratus covering the entire sky.

During the day, when the sun is sufficiently high above the horizon, the sheet is never thick enough to prevent shadows of objects on the ground.

← CIRROSTRATUS CODE 2

H8: Cirrostratus not increasing and not covering the whole sky; cirrus and cirrocumulus may be present.

If cirrocumulus is present, the cirrostratus must predominate to satisfy the requirements of Code 2. If the cirrocumulus predominates, the sky would be coded as Code 3.

← CIRROCUMULUS CODE 3

H9: Cirrocumulus alone or cirrocumulus with some cirrus or cirrostratus, but the cirrocumulus being the main cirriform cloud present. (Cirrocumulus may be present in Code 1 to Code 2.

Family "B" Middle Clouds: Altocumulus (Ac), Altostratus (As). Mean upper level, 6,000 meters, 20,000 feet; mean lower level, 2,000 meters, 6,500 feet.

← ALTOSTRATUS CODE 5

M1: Thin altostratus (semitransparent everywhere) through which the sun or moon can be dimly seen. A sheet of this cloud resembles thick cirrostratus from which it is often derived without any break; but halo phenomena, sun pillar, etc., are not seen in cirrostratus, and the sun or moon appears as though shining through ground glass and does not cast shadows.

ALTOSTRATUS OR NIMBOSTRATUS →
CODES 5 & 7

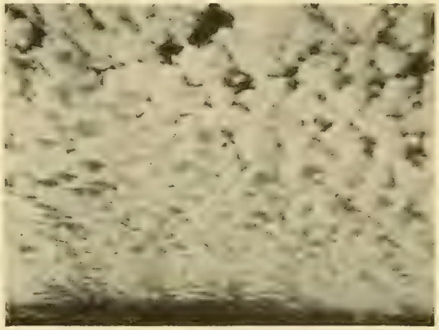
M2: Thick altostratus or nimbostratus (through portions of the sheet the position of the sun or moon may be indicated by a light patch).

The sun and moon are completely hidden by at least some parts of the cloud sheet, which may be fibrous in appearance. Thick altostratus can be formed either by thickening of thin altostratus or by the fusing together of cloudlets in a sheet of altocumulus.

Nimbostratus is derived either by a change from thick altostratus or by the fusing together of the cloud elements in a sheet of dense altocumulus, stratocumulus, or stratus.

When nimbostratus gives precipitation it is in the form of continuous rain or snow. Nimbostratus usually has a dark gray color and its lower surface always has a wet appearance, widespread trailing precipitation, "virga," which may or may not reach the ground; it is quite uniform and it is not possible to make out definite detail.

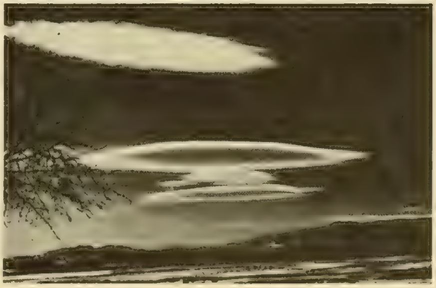
CODE 4 ALTOCUMULUS →



M3: Thin (semitransparent) altocumulus; cloud elements not changing much; at a single level.

This cloud is fairly regular and of uniform thickness. The cloudlets or waves are always separated by clear spaces or lighter patches and are neither very large nor very dark.

CODE 4 ALTOCUMULUS →



M4: Thin (semitransparent) altocumulus in patches (often almond- or fish-shaped); cloud elements continually changing and/or occurring at more than one level.

Lenticular patches often pile up in layers, at times with clear spaces between. They also merge horizontally in the form of rafts or somewhat discontinuous sheets.

← ALTOCUMULUS CODE 4

M5: Thin (semitransparent) altocumulus in bands or in a layer gradually spreading over the sky and usually thickening as a whole; it may become partly opaque or double-layered.

M5 designates one or perhaps two advancing layers of altocumulus, usually of irregular thickness, the amount and thickness of which are definitely increasing. The altocumulus stretches to the horizon, at least in the direction from which it is advancing.

← ALTOCUMULUS CODE 4

M6: Altocumulus formed by the spreading out of cumulus.

Cumulus clouds of sufficiently great vertical development may undergo an extension of their summits while their bases may gradually melt away. Sheets of altocumulus, which are generally fairly thick and opaque at first, are formed in this manner. They have rather large elements, dark and soft; later they may thin out and finally have rifts in them or, at any rate, semitransparent intervening spaces.

When there is doubt as to whether a spreading sheet should be termed altocumulus or stratocumulus, it is best to code 4, since the cumulus clouds may then also be coded 8.

M7: Any of the following cases:

(*a*) Double-layered altocumulus, usually opaque in parts, not increasing.

(*b*) A thick (opaque) layer of altocumulus, not increasing.

(*c*) Altostratus and altocumulus both present at the same or different levels.

Type (*a*): Two layers of altocumulus, the lower of which resembles a gray veil, often hardly visible, lying at a level very little lower in places and for a short time hiding the cloudlets of the altocumulus sheet sufficiently to give it the appearance of altostratus. This double-layered altocumulus is coded M7 only if the altocumulus is not systematically increasing; otherwise it is coded M5.

Type (*b*): The under surface of opaque altocumulus is marked by a more or less corrugated or wave-like structure, sometimes called wrinkled.

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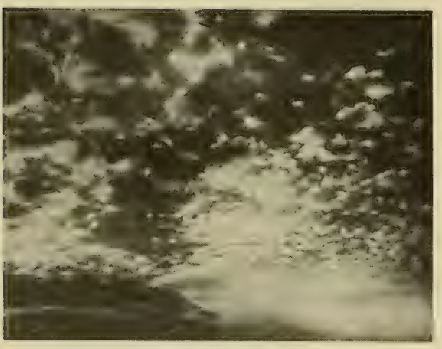
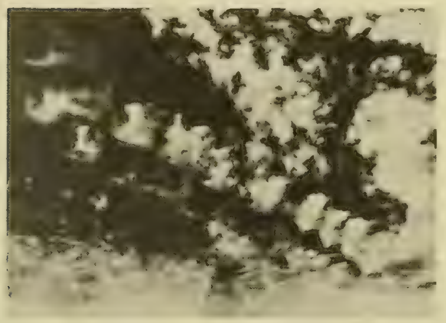


← ALTOCUMULUS CODE 4

M8: Altocumulus in the form of cumulus-shaped tufts or altocumulus with turrets.

Tufted altocumulus are white or gray cloudlets that have no definite shadows and that have very slightly domed tops. The tufts resemble very small broken cumulus clouds whose bases are not flat. Turreted altocumulus shows somewhat greater vertical development than the tufted form. The turrets rise from a common flat base.



← ALTOCUMULUS CODE 4

M9: Altocumulus of a chaotic sky; generally at more than two different levels; dense cirrus in patches is usually also present.

These clouds are characterized by a lack of regularity with respect to form and distribution in space, both horizontally and vertically.

Family "C" Low Clouds: Stratocumulus (Sc), Stratus (St), Nimbostratus (Ns). Mean upper level, 2,000 meters, 6,500 feet; mean lower level, close to surface.

Family "D" Clouds With Vertical Development: Cumulus (Cu), Cumulonimbus (Cb).

CODE 8 — CUMULUS →

L1: Cumulus with little vertical development and seemingly flattened.

These clouds occur in three forms:

A. In a state of formation.
B. Completely formed.
C. Completely formed but broken up by the wind (fractocumulus).

They usually have a marked diurnal growth over land, developing until the middle of the afternoon and decreasing later, both as to amount and vertical extent. At sea and on coasts, cumulus clouds often occur at night.

The presence of even a single cumulonimbus with any amount of stratocumulus, stratus, or cumulus clouds will require coding.

When the cumulus clouds begin to spread out in any part of the sky, the clouds will be coded 6 rather than 8, unless the spreading portions form altocumulus, in which case they will be coded 4 and 8.

Fractocumulus of fine weather are detached white clouds usually in an otherwise clear sky. (See L7 for description of fracto cumulus of bad weather.)

CODE 8 — CUMULUS →

L2: Cumulus of considerable development, generally towering, with or without other cumulus or stratocumulus; bases all at the same level.

These clouds are massive in appearance, occasionally wind-tossed and broken, with horizontal bases and very great vertical development. They are sometimes in the form of towers or of complex heaps with "cauliflower" formation. They often have caps or hoods (pileus), which are distinguished from the spreading tops of cumulonimbus by their smoothness, sharpness, and short duration (a few minutes).

(See L8 for the coding of cumulus of considerable development and stratocumulus with bases at different levels.)

← CUMULONIMBUS CODE 9

L3: Cumulonimbus with tops lacking clear-cut outlines but distinctly not cirriform or anvil-shaped; with or without cumulus, stratocumulus, or stratus.

These are cumuliform clouds of great vertical development with tops composed in part at least of ice crystals, the presence of which is revealed by a partial or general indefiniteness of previously well-defined "cauliflower" tops.

(See L9 for the coding of cumulonimbus having clearly fibrous tops.)

← STRATOCUMULUS CODE 6

L4: Stratocumulus formed by the spreading out of cumulus; cumulus also often present.

← STRATOCUMULUS CODE 6

L5: Stratocumulus not formed by the spreading out of cumulus.

This includes a wide variety of aspects of stratocumulus, ranging from thin clouds at a single level with semitransparent parts or even clear spaces, to the dark and menacing clouds, often at two or more levels, immediately before or after precipitation. Code 6 applies only in the absence of fractocumulus of bad weather, cumulus, or cumulonimbus. If stratus and stratocumulus are both present, code 6 applies while stratocumulus is dominant.

STRATUS OR FRACTOSTRATUS →
CODE 0

L6: Stratus or Fractostratus, or both, but not fractostratus of bad weather.

These clouds are usually in a low single layer and may be localized in extent. Clouds properly coded 0, unlike those coded 0 and 8, are not very dark or menacing.

The designation "fractostratus" is used when a layer of stratus is broken up into irregular shreds.

FRACTOSTRATUS OR FRACTOCUMULUS
CODES 0 & 8 →

L7: Fractostratus and/or fractocumulus of bad weather ("scud") usually under altostratus and nimbostratus. (By "bad weather" is meant the conditions usually prevailing immediately before, during, or immediately after precipitation.)

Fractocumulus clouds of bad weather are usually dark, receive little light; these clouds generally become very numerous and may merge into a sheet covering the entire sky.

(See L1 for description of fractocumulus of good weather.)

CUMULUS & STRATOCUMULUS →
CODES 6 & 8

L8: Cumulus and stratocumulus other than those formed by the spreading out of cumulus with bases at different levels. The lower cumulus clouds may or may not extend up through the upper stratocumulus layer.

← CUMULONIMBUS Code 9

L9: Cumulonimbus having a clearly fibrous (cirriform) top, often anvil-shaped, with or without cumulus, stratocumulus, or stratus, or "scud."

By extension at various levels, cumulonimbus often produces cirrus, altocumulus, or stratocumulus clouds. Therefore, cumulonimbus may coexist with clouds that should be coded, when detached from the parent cloud, Code 1 or 2 If these clouds are not detached, they should not be coded separately.

Cumulonimbus clouds generally produce showers of rain or snow and sometimes of hail, and often thunderstorms as well.

If the whole of the cloud cannot be seen the fall of a real heavy shower is enough to characterize the cloud as a cumulonimbus.

Table 3.—CLOUD COVER CODE

Code	*Amount of sky covered in tenths*
0	No clouds.
1	Less than 1 and 1.
2	2 and 3.
3	4.
4	5.
5	6.
6	7 and 8.
7	9 and 9 plus.
8	10.
9	Sky obscured.

Table 4.—VISIBILITY CODE

[Use range-finder readings of known landmarks if possible.]

Code	Objects not visible at—	Description
0	50 yards	Dense fog.
1	200 yards	Thick fog.
2	400 yards	Fog.
3	1,000 yards	Moderate fog.
4	1 nautical mile	Thin fog or mist.
5	2 nautical miles	Visibility poor.
6	5 nautical miles	Visibility moderate.
7	10 nautical miles	Visibility good.
8	30 nautical miles	Visibility very good.
9	Over 30	Visibility excellent.

Table 5.—STATE OF SEA—WIND WAVES
(WMO Code 75)

Code	Description	Height	
		Feet	Meters
0	Calm—glassy	0	0
1	Calm—ripples	0–⅓	0–1/10
2	Smooth—wavelets	⅓–1⅔	1/10–½
3	Slight	1⅔–4	½–1¼
4	Moderate	4–8	1¼–2½
5	Rough	8–13	2½–4
6	Very rough	13–20	4–6
7	High	20–30	6–9
8	Very high	30–45	9–14
9	Phenomenal	over 45	over 14

NOTE: The exact bounding height is to be assigned to the lower code figure, that is, a height of 4 feet is coded as 3.

Table 6.—SWELL CONDITION CODE

Code	Height in feet	Description	Approximate length in feet
0	0—no swell		0.
1	1 to 6—low swell	Short or average	0 to 600.
2	1 to 6—low swell	Long	Above 600.
3	6 to 12—moderate	Short	0 to 300.
4	6 to 12—moderate	Average	300 to 600.
5	6 to 12—moderate	Long	Above 600.
6	Greater than 12—high	Short	0 to 300.
7	Greater than 12—high	Average	300 to 600.
8	Greater than 12—high	Long	Above 600.
9	Confused		

Table 7.—BOTTOM TYPE CODE

Code	*Description*
0	Not otherwise specified.
1	Mud or ooze.
2	Sand and mud.
3	Sand.
4	Sand, with shells and/or gravel.
5	Shells.
6	Gravel.
7	Rock.
8	Coral.
9	Stone.

Table 8.—COMPASS DIRECTION CODE

True Direction From Which Surface Wind is Blowing or From Which Wave System is Approaching, in 10° intervals. (WMO Code 23)

Code	
00	Calm.
01	5° to 14°.
02	15° to 24° NNE.
03	25° to 34°.
04	35° to 44°.
05	45° to 54° NE.
06	55° to 64°.
07	65° to 74° ENE.
08	75° to 84°.
09	85° to 94° E.
10	95° to 104°.
11	105° to 114° ESE.
12	115° to 124°.
13	125° to 134°.
14	135° to 144° SE.
15	145° to 154°.
16	155° to 164° SSE.
17	165° to 174°.
18	175° to 184° S.
19	185° to 194°.
20	195° to 204° SSW.
21	205° to 214°.
22	215° to 224°.
23	225° to 234° SW.
24	235° to 244°.
25	245° to 254° WSW.
26	255° to 264°.
27	265° to 274° W.
28	275° to 284°.
29	285° to 294° WNW.
30	295° to 304°.
31	305° to 314°.
32	315° to 324° NW.
33	325° to 334°.
34	335° to 344° NNW.
35	345° to 354°.
36	355° to 4° N.
99	Direction variable or unknown.

Table 9.—WIND FORCE CODE—BEAUFORT'S SCALE AND VELOCITY

(WMO Code 30)

Code	Description	Knots
0	Calm	Less than 1.
1	Light air	1 to 3.
2	Light breeze	4 to 6.
3	Gentle breeze	7 to 10.
4	Moderate breeze	11 to 16.
5	Fresh breeze	17 to 21.
6	Strong breeze	22 to 27.
7	Moderate gale	28 to 33.
8	Fresh gale	34 to 40.
9	Strong gale	41 to 47.
10	Whole gale	48 to 55.
11	Storm	56 to 63.
12	Hurricane	64 to 71.
13	do	72 to 80.
14	do	81 to 89.
15	do	90 to 99.
16	do	100 to 109.
17	do	110 to 118.

Table 10A.—VELOCITY CONVERSION—KNOTS TO METERS PER SECOND

Knots	0	1	2	3	4	5	6	7	8	9
00	00. 0	00. 5	01. 0	01. 5	02. 1	02. 6	03. 1	03. 6	04. 1	04. 6
10	05. 2	05. 7	06. 2	06. 7	07. 2	07. 7	08. 2	08. 8	09. 3	09. 8
20	10. 3	10. 8	11. 3	11. 8	12. 4	12. 9	13. 4	13. 9	14. 4	14. 9
30	15. 4	16. 0	16. 5	17. 0	17. 5	18. 0	18. 5	19. 1	19. 6	20. 1
40	20. 6	21. 1	21. 6	22. 1	22. 7	23. 2	23. 7	24. 2	24. 7	25. 2
50	25. 7	26. 3	26. 8	27. 3	27. 8	28. 3	28. 8	29. 3	29. 9	30. 4
60	30. 9	31. 4	31. 9	32. 4	33. 0	33. 5	34. 0	34. 5	35. 0	35. 5
70	36. 0	36. 6	37. 1	37. 6	38. 1	38. 6	39. 1	39. 6	40. 2	40. 7
80	41. 2	41. 7	42. 2	42. 7	43. 2	43. 8	44. 3	44. 8	45. 3	45. 9
90	46. 3	46. 9	47. 4	47. 9	48. 4	48. 9	49. 4	49. 9	50. 5	51. 0

Table 10B.—VELOCITY CONVERSION—KNOTS TO CENTIMETERS PER SECOND

Knots	0. 0	0. 1	0. 2	0. 3	0. 4	0. 5	0. 6	0. 7	0. 8	0. 9
0	0. 0	5. 1	10. 3	15. 4	20. 6	25. 7	30. 9	36. 0	41. 2	46. 3
1	51. 5	56. 6	61. 8	66. 9	72. 1	77. 2	82. 4	87. 5	92. 7	97. 8
2	103. 0	108. 1	113. 3	118. 4	123. 5	128. 7	133. 8	139. 0	144. 1	149. 3
3	154. 4	159. 6	164. 7	169. 9	175. 0	180. 2	185. 3	190. 5	195. 6	200. 8
4	205. 9	211. 1	216. 2	221. 4	226. 5	231. 7	236. 8	242. 0	247. 1	252. 2
5	257. 4	262. 5	267. 7	272. 8	278. 0	283. 1	288. 3	293. 4	298. 6	303. 7
6	308. 9	314. 0	319. 2	324. 3	329. 5	334. 6	339. 8	344. 9	350. 1	355. 2
7	360. 4	365. 5	370. 6	375. 8	380. 9	386. 1	391. 2	396. 4	401. 5	406. 7
8	411. 8	417. 0	422. 1	427. 3	432. 4	437. 6	442. 7	447. 9	453. 0	458. 2
9	463. 3	468. 5	473. 6	478. 8	483. 9	489. 1	494. 2	499. 3	504. 5	509. 6

Table 10C.—VELOCITY CONVERSION—CENTIMETERS PER SECOND TO KNOTS

Cm./sec.	0	1	2	3	4	5	6	7	8	9
0	0. 00	0. 02	0. 04	0. 06	0. 08	0. 10	0. 12	0. 14	0. 16	0. 17
10	. 19	. 21	. 23	. 25	. 27	. 29	. 31	. 33	. 35	. 37
20	. 39	. 41	. 43	. 45	. 47	. 49	. 51	. 52	. 54	. 56
30	. 58	. 60	. 62	. 64	. 66	. 68	. 70	. 72	. 74	. 76
40	. 78	. 80	. 82	. 84	. 85	. 87	. 89	. 91	. 93	. 95
50	. 97	. 99	1. 01	1. 03	1. 05	1. 07	1. 09	1. 11	1. 13	1. 15
60	1. 17	1. 18	1. 20	1. 22	1. 24	1. 26	1. 28	1. 30	1. 32	1. 34
70	1. 36	1. 38	1. 40	1. 42	1. 44	1. 46	1. 48	1. 50	1. 52	1. 53
80	1. 55	1. 57	1. 59	1. 61	1. 63	1. 65	1. 67	1. 69	1. 71	1. 73
90	1. 75	1. 77	1. 79	1. 81	1. 83	1. 85	1. 86	1. 88	1. 90	1. 92
100	1. 94	1. 96	1. 98	2. 00	2. 02	2. 04	2. 06	2. 08	2. 10	2. 12
110	2. 14	2. 16	2. 18	2. 20	2. 21	2. 23	2. 25	2. 27	2. 29	2. 31
120	2. 33	2. 35	2. 37	2. 39	2. 41	2. 43	2. 45	2. 47	2. 49	2. 51
130	2. 53	2. 54	2. 56	2. 58	2. 60	2. 62	2. 64	2. 66	2. 68	2. 70
140	2. 72	2. 74	2. 76	2. 78	2. 80	2. 82	2. 84	2. 86	2. 87	2. 89
150	2. 91	2. 93	2. 95	2. 97	2. 99	3. 01	3. 03	3. 05	3. 07	3. 09
160	3. 11	3. 13	3. 15	3. 17	3. 19	3. 21	3. 22	3. 24	3. 26	3. 28
170	3. 30	3. 32	3. 34	3. 36	3. 38	3. 40	3. 42	3. 44	3. 46	3. 48
180	3. 50	3. 52	3. 54	3. 55	3. 57	3. 59	3. 61	3. 63	3. 65	3. 67
190	3. 69	3. 71	3. 73	3. 75	3. 77	3. 79	3. 81	3. 83	3. 85	3. 87
200	3. 89	3. 90	3. 92	3. 94	3. 96	3. 98	4. 00	4. 02	4. 04	4. 06
210	4. 08	4. 10	4. 12	4. 14	4. 16	4. 18	4. 20	4. 22	4. 23	4. 25
220	4. 27	4. 29	4. 31	4. 33	4. 35	4. 37	4. 39	4. 41	4. 43	4. 45
230	4. 47	4. 49	4. 51	4. 53	4. 55	4. 56	4. 58	4. 60	4. 62	4. 64
240	4. 66	4. 68	4. 70	4. 72	4. 74	4. 76	4. 78	4. 80	4. 82	4. 84
250	4. 86	4. 88	4. 90	4. 91	4. 93	4. 95	4. 97	4. 99	5. 01	5. 03
260	5. 05	5. 07	5. 09	5. 11	5. 13	5. 15	5. 17	5. 19	5. 21	5. 23
270	5. 24	5. 26	5. 28	5. 30	5. 32	5. 34	5. 36	5. 38	5. 40	5. 42
280	5. 44	5. 46	5. 48	5. 50	5. 52	5. 54	5. 56	5. 58	5. 59	5. 61
290	5. 63	5. 65	5. 67	5. 69	5. 71	5. 73	5. 75	5. 77	5. 79	5. 81

Table 10D.—VELOCITY CONVERSION—FEET PER SECOND TO KNOTS

Ft./sec.	0. 00	0. 01	0. 02	0. 03	0. 04	0. 05	0. 06	0. 07	0. 08	0. 09
0. 00										0. 05
0. 10	0. 06	0. 07	0. 07	0. 08	0. 08	0. 09	0. 09	0. 10	0. 11	. 11
0. 20	. 12	. 12	. 13	. 14	. 14	. 15	. 15	. 16	. 17	. 17
0. 30	. 18	. 18	. 19	. 20	. 20	. 21	. 21	. 22	. 23	. 23
0. 40	. 24	. 24	. 25	. 26	. 26	. 27	. 27	. 28	. 28	. 29
0. 50	. 30	. 30	. 31	. 31	. 32	. 33	. 33	. 34	. 34	. 35
0. 60	. 36	. 36	. 37	. 37	. 38	. 39	. 39	. 40	. 40	. 41
0. 70	. 41	. 42	. 43	. 43	. 44	. 44	. 45	. 46	. 46	. 47
0. 80	. 47	. 48	. 49	. 49	. 50	. 50	. 51	. 52	. 52	. 53
0. 90	. 53	. 54	. 54	. 55	. 56	. 56	. 57	. 57	. 58	. 59

Ft./sec.	0. 0	0. 1	0. 2	0. 3	0. 4	0. 5	0. 6	0. 7	0. 8	0. 9
1. 0	0. 6	0. 7	0. 7	0. 8	0. 8	0. 9	1. 0	1. 0	1. 1	1. 1
2. 0	1. 2	1. 2	1. 3	1. 4	1. 4	1. 5	1. 5	1. 6	1. 7	1. 7
3. 0	1. 8	1. 8	1. 9	2. 0	2. 0	2. 1	2. 1	2. 2	2. 2	2. 3
4. 0	2. 4	2. 4	2. 5	2. 5	2. 6	2. 7	2. 7	2. 8	2. 8	2. 9
5. 0	3. 0	3. 0	3. 1	3. 1	3. 2	3. 3	3. 3	3. 4	3. 4	3. 5
6. 0	3. 6	3. 6	3. 7	3. 7	3. 8	3. 8	3. 9	4. 0	4. 0	4. 1
7. 0	4. 1	4. 2	4. 3	4. 3	4. 4	4. 4	4. 5	4. 6	4. 6	4. 7
8. 0	4. 7	4. 8	4. 9	4. 9	5. 0	5. 0	5. 1	5. 2	5. 2	5. 3
9. 0	5. 3	5. 4	5. 4	5. 5	5. 6	5. 6	5. 7	5. 7	5. 8	5. 9

Table 11A.—BAROMETRIC PRESSURE CONVERSION—INCHES TO MILLIBARS

[Neglecting 900 and 1,000 millibars. For example: 45=945, and 03=1003.]

Inches	0. 00	0. 01	0. 02	0. 03	0. 04	0. 05	0. 06	0. 07	0. 08	0. 09
27.9	45	45	46	46	46	46	47	47	48	48
28.0	48	48	49	49	50	50	50	51	51	51
28.1	52	52	52	53	53	53	54	54	54	55
28.2	55	55	56	56	56	57	57	57	58	58
28.3	58	59	59	59	60	60	60	61	61	61
28.4	62	62	62	63	63	63	64	64	64	65
28.5	65	66	66	66	66	67	67	68	68	68
28.6	68	68	69	70	70	70	70	71	72	72
28.7	72	72	73	73	73	74	74	74	75	75
28.8	75	76	76	76	77	77	77	78	78	78
28.9	79	79	79	80	80	80	81	81	81	82
29.0	82	82	83	83	83	84	84	84	85	85
29.1	85	86	86	86	87	87	88	88	88	88
29.2	89	89	90	90	90	90	91	91	92	92
29.3	92	93	93	93	94	94	94	95	95	95
29.4	96	96	96	97	97	97	98	98	98	99
29.5	99	99	00	00	00	01	01	01	02	02
29.6	02	03	03	03	04	04	04	05	05	05
29.7	06	06	06	07	07	08	08	08	08	09
29.8	09	10	10	10	10	11	11	12	12	12
29.9	12	13	13	14	14	14	15	15	15	16
30.0	16	16	17	17	17	18	18	18	19	19
30.1	19	20	20	20	21	21	21	22	22	22
30.2	23	23	23	24	24	24	25	25	25	26
30.3	26	26	27	27	27	28	28	28	29	29
30.4	30	30	30	30	31	31	32	32	32	32
30.5	33	33	34	34	34	34	35	35	36	36
30.6	36	37	37	37	38	38	38	39	39	39
30.7	40	40	40	41	41	41	42	42	42	43
30.8	43	43	44	44	44	------	------	------	------	------

Table 11B.—BAROMETRIC PRESSURE CONVERSION—MILLIMETERS TO MILLIBARS

[Neglecting 900 and 1,000 millibars. For example: 45=945, and 03=1003.]

Millimeters	0	1	2	3	4	5	6	7	8	9
720	60	61	63	64	65	67	68	69	71	72
730	73	75	76	77	79	80	81	83	84	85
740	87	88	89	91	92	93	95	96	97	99
750	00	01	03	04	05	07	08	09	11	12
760	13	15	16	17	19	20	21	23	24	25
770	27	28	29	31	32	33	35	36	37	39
780	40	41	43	44	45	47	48	49	51	52
790	53	55	56	57	59	60	61	63	64	65

Table 12A.—DEPTH CONVERSION—FATHOMS TO METERS

[1 fathom=1.8285 meters]

Fathoms	0	1	2	3	4	5	6	7	8	9
0	0. 0	1. 8	3. 7	5. 5	7. 3	9. 1	11. 0	12. 8	14. 6	16. 5
10	18. 3	20. 1	21. 9	23. 8	25. 6	27. 4	29. 3	31. 1	32. 9	34. 7
20	36. 6	38. 4	40. 2	42. 1	43. 9	45. 7	47. 5	49. 4	51. 2	53. 0
30	54. 9	56. 7	58. 5	60. 3	62. 2	64. 0	65. 8	67. 7	69. 5	71. 3
40	73. 2	75. 0	76. 8	78. 6	80. 5	82. 3	84. 1	86. 0	87. 8	89. 6
50	91. 4	93. 3	95. 1	96. 9	98. 8	100. 6	102. 4	104. 2	106. 1	107. 9
60	109. 7	111. 6	113. 4	115. 2	117. 0	118. 9	120. 7	122. 5	124. 4	126. 2
70	128. 0	129. 8	131. 7	133. 5	135. 3	137. 2	139. 0	140. 8	142. 6	144. 5
80	146. 3	148. 1	150. 0	151. 8	153. 6	155. 4	157. 3	159. 1	160. 9	162. 8
90	164. 6	166. 4	168. 2	170. 1	171. 9	173. 7	175. 6	177. 4	179. 2	181. 0
100	182. 9	184. 7	186. 5	188. 4	190. 2	192. 0	193. 8	195. 7	197. 5	199. 3
110	201. 2	203. 0	204. 8	206. 7	208. 5	210. 3	212. 1	214. 0	215. 8	217. 6
120	219. 5	221. 3	223. 1	224. 9	226. 8	228. 6	230. 4	232. 3	234. 1	235. 9
130	237. 7	239. 6	241. 4	243. 2	245. 1	246. 9	248. 7	250. 5	252. 4	254. 2
140	256. 0	257. 9	259. 7	261. 5	263. 3	265. 2	267. 0	268. 8	270. 7	272. 5
150	274. 3	276. 1	278. 0	279. 8	281. 6	283. 5	285. 3	287. 1	288. 9	290. 8
160	292. 6	294. 4	296. 3	298. 1	299. 9	301. 7	303. 6	305. 4	307. 2	309. 1
170	310. 9	312. 7	314. 5	316. 4	318. 2	320. 0	321. 9	323. 7	325. 5	327. 3
180	329. 2	331. 0	332. 8	334. 7	336. 5	338. 3	340. 2	342. 0	343. 8	345. 6
190	347. 5	349. 3	351. 1	353. 0	354. 8	356. 6	358. 4	360. 3	362. 1	363. 9
200	365. 8	367. 6	369. 4	371. 2	373. 1	374. 9	376. 7	378. 6	380. 4	382. 2
210	384. 0	385. 9	387. 7	389. 5	391. 4	393. 2	395. 0	396. 8	398. 7	400. 5
220	402. 3	404. 2	406. 0	407. 8	409. 6	411. 5	413. 3	415. 1	417. 0	418. 8
230	420. 6	422. 4	424. 3	426. 1	427. 9	429. 8	431. 6	433. 4	435. 2	437. 1
240	438. 9	440. 7	442. 6	444. 4	446. 2	448. 0	449. 9	451. 7	453. 5	455. 4
250	457. 2	459. 0	460. 1	462. 7	464. 5	466. 3	468. 2	470. 0	471. 8	473. 7
260	475. 5	477. 3	479. 1	481. 0	482. 7	484. 6	486. 5	488. 3	490. 1	491. 9
270	493. 8	495. 6	497. 4	499. 3	501. 1	502. 9	504. 7	506. 6	508. 4	510. 2
280	512. 1	513. 9	515. 7	517. 5	519. 4	521. 2	523. 0	524. 9	526. 7	528. 5
290	530. 3	532. 2	534. 0	535. 8	537. 7	539. 5	541. 3	543. 1	545. 0	546. 8

Fathoms	0	10	20	30	40	50	60	70	80	90
300	549	567	585	603	622	640	658	677	695	713
400	732	750	768	786	805	823	841	860	878	896
500	914	933	951	969	988	1, 006	1, 024	1, 042	1, 061	1, 079
600	1, 097	1, 116	1, 134	1, 152	1, 170	1, 189	1, 207	1, 225	1, 244	1, 262
700	1, 280	1, 298	1, 317	1, 335	1, 353	1, 372	1, 390	1, 408	1, 426	1, 445
800	1, 463	1, 481	1, 500	1, 518	1, 536	1, 554	1, 573	1, 591	1, 609	1, 628
900	1, 646	1, 664	1, 682	1, 701	1, 719	1, 737	1, 756	1, 774	1, 792	1, 810

Fathoms	0	100	200	300	400	500	600	700	800	900
1,000	1, 829	2, 012	2, 195	2, 377	2, 560	2, 743	2, 926	3, 109	3, 292	3, 475
2,000	3, 658	3, 840	4, 023	4, 206	4, 389	4, 572	4, 755	4, 938	5, 121	5, 303
3,000	5, 486	5, 669	5, 852	6, 035	6, 218	6, 401	6, 584	6, 766	6, 949	7, 132
4,000	7, 315	7, 498	7, 681	7, 864	8, 047	8, 229	8, 412	8, 595	8, 778	8, 961
5,000	9, 144	9, 327	9, 510	9, 692	9, 875	10, 058	10, 241	10, 424	10, 607	10, 790
6,000	10, 973	11, 155	11, 338	11, 521	11, 704	11, 887	12, 070	12, 253	12, 436	12, 618
7,000	12, 801	12, 984	13, 167	13, 350	13, 533	13, 716	13, 899	14, 082	14, 264	14, 447
8,000	14, 630	14, 813	14, 996	15, 179	15, 362	15, 545	15, 727	15, 910	16, 093	16, 276
9,000	16, 459	16, 642	16, 825	17, 008	17, 190	17, 373	17, 556	17, 739	17, 922	18, 105

Meters	0	1	2	3	4	5	6	7	8	9
0	0.0	0.5	1.1	1.6	2.2	2.7	3.3	3.8	4.4	4.9
10	5.5	6.0	6.6	7.1	7.7	8.2	8.7	9.3	9.8	10.4
20	10.9	11.5	12.0	12.6	13.1	13.7	14.2	14.8	15.3	15.9
30	16.4	17.0	17.5	18.0	18.6	19.1	19.7	20.2	20.8	21.3
40	21.9	22.4	23.0	23.5	24.1	24.6	25.2	25.7	26.2	26.8
50	27.3	27.9	28.4	29.0	29.5	30.1	30.6	31.2	31.7	32.3
60	32.8	33.4	33.9	34.4	35.0	35.5	36.1	36.6	37.2	37.7
70	38.3	38.8	39.4	39.9	40.5	41.0	41.6	42.1	42.7	43.2
80	43.7	44.3	44.8	45.4	45.9	46.5	47.0	47.6	48.1	48.7
90	49.2	49.8	50.3	50.9	51.4	51.9	52.5	53.0	53.6	54.1
100	54.7	55.2	55.8	56.3	56.9	57.4	58.0	58.5	59.1	59.6
110	60.1	60.7	61.2	61.8	62.3	62.9	63.4	64.0	64.5	65.1
120	65.6	66.2	66.7	67.3	67.8	68.4	68.9	69.4	70.0	70.5
130	71.1	71.6	72.2	72.7	73.3	73.8	74.4	74.9	75.5	76.0
140	76.6	77.1	77.6	78.2	78.7	79.3	79.8	80.4	80.9	81.5
150	82.0	82.6	83.1	83.7	84.2	84.8	85.3	85.9	86.4	86.9
160	87.5	88.0	88.6	89.1	89.7	90.2	90.8	91.3	91.9	92.4
170	93.0	93.5	94.1	94.6	95.1	95.7	96.2	96.8	97.3	97.9
180	98.4	99.0	99.5	100.1	100.6	101.2	101.7	102.3	102.8	103.3
190	103.9	104.4	105.0	105.5	106.1	106.6	107.2	107.7	108.3	108.8
200	109.4	109.9	110.5	111.0	111.6	112.1	112.6	113.2	113.7	114.3
210	114.8	115.4	115.9	116.5	117.0	117.6	118.1	118.7	119.2	119.8
220	120.3	120.8	121.4	121.9	122.5	123.0	123.6	124.1	124.7	125.2
230	125.8	126.3	126.9	127.4	128.0	128.5	129.0	129.6	130.1	130.7
240	131.2	131.8	132.3	132.9	133.4	134.0	134.5	135.1	135.6	136.2
250	136.7	137.3	137.8	138.3	138.9	139.4	140.0	140.5	141.1	141.6
260	142.2	142.7	143.3	143.8	144.4	144.9	145.5	146.0	146.5	147.1
270	147.6	148.2	148.7	149.3	149.8	150.4	150.9	151.5	152.0	152.6
280	153.1	153.7	154.2	154.7	155.3	155.8	156.4	156.9	157.5	158.0
290	158.6	159.1	159.7	160.2	160.8	161.3	161.9	162.4	163.0	163.5

Meters	0	10	20	30	40	50	60	70	80	90
300	164	170	175	180	186	191	197	202	208	213
400	219	224	230	235	241	246	252	257	262	268
500	273	279	284	290	295	301	306	312	317	323
600	328	334	339	344	350	355	361	366	372	377
700	383	388	394	399	405	410	416	421	427	432
800	437	443	448	454	459	465	470	476	481	487
900	492	498	503	509	514	519	525	530	536	541

Meters	0	100	200	300	400	500	600	700	800	900
1,000	547	601	656	711	766	820	875	930	984	1,039
2,000	1,094	1,148	1,203	1,258	1,312	1,367	1,422	1,476	1,531	1,586
3,000	1,640	1,695	1,750	1,804	1,859	1,914	1,969	2,023	2,078	2,133
4,000	2,187	2,242	2,297	2,351	2,406	2,461	2,515	2,570	2,625	2,679
5,000	2,734	2,789	2,843	2,898	2,953	3,007	3,062	3,117	3,172	3,226
6,000	3,281	3,336	3,390	3,445	3,500	3,554	3,609	3,664	3,718	3,773
7,000	3,828	3,882	3,937	3,992	4,046	4,101	4,156	4,210	4,265	4,320
8,000	4,375	4,429	4,484	4,539	4,593	4,648	4,703	4,757	4,812	4,867
9,000	4,921	4,976	5,031	5,085	5,140	5,195	5,249	5,304	5,359	5,413

Table 12C.—DEPTH CONVERSION—FEET TO METERS

Feet	0	1	2	3	4	5	6	7	8	9
0	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7
10	3.0	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.5	5.8
20	6.1	6.4	6.7	7.0	7.3	7.6	7.9	8.2	8.5	8.8
30	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.6	11.9
40	12.2	12.5	12.8	13.1	13.4	13.7	14.0	14.3	14.6	14.9
50	15.2	15.5	15.8	16.1	16.5	16.8	17.1	17.4	17.7	18.0
60	18.3	18.6	18.9	19.2	19.5	19.8	20.1	20.4	20.7	21.0
70	21.3	21.6	21.9	22.3	22.6	22.9	23.2	23.5	23.8	24.1
80	24.4	24.7	25.0	25.3	25.6	25.9	26.2	26.5	26.8	27.1
90	27.4	27.7	28.0	28.3	28.7	29.0	29.3	29.6	29.9	30.2
100	30.5	30.8	31.1	31.4	31.7	32.0	32.3	32.6	32.9	33.2
110	33.5	33.8	34.1	34.4	34.7	35.1	35.4	35.7	36.0	36.3
120	36.6	36.9	37.2	37.5	37.8	38.1	38.4	38.7	39.0	39.3
130	39.6	39.9	40.2	40.5	40.8	41.1	41.5	41.8	42.1	42.4
140	42.7	43.0	43.3	43.6	43.9	44.2	44.5	44.8	45.1	45.4
150	45.7	46.0	46.3	46.6	46.9	47.2	47.5	47.9	48.2	48.5
160	48.8	49.1	49.4	49.7	50.0	50.3	50.6	50.9	51.2	51.5
170	51.8	52.1	52.4	52.7	53.0	53.3	53.6	53.9	54.3	54.6
180	54.9	55.2	55.5	55.8	56.1	56.4	56.7	57.0	57.3	57.6
190	57.9	58.2	58.5	58.8	59.1	59.4	59.7	60.0	60.4	60.7
200	61.0	61.3	61.6	61.9	62.2	62.5	62.8	63.1	63.4	63.7
210	64.0	64.3	64.6	64.9	65.2	65.5	65.8	66.1	66.4	66.8
220	67.1	67.4	67.7	68.0	68.3	68.6	68.9	69.2	69.5	69.8
230	70.1	70.4	70.7	71.0	71.3	71.6	71.9	72.2	72.5	72.8
240	73.2	73.5	73.8	74.1	74.4	74.7	75.0	75.3	75.6	75.9
250	76.2	76.5	76.8	77.1	77.4	77.7	78.0	78.3	78.6	78.9
260	79.2	79.6	79.9	80.2	80.5	80.8	81.1	81.4	81.7	82.0
270	82.3	82.6	82.9	83.2	83.5	83.8	84.1	84.4	84.7	85.0
280	85.3	85.6	86.0	86.3	86.6	86.9	87.2	87.5	87.8	88.1
290	88.4	88.7	89.0	89.3	89.6	89.9	90.2	90.5	90.8	91.1

Feet	00	10	20	30	40	50	60	70	80	90
300	91.4	94.5	97.5	100.6	103.6	106.7	109.7	112.8	115.8	118.9
400	121.9	125.0	128.0	131.1	134.1	137.2	140.2	143.3	146.3	149.4
500	152.4	155.4	158.5	161.5	164.6	167.6	170.7	173.7	176.8	179.8
600	182.9	185.9	189.0	192.0	195.1	198.1	201.2	204.2	207.3	210.3
700	213.4	216.4	219.5	222.5	225.6	228.6	231.6	234.7	237.7	240.8
800	243.8	246.9	249.9	253.0	256.0	259.1	262.1	265.2	268.2	271.3
900	274.3	277.4	280.4	283.5	286.5	289.6	292.6	295.7	298.7	301.8

Feet	000	100	200	300	400	500	600	700	800	900
1,000	305	335	366	396	427	457	488	518	549	579
2,000	610	640	671	701	732	762	792	823	853	884
3,000	914	945	975	1,006	1,036	1,067	1,097	1,128	1,158	1,189
4,000	1,219	1,250	1,280	1,311	1,341	1,372	1,402	1,433	1,463	1,494
5,000	1,524	1,554	1,585	1,615	1,646	1,676	1,707	1,737	1,768	1,798
6,000	1,829	1,859	1,890	1,920	1,951	1,981	2,012	2,042	2,073	2,103
7,000	2,134	2,164	2,195	2,225	2,256	2,286	2,316	2,347	2,377	2,408
8,000	2,438	2,469	2,499	2,530	2,560	2,591	2,621	2,652	2,682	2,713
9,000	2,743	2,774	2,804	2,835	2,865	2,896	2,926	2,957	2,987	3,018

Table 12D.—DEPTH CONVERSION—METERS TO FEET

Meters	0	1	2	3	4	5	6	7	8	9
0	0. 0	3. 3	6. 6	9. 8	13. 1	16. 4	19. 7	23. 0	26. 2	29. 5
10	32. 8	36. 1	39. 4	42. 7	45. 9	49. 2	52. 5	55. 8	59. 1	62. 3
20	65. 6	68. 9	72. 2	75. 5	78. 7	82. 0	85. 3	88. 6	91. 9	95. 1
30	98. 4	101. 7	105. 0	108. 3	111. 5	114. 8	118. 1	121. 4	124. 7	128. 0
40	131. 2	134. 5	137. 8	141. 1	144. 4	147. 6	150. 9	154. 2	157. 5	160. 8
50	164. 0	167. 3	170. 6	173. 9	177. 2	180. 4	183. 7	187. 0	190. 3	193. 6
60	196. 8	200. 1	203. 4	206. 7	210. 0	213. 3	216. 5	219. 8	223. 1	226. 4
70	229. 7	232. 9	236. 2	239. 5	242. 8	246. 1	249. 3	252. 6	255. 9	259. 2
80	262. 5	265. 7	269. 0	272. 3	275. 6	278. 9	282. 2	285. 4	288. 7	292. 0
90	295. 3	298. 6	301. 8	305. 1	308. 4	311. 7	315. 0	318. 2	321. 5	324. 8
100	328. 1	331. 4	334. 6	337. 9	341. 2	344. 5	347. 8	351. 0	354. 3	357. 6
110	360. 9	364. 2	367. 5	370. 7	374. 0	377. 3	380. 6	383. 9	387. 1	390. 4
120	393. 7	397. 0	400. 3	403. 5	406. 8	410. 1	413. 4	416. 7	419. 9	423. 2
130	426. 5	429. 8	433. 1	436. 4	439. 6	442. 9	446. 2	449. 5	452. 8	456. 0
140	459. 3	462. 6	465. 9	469. 2	472. 4	475. 7	479. 0	482. 3	485. 6	488. 8
150	492. 1	495. 4	498. 7	502. 0	505. 2	508. 5	511. 8	515. 1	518. 4	521. 7
160	524. 9	528. 2	531. 5	534. 8	538. 1	541. 3	544. 6	547. 9	551. 2	554. 5
170	557. 7	561. 0	564. 3	567. 6	570. 9	574. 1	577. 4	580. 7	584. 0	587. 3
180	590. 5	593. 8	597. 1	600. 4	603. 7	607. 0	610. 2	613. 5	616. 8	620. 1
190	623. 4	626. 6	629. 9	633. 2	636. 5	639. 8	643. 0	646. 3	649. 6	652. 9
200	656. 2	659. 4	662. 7	666. 0	669. 3	672. 6	675. 9	679. 1	682. 4	685. 7
210	689. 0	692. 3	695. 5	698. 8	702. 1	705. 4	708. 7	711. 9	715. 2	718. 5
220	721. 8	725. 1	728. 3	731. 6	734. 9	738. 2	741. 5	744. 7	748. 0	751. 3
230	754. 6	757. 9	761. 2	764. 4	767. 7	771. 0	774. 3	777. 6	780. 8	784. 1
240	787. 4	790. 7	794. 0	797. 2	800. 5	803. 8	807. 1	810. 4	813. 6	816. 9
250	820. 2	823. 5	826. 8	830. 1	833. 3	836. 6	839. 9	843. 2	846. 5	849. 7
260	853. 0	856. 3	859. 6	862. 9	866. 1	869. 4	872. 7	876. 0	879. 3	882. 5
270	885. 8	889. 1	892. 4	895. 7	898. 9	902. 2	905. 5	908. 8	912. 1	915. 4
280	918. 6	921. 9	925. 2	928. 5	931. 8	935. 0	938. 3	941. 6	944. 9	948. 2
290	951. 4	954. 7	958. 0	961. 3	964. 6	967. 8	971. 1	974. 4	977. 7	981. 0

Meters	00	10	20	30	40	50	60	70	80	90
300	984. 2	1, 017. 1	1, 049. 9	1, 082. 7	1, 115. 5	1, 148. 3	1, 181. 1	1, 213. 9	1, 246. 7	1, 279. 5
400	1, 312. 3	1, 345. 1	1, 377. 9	1, 410. 8	1, 443. 6	1, 476. 4	1, 509. 2	1, 542. 0	1, 574. 8	1, 607. 6
500	1, 640. 4	1, 673. 2	1, 706. 0	1, 738. 8	1, 771. 6	1, 804. 5	1, 837. 3	1, 870. 1	1, 902. 9	1, 935. 7
600	1, 968. 5	2, 001. 3	2, 034. 1	2, 066. 9	2, 099. 7	2, 132. 5	2, 165. 3	2, 198. 2	2, 231. 0	2, 263. 8
700	2, 296. 6	2, 329. 4	2, 362. 2	2, 395. 0	2, 427. 8	2, 460. 6	2, 493. 4	2, 526. 2	2, 559. 0	2, 591. 9
800	2, 624. 7	2, 657. 5	2, 690. 3	2, 723. 1	2, 755. 9	2, 788. 7	2, 821. 5	2, 854. 3	2, 887. 1	2, 919. 9
900	2, 952. 7	2, 985. 6	3, 018. 4	3, 051. 2	3, 084. 0	3, 116. 8	3, 149. 6	3, 182. 4	3, 215. 2	3, 248. 0

Meters	000	100	200	300	400	500	600	700	800	900
1, 000	3, 281	3, 609	3, 937	4, 265	4, 593	4, 921	5, 249	5, 577	5, 905	6, 234
2, 000	6, 562	6, 890	7, 218	7, 546	7, 874	8, 202	8, 530	8, 858	9, 186	9, 514
3, 000	9, 842	10, 171	10, 499	10, 827	11, 155	11, 483	11, 811	12, 139	12, 467	12, 795
4, 000	13, 123	13, 451	13, 779	14, 108	14, 436	14, 764	15, 092	15, 420	15, 748	16, 076
5, 000	16, 404	16, 732	17, 060	17, 388	17, 716	18, 045	18, 373	18, 701	19, 028	19, 357
6, 000	19, 685	20, 013	20, 341	20, 669	20, 997	21, 325	21, 653	21, 982	22, 310	22, 638
7, 000	22, 966	23, 294	23, 622	23, 950	24, 278	24, 606	24, 934	25, 262	25, 590	25, 919
8, 000	26, 247	26, 575	26, 903	27, 231	27, 559	27, 887	28, 215	28, 543	28, 871	29, 199
9, 000	29, 527	29, 856	30, 184	30, 512	30, 840	31, 168	31, 496	31, 824	32, 152	32, 480

Table 13A.—TEMPERATURE CONVERSION—FAHRENHEIT TO CELSIUS (Centigrade)

°F.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
28	−2.22	−2.17	−2.11	−2.06	−2.00	−1.94	−1.89	−1.83	−1.78	−1.72
29	−1.67	−1.61	−1.56	−1.50	−1.44	−1.39	−1.33	−1.28	−1.22	−1.17
30	−1.11	−1.06	−1.00	−.94	−.89	−.83	−.78	−.72	−.67	−.61
31	−.56	−.50	−.44	−.39	−.33	−.28	−.22	−.17	−.11	−.06
32	.00	.06	.11	.17	.22	.28	.33	.39	.44	.50
33	.56	.61	.67	.72	.78	.83	.89	.94	1.00	1.06
34	1.11	1.17	1.22	1.28	1.33	1.39	1.44	1.50	1.56	1.61
35	1.67	1.72	1.78	1.83	1.89	1.94	2.00	2.06	2.11	2.17
36	2.22	2.28	2.33	2.39	2.44	2.50	2.56	2.61	2.67	2.72
37	2.78	2.83	2.89	2.94	3.00	3.06	3.11	3.17	3.22	3.28
38	3.33	3.39	3.44	3.50	3.56	3.61	3.67	3.72	3.78	3.83
39	3.89	3.94	4.00	4.06	4.11	4.17	4.22	4.28	4.33	4.39
40	4.44	4.50	4.56	4.61	4.67	4.72	4.78	4.83	4.89	4.94
41	5.00	5.06	5.11	5.17	5.22	5.28	5.33	5.39	5.44	5.50
42	5.56	5.61	5.67	5.72	5.78	5.83	5.89	5.94	6.00	6.06
43	6.11	6.17	6.22	6.28	6.33	6.39	6.44	6.50	6.56	6.61
44	6.67	6.72	6.78	6.83	6.89	6.94	7.00	7.06	7.11	7.17
45	7.22	7.28	7.33	7.39	7.44	7.50	7.56	7.61	7.67	7.72
46	7.78	7.83	7.89	7.94	8.00	8.06	8.11	8.17	8.22	8.28
47	8.33	8.39	8.44	8.50	8.56	8.61	8.67	8.72	8.78	8.83
48	8.89	8.94	9.00	9.06	9.11	9.17	9.22	9.28	9.33	9.39
49	9.44	9.50	9.56	9.61	9.67	9.72	9.78	9.83	9.89	9.94
50	10.00	10.06	10.11	10.17	10.22	10.28	10.33	10.39	10.44	10.50
51	10.56	10.61	10.67	10.72	10.78	10.83	10.89	10.94	11.00	11.06
52	11.11	11.17	11.22	11.28	11.33	11.39	11.44	11.50	11.56	11.61
53	11.67	11.72	11.78	11.83	11.89	11.94	12.00	12.06	12.11	12.17
54	12.22	12.28	12.33	12.39	12.44	12.50	12.56	12.61	12.67	12.72
55	12.78	12.83	12.89	12.94	13.00	13.06	13.11	13.17	13.22	13.28
56	13.33	13.39	13.44	13.50	13.56	13.61	13.67	13.72	13.78	13.83
57	13.89	13.94	14.00	14.06	14.11	14.17	14.22	14.28	14.33	14.39
58	14.44	14.50	14.56	14.61	14.67	14.72	14.78	14.83	14.89	14.94
59	15.00	15.06	15.11	15.17	15.22	15.28	15.33	15.39	15.44	15.50
60	15.56	15.61	15.67	15.72	15.78	15.83	15.89	15.94	16.00	16.06
61	16.11	16.17	16.22	16.28	16.33	16.39	16.44	16.50	16.56	16.61
62	16.67	16.72	16.78	16.83	16.89	16.94	17.00	17.06	17.11	17.17
63	17.22	17.28	17.33	17.39	17.44	17.50	17.56	17.61	17.67	17.72
64	17.78	17.83	17.89	17.94	18.00	18.06	18.11	18.17	18.22	18.28
65	18.33	18.39	18.44	18.50	18.56	18.61	18.67	18.72	18.78	18.83
66	18.89	18.94	19.00	19.06	19.11	19.17	19.22	19.28	19.33	19.39
67	19.44	19.50	19.56	19.61	19.67	19.72	19.78	19.83	19.89	19.94
68	20.00	20.06	20.11	20.17	20.22	20.28	20.33	20.39	20.44	20.50
69	20.56	20.61	20.67	20.72	20.78	20.83	20.89	20.94	21.00	21.06
70	21.11	21.17	21.22	21.28	21.33	21.39	21.44	21.50	21.56	21.61
71	21.67	21.72	21.78	21.83	21.89	21.94	22.00	22.06	22.11	22.17
72	22.22	22.28	22.33	22.39	22.44	22.50	22.56	22.61	22.67	22.72
73	22.78	22.83	22.89	22.94	23.00	23.06	23.11	23.17	23.22	23.28
74	23.33	23.39	23.44	23.50	23.56	23.61	23.67	23.72	23.78	23.83
75	23.89	23.94	24.00	24.06	24.11	24.17	24.22	24.28	24.33	24.39
76	24.44	24.50	24.56	24.61	24.67	24.72	24.78	24.83	24.89	24.94
77	25.00	25.06	25.11	25.17	25.22	25.28	25.33	25.39	25.44	25.50
78	25.56	25.61	25.67	25.72	25.78	25.83	25.89	25.94	26.00	26.06
79	26.11	26.17	26.22	26.28	26.33	26.39	26.44	26.50	26.56	26.61
80	26.67	26.72	26.78	26.83	26.89	26.94	27.00	27.06	27.11	27.17
81	27.22	27.28	27.33	27.39	27.44	27.50	27.56	27.61	27.67	27.72
82	27.78	27.83	27.89	27.94	28.00	28.06	28.11	28.17	28.22	28.28
83	28.33	28.39	28.44	28.50	28.56	28.61	28.67	28.72	28.78	28.83
84	28.89	28.94	29.00	29.06	29.11	29.17	29.22	29.28	29.33	29.39

°F.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
85	29. 44	29. 50	29. 56	29. 61	29. 67	29. 72	29. 78	29. 83	29. 89	29. 94
86	30. 00	30. 06	30. 11	30. 17	30. 22	30. 28	30. 33	30. 39	30. 44	30. 50
87	30. 56	30. 61	30. 67	30. 72	30. 78	30. 83	30. 89	30. 94	31. 00	31. 06
88	31. 11	31. 17	31. 22	31. 28	31. 33	31. 39	31. 44	31. 50	31. 56	31. 61
89	31. 67	31. 72	31. 78	31. 83	31. 89	31. 94	32. 00	32. 06	32. 11	32. 17
90	32. 22	32. 28	32. 33	32. 39	32. 44	32. 50	32. 56	32. 61	32. 67	32. 72
91	32. 78	32. 83	32. 89	32. 94	33. 00	33. 06	33. 11	33. 17	33. 22	33. 28
92	33. 33	33. 39	33. 44	33. 50	33. 56	33. 61	33. 67	33. 72	33. 78	33. 83
93	33. 89	33. 94	34. 00	34. 06	34. 11	34. 17	34. 22	34. 28	34. 33	34. 39
94	34. 44	34. 50	34. 56	34. 61	34. 67	34. 72	34. 78	34. 83	34. 89	34. 94
95	35. 00	35. 06	35. 11	35. 17	35. 22	35. 28	35. 33	35. 39	35. 44	35. 50
96	35. 56	35. 61	35. 67	35. 72	35. 78	35. 83	35. 89	35. 94	36. 00	36. 06
97	36. 11	36. 17	36. 22	36. 28	36. 33	36. 39	36. 44	36. 50	36. 56	36. 61
98	36. 67	36. 72	36. 78	36. 83	36. 89	36. 94	37. 00	37. 06	37. 11	37. 17
99	37. 22	37. 28	37. 33	37. 39	37. 44	37. 50	37. 56	37. 61	37. 67	37. 72
100	37. 78	37. 83	37. 89	37. 94	38. 00	38. 06	38. 11	38. 17	38. 22	38. 28
101	38. 33	38. 39	38. 44	38. 50	38. 56	38. 61	38. 67	38. 72	38. 78	38. 83
102	38. 89	38. 94	39. 00	39. 06	39. 11	39. 17	39. 22	39. 28	39. 33	39. 39
103	39. 44	39. 50	39. 56	39. 61	39. 67	39. 72	39. 78	39. 83	39. 89	39. 94
104	40. 00	40. 06	40. 11	40. 17	40. 22	40. 28	40. 33	40. 39	40. 44	40. 50
105	40. 56	40. 61	40. 67	40. 72	40. 78	40. 83	40. 89	40. 94	41. 00	41. 06
106	41. 11	41. 17	41. 22	41. 28	41. 33	41. 39	41. 44	41. 50	41. 56	41. 61
107	41. 67	41. 72	41. 78	41. 83	41. 89	41. 94	42. 00	42. 06	42. 11	42. 17
108	42. 22	42. 28	42. 33	42. 39	42. 44	42. 50	42. 56	42. 61	42. 67	42. 72
109	42. 78	42. 83	42. 89	42. 94	43. 00	43. 06	43. 11	43. 17	43. 22	43. 28
110	43. 33	43. 39	43. 44	43. 50	43. 56	43. 61	43. 67	43. 72	43. 78	43. 83
111	43. 89	43. 94	44. 00	44. 06	44. 11	44. 17	44. 22	44. 28	44. 33	44. 39
112	44. 44	44. 50	44. 56	44. 61	44. 67	44. 72	44. 78	44. 83	44. 89	44. 94
113	45. 00	45. 06	45. 11	45. 17	45. 22	45. 28	45. 33	45. 39	45. 44	45. 50
114	45. 56	45. 61	45. 67	45. 72	45. 78	45. 83	45. 89	45. 94	46. 00	46. 06
115	46. 11	46. 17	46. 22	46. 28	46. 33	46. 39	46. 44	46. 50	46. 56	46. 61
116	46. 67	46. 72	46. 78	46. 83	46. 89	46. 94	47. 00	47. 06	47. 11	47. 17
117	47. 22	47. 28	47. 33	47. 39	47. 44	47. 50	47. 56	47. 61	47. 67	47. 72
118	47. 78	47. 83	47. 89	47. 94	48. 00	48. 06	48. 11	48. 17	48. 22	48. 28
119	48. 33	48. 39	48. 44	48. 50	48. 56	48. 61	48. 67	48. 72	48. 78	48. 83
120	48. 89	48. 94	49. 00	49. 06	49. 11	49. 17	49. 22	49. 28	49. 33	49. 39
121	49. 44	49. 50	49. 56	49. 61	49. 67	49. 72	49. 78	49. 83	49. 89	49. 94
122	50. 00	50. 06	50. 11	50. 17	50. 22	50. 28	50. 33	50. 39	50. 44	50. 50
123	50. 56	50. 61	50. 67	50. 72	50. 78	50. 83	50. 89	50. 94	51. 00	51. 06
124	51. 11	51. 17	51. 22	51. 28	51. 33	51. 33	51. 44	51. 50	51. 56	51. 61
125	51. 67	51. 72	51. 78	51. 83	51. 89	51. 94	52. 00	52. 06	52. 11	52. 17
126	52. 22	52. 28	52. 33	52. 39	52. 44	52. 50	52. 56	52. 61	52. 67	52. 72
127	52. 78	52. 83	52. 89	52. 94	53. 00	53. 06	53. 11	53. 17	53. 22	53. 28
128	53. 33	53. 39	53. 44	53. 50	53. 56	53. 61	53. 67	53. 72	53. 78	53. 83
129	53. 89	53. 94	54. 00	54. 06	54. 11	54. 17	54. 22	54. 28	54. 33	54. 39

350676 O—56——14

Table 13B.—TEMPERATURE CONVERSION—CELSIUS (Centigrade) TO FAHRENHEIT

°C.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
−2	28. 40	28. 22	28. 04	27. 86	27. 68	27. 50	27. 32	27. 14	26. 96	26. 78
−1	30. 20	30. 02	29. 84	29. 66	29. 48	29. 30	29. 12	28. 94	28. 76	28. 58
−0	32. 00	31. 82	31. 64	31. 46	31. 28	31. 10	30. 92	30. 74	30. 56	30. 38
0	32. 00	32. 18	32. 36	32. 54	32. 72	32. 90	33. 08	33. 26	33. 44	33. 62
1	33. 80	33. 98	34. 16	34. 34	34. 52	34. 70	34. 88	35. 06	35. 24	35. 42
2	35. 60	35. 78	35. 96	36. 14	36. 32	36. 50	36. 68	36. 86	37. 04	37. 22
3	37. 40	37. 58	37. 76	37. 94	38. 12	38. 30	38. 48	38. 66	38. 84	39. 02
4	39. 20	39. 38	39. 56	39. 74	39. 92	40. 10	40. 28	40. 46	40. 64	40. 82
5	41. 00	41. 18	41. 36	41. 54	41. 72	41. 90	42. 08	42. 26	42. 44	42. 62
6	42. 80	42. 98	43. 16	43. 34	43. 52	43. 70	43. 88	44. 06	44. 24	44. 42
7	44. 60	44. 78	44. 96	45. 14	45. 32	45. 50	45. 68	45. 86	46. 04	46. 22
8	46. 40	46. 58	46. 76	46. 94	47. 12	47. 30	47. 48	47. 66	47. 84	48. 02
9	48. 20	48. 38	48. 56	48. 74	48. 92	49. 10	49. 28	49. 46	49. 64	49. 82
10	50. 00	50. 18	50. 36	50. 54	50. 72	50. 90	51. 08	51. 26	51. 44	51. 62
11	51. 80	51. 98	52. 16	52. 34	52. 52	52. 70	52. 88	53. 06	53. 24	53. 42
12	53. 60	53. 78	53. 96	54. 14	54. 32	54. 50	54. 68	54. 86	55. 04	55. 22
13	55. 40	55. 58	55. 76	55. 94	56. 12	56. 30	56. 48	56. 66	56. 84	57. 02
14	57. 20	57. 38	57. 56	57. 74	57. 92	58. 10	58. 28	58. 46	58. 64	58. 82
15	59. 00	59. 18	59. 36	59. 54	59. 72	59. 90	60. 08	60. 26	60. 44	60. 62
16	60. 80	60. 98	61. 16	61. 34	61. 52	61. 70	61. 88	62. 06	62. 24	62. 42
17	62. 60	62. 78	62. 96	63. 14	63. 32	63. 50	63. 68	63. 86	64. 04	64. 22
18	64. 40	64. 58	64. 76	64. 94	65. 12	65. 30	65. 48	65. 66	65. 84	66. 02
19	66. 20	66. 38	66. 56	66. 74	66. 92	67. 10	67. 28	67. 46	67. 64	67. 82
20	68. 00	68. 18	68. 36	68. 54	68. 72	68. 90	69. 08	69. 26	69. 44	69. 62
21	69. 80	69. 98	70. 16	70. 34	70. 52	70. 70	70. 88	71. 06	71. 24	71. 42
22	71. 60	71. 78	71. 96	72. 14	72. 32	72. 50	72. 68	72. 86	73. 04	73. 22
23	73. 40	73. 58	73. 76	73. 94	74. 12	74. 30	74. 48	74. 66	74. 84	75. 02
24	75. 20	75. 38	75. 56	75. 74	75. 92	76. 10	76. 28	76. 46	76. 64	76. 82
25	77. 00	77. 18	77. 36	77. 54	77. 72	77. 90	78. 08	78. 26	78. 44	78. 62
26	78. 80	78. 98	79. 16	79. 34	79. 52	79. 70	79. 88	80. 06	80. 24	80. 42
27	80. 60	80. 78	80. 96	81. 14	81. 32	81. 50	81. 68	81. 86	82. 04	82. 22
28	82. 40	82. 58	82. 76	82. 94	83. 12	83. 30	83. 48	83. 66	83. 84	84. 02
29	84. 20	84. 38	84. 56	84. 74	84. 92	85. 10	85. 28	85. 46	85. 64	85. 82
30	86. 00	86. 18	86. 36	86. 54	86. 72	86. 90	87. 08	87. 26	87. 44	87. 62
31	87. 80	87. 98	88. 16	88. 34	88. 52	88. 70	88. 88	89. 06	89. 24	89. 42
32	89. 60	89. 78	89. 96	90. 14	90. 32	90. 50	90. 68	90. 86	91. 04	91. 22
33	91. 40	91. 58	91. 76	91. 94	92. 12	92. 30	92. 48	92. 66	92. 84	93. 02
34	93. 20	93. 38	93. 56	93. 74	93. 92	94. 10	94. 28	94. 46	94. 64	94. 82
35	95. 00	95. 18	95. 36	95. 54	95. 72	95. 90	96. 08	96. 26	96. 44	96. 62
36	96. 80	96. 98	97. 16	97. 34	97. 52	97. 70	97. 88	98. 06	98. 24	98. 42
37	98. 60	98. 78	98. 96	99. 14	99. 32	99. 50	99. 68	99. 86	100. 04	100. 22
38	100. 40	100. 58	100. 76	100. 94	101. 12	101. 30	101. 48	101. 66	101. 84	102. 02
39	102. 20	102. 38	102. 56	102. 74	102. 92	103. 10	103. 28	103. 46	103. 64	103. 82
40	104. 00	104. 18	104. 36	104. 54	104. 72	104. 90	105. 08	105. 26	105. 44	105. 62
41	105. 80	105. 98	106. 16	106. 34	106. 52	106. 70	106. 88	107. 06	107. 24	107. 42
42	107. 60	107. 78	107. 96	108. 14	108. 32	108. 50	108. 68	108. 86	109. 04	109. 22
43	109. 40	109. 58	109. 76	109. 94	110. 12	110. 30	110. 48	110. 66	110. 84	111. 02
44	111. 20	111. 38	111. 56	111. 74	111. 92	112. 10	112. 28	112. 46	112. 64	112. 82
45	113. 00	113. 18	113. 36	113. 54	113. 72	113. 90	114. 08	114. 26	114. 44	114. 62
46	114. 80	114. 98	115. 16	115. 34	115. 52	115. 70	115. 88	116. 06	116. 24	116. 42
47	116. 60	116. 78	116. 96	117. 14	117. 32	117. 50	117. 68	117. 86	118. 04	118. 22
48	118. 40	118. 58	118. 76	118. 94	119. 12	119. 30	119. 48	119. 66	119. 84	120. 02
49	120. 20	120. 38	120. 56	120. 74	120. 92	121. 10	121. 28	121. 46	121. 64	121. 82

Table 14.—RELATIVE HUMIDITY, PERCENT

[Pressure=30.0 inches]

Wet bulb (°F.):	Dry bulb (°F.)																			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
14	1																			
15	15	4																		
16	28	17	7																	
17	42	31	20	10	1															
18	56	44	33	22	13	4														
19	71	58	46	35	25	16	7													
20	85	71	59	47	37	27	18	10	3											
21	100	86	72	60	49	39	29	21	13	6										
22		100	86	73	62	51	41	32	23	16	8	2								
23			100	87	74	63	52	43	34	26	18	11	5							
24				100	87	75	64	54	44	36	28	20	14	8	2					
25					100	87	76	65	55	46	37	30	23	16	10	5				
26						100	88	76	66	56	47	39	32	25	19	13	7	2		
27							100	88	77	67	58	49	41	34	27	21	15	10	5	
28								100	88	78	68	59	51	43	36	29	23	17	12	7
29									100	89	78	69	60	52	45	38	31	25	20	15
30										100	89	79	70	62	54	46	40	33	27	22
31											100	89	80	71	63	55	48	42	35	29
32												100	90	81	72	64	57	50	43	37
33													100	90	81	73	65	58	51	45
34														100	91	82	74	66	59	52
35															100	91	83	75	67	60
36																100	91	83	75	68
37																	100	91	83	75
38																		100	92	83
39																			100	92
40																				100

Wet bulb (°F.):	Dry bulb (°F.)																			
	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
28	3																			
29	10	5																		
30	17	12	8	4																
31	24	19	14	10	6															
32	31	26	21	16	12	8	5	1												
33	39	33	28	23	18	14	10	7	3											
34	46	40	35	30	25	20	16	12	9	5										
35	54	47	42	36	31	26	22	18	14	10	7	4	1							
36	61	55	48	43	38	32	28	23	19	16	12	9	6	3						
37	69	62	55	49	44	39	34	29	25	21	17	14	10	8	5	2				
38	76	69	63	56	51	45	40	35	31	27	23	19	16	12	9	7	4	1		
39	84	77	70	63	57	52	46	41	36	32	28	24	20	17	14	11	8	6	3	1
40	92	85	77	71	64	58	52	47	42	38	34	29	26	22	19	16	13	10	7	5
51	100	92	85	78	71	65	59	54	48	43	39	35	31	27	23	20	17	14	11	9
42		100	92	85	78	72	66	60	54	49	45	40	36	32	28	25	22	18	16	13
43			100	93	86	79	72	66	61	55	50	46	41	37	33	30	26	23	20	17
44				100	93	86	79	73	67	61	56	51	47	42	38	34	31	27	24	21
45					100	93	86	79	73	67	62	57	52	48	43	39	35	32	29	26
46						100	93	86	80	74	68	63	58	53	49	44	40	37	33	30
47							100	93	86	80	75	69	63	59	54	50	45	41	38	34
48								100	93	87	81	75	69	64	59	55	50	46	42	39

Table 14.—RELATIVE HUMIDITY, PERCENT—Continued
[Pressure=30.0 inches]

	Dry bulb (°F.)																			
	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Wet bulb (°F.):																				
49	---	---	---	---	---	---	---	---	100	93	87	81	75	70	65	60	55	51	47	43
50	---	---	---	---	---	---	---	---	---	100	94	87	81	76	70	65	61	56	52	48
51	---	---	---	---	---	---	---	---	---	---	100	94	87	82	76	71	66	61	57	53
52	---	---	---	---	---	---	---	---	---	---	---	100	94	88	82	76	71	66	62	58
53	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	82	77	72	67	63
54	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	82	77	72	68
55	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	83	78	73
56	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	83	78
57	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	89	83
58	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	89
59	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94
60	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100

	Dry bulb (°F.)																			
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Wet bulb (°F.):																				
41	7	4	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
42	10	8	6	4	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
43	14	12	10	7	5	3	2	---	---	---	---	---	---	---	---	---	---	---	---	---
44	18	16	13	11	9	7	5	3	1	---	---	---	---	---	---	---	---	---	---	---
45	22	20	17	15	12	10	8	6	5	3	1	---	---	---	---	---	---	---	---	---
46	27	24	21	18	16	14	12	10	8	6	4	3	1	---	---	---	---	---	---	---
47	31	28	25	22	20	17	15	13	11	9	7	6	4	3	1	---	---	---	---	---
48	35	32	29	26	24	21	19	16	14	12	10	9	7	5	4	3	1	---	---	---
49	40	36	33	30	27	25	22	20	18	15	13	12	10	8	7	5	4	3	1	---
50	44	41	37	34	31	29	26	23	21	19	17	15	13	11	9	8	6	5	4	3
51	49	45	42	38	35	32	30	25	24	22	20	18	16	14	12	11	9	8	6	5
52	54	50	46	43	39	36	33	31	28	25	23	21	19	17	15	13	12	10	9	7
53	58	54	50	47	44	40	37	34	32	29	27	24	22	20	18	16	14	13	11	10
54	63	59	55	51	48	44	41	38	35	33	30	28	25	23	21	19	17	16	14	12
55	68	64	60	56	52	48	45	42	39	36	33	31	29	26	24	22	20	18	17	15
56	73	69	64	60	56	53	49	46	43	40	37	34	32	29	27	25	23	21	19	18
57	78	74	69	65	61	57	53	50	47	44	41	38	35	33	30	28	26	24	22	20
58	84	79	74	70	66	61	58	54	51	48	45	42	39	36	34	31	29	27	25	23
59	89	84	79	74	70	66	62	58	55	51	48	45	42	39	37	34	32	30	28	26
60	94	89	84	79	75	71	66	62	59	55	52	49	46	43	40	38	35	33	31	29
61	100	94	89	84	80	75	71	67	63	59	56	53	50	47	44	41	39	36	34	32
62	---	100	95	90	85	80	75	71	67	64	60	57	53	50	47	44	42	39	37	35
63	---	---	100	95	90	85	80	76	72	68	64	61	57	54	51	48	45	43	40	38
64	---	---	---	100	95	90	85	80	76	72	68	65	61	58	54	51	48	46	43	41
65	---	---	---	---	100	95	90	85	81	77	72	69	65	61	58	55	52	49	46	44
66	---	---	---	---	---	100	95	90	85	81	77	73	69	65	62	59	56	53	50	47
67	---	---	---	---	---	---	100	95	90	86	81	77	73	69	66	62	59	56	53	50
68	---	---	---	---	---	---	---	100	95	90	86	82	78	74	70	66	63	60	57	54
69	---	---	---	---	---	---	---	---	100	95	90	86	82	78	74	70	67	63	60	57
70	---	---	---	---	---	---	---	---	---	100	95	91	86	82	78	74	71	67	64	61
71	---	---	---	---	---	---	---	---	---	---	100	95	91	86	82	78	74	71	68	64
72	---	---	---	---	---	---	---	---	---	---	---	100	95	91	86	82	79	75	71	68
73	---	---	---	---	---	---	---	---	---	---	---	---	100	95	91	87	83	79	75	72
74	---	---	---	---	---	---	---	---	---	---	---	---	---	100	96	91	87	83	79	75
75	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	96	91	87	83	79
76	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	96	91	87	83
77	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	96	91	87
78	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	96	91
79	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	96
80	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100

Table 14.—RELATIVE HUMIDITY, PERCENT—Continued

[Pressure=30.0 inches]

	Dry bulb (°F.)																				
	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122
Wet bulb (°F.):																					
54	10	7	5	3	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
56	14	12	9	7	5	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
58	20	16	14	11	9	7	5	3	---	---	---	---	---	---	---	---	---	---	---	---	---
60	25	21	18	15	13	11	9	7	5	---	---	---	---	---	---	---	---	---	---	---	---
62	30	26	23	20	17	15	12	10	8	7	5	---	---	---	---	---	---	---	---	---	---
64	36	32	28	25	22	19	16	14	12	10	8	7	5	---	---	---	---	---	---	---	---
66	42	37	33	30	26	23	20	18	15	13	11	10	8	7	---	---	---	---	---	---	---
68	48	43	39	35	31	28	24	22	19	17	15	13	11	10	8	7	6	---	---	---	---
70	55	49	44	40	36	32	29	26	23	21	18	16	14	12	11	9	8	---	---	---	---
72	61	56	50	46	41	37	33	30	27	24	22	20	17	16	14	12	11	9	8	---	---
74	69	62	57	51	47	42	38	35	32	28	26	23	21	19	17	15	13	12	11	9	8
76	76	69	63	57	52	48	43	39	36	33	30	27	24	22	20	18	16	14	13	12	10
78	84	76	70	64	58	53	49	44	40	37	34	31	28	25	23	21	19	17	16	14	13
80	92	84	77	70	65	59	54	50	45	41	38	35	32	29	26	24	22	20	18	17	15
82	100	92	84	77	71	65	60	55	50	46	42	39	36	33	30	27	25	23	21	19	18
84		100	92	85	78	72	66	61	55	51	47	43	40	37	34	31	28	26	24	22	20
86			100	92	85	78	72	66	61	56	52	48	44	41	38	35	32	29	27	25	23
88				100	92	85	79	73	67	62	57	53	49	45	42	38	35	33	30	28	26
90					100	92	85	79	73	68	62	58	53	49	46	42	39	36	34	31	29
92						100	93	86	79	73	68	63	58	54	50	47	43	40	37	34	32
94							100	93	86	80	74	69	64	59	55	51	47	44	41	38	35
96	---	---	---	---	---	---	---	100	93	86	80	74	69	64	60	55	52	48	45	41	39
98	---	---	---	---	---	---	---	---	100	93	86	80	75	70	65	60	56	52	49	45	42
100	---	---	---	---	---	---	---	---	---	100	93	87	81	75	70	65	61	57	53	49	46
102	---	---	---	---	---	---	---	---	---	---	100	93	87	81	75	70	66	61	57	53	50
104	---	---	---	---	---	---	---	---	---	---	---	100	93	87	81	76	71	66	62	58	54
106	---	---	---	---	---	---	---	---	---	---	---	---	100	93	87	81	76	71	67	62	58
108	---	---	---	---	---	---	---	---	---	---	---	---	---	100	93	87	82	76	72	67	65
110	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	82	77	72	67
112	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	82	77	72
114	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	82	77
116	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88	83
118	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94	88
120	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100	94
122	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	100

Table 15.—FOREL WATER COLOR SCALE CODE

Code	*Description*
00	Deep blue.
10	Blue.
20	Greenish-blue (or green blue).
30	Bluish-green (or blue green).
40	Green
50	Light green
60	Yellowish-green
70	Yellow green.
80	Green yellow.
90	Greenish-yellow.
99	Yellow.

Table 16.—CHLORINITY (Cl. °/₀₀) TO SALINITY (S. °/₀₀) CONVERSION

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
1.00	1.84	1.55	2.83	2.10	3.82	2.65	4.81	3.20	5.81
1.01	1.85	1.56	2.85	2.11	3.84	2.66	4.83	3.21	5.82
1.02	1.87	1.57	2.86	2.12	3.86	2.67	4.85	3.22	5.84
1.03	1.89	1.58	2.88	2.13	3.87	2.68	4.87	3.23	5.86
1.04	1.91	1.59	2.90	2.14	3.89	2.69	4.89	3.24	5.88
1.05	1.93	1.60	2.92	2.15	3.91	2.70	4.90	3.25	5.90
1.06	1.94	1.61	2.94	2.16	3.93	2.71	4.92	3.26	5.91
1.07	1.96	1.62	2.95	2.17	3.95	2.72	4.94	3.27	5.93
1.08	1.98	1.63	2.97	2.18	3.96	2.73	4.96	3.28	5.95
1.09	2.00	1.64	2.99	2.19	3.98	2.74	4.98	3.29	5.97
1.10	2.02	1.65	3.01	2.20	4.00	2.75	4.99	3.30	5.99
1.11	2.03	1.66	3.03	2.21	4.02	2.76	5.01	3.31	6.00
1.12	2.05	1.67	3.04	2.22	4.04	2.77	5.03	3.32	6.02
1.13	2.07	1.68	3.06	2.23	4.06	2.78	5.05	3.33	6.04
1.14	2.09	1.69	3.08	2.24	4.07	2.79	5.07	3.34	6.06
1.15	2.11	1.70	3.10	2.25	4.09	2.80	5.08	3.35	6.08
1.16	2.12	1.71	3.12	2.26	4.11	2.81	5.10	3.36	6.09
1.17	2.14	1.72	3.13	2.27	4.13	2.82	5.12	3.37	6.11
1.18	2.16	1.73	3.15	2.28	4.15	2.83	5.14	3.38	6.13
1.19	2.18	1.74	3.17	2.29	4.16	2.84	5.16	3.39	6.15
1.20	2.20	1.75	3.19	2.30	4.18	2.85	5.17	3.40	6.17
1.21	2.21	1.76	3.21	2.31	4.20	2.86	5.19	3.41	6.19
1.22	2.23	1.77	3.22	2.32	4.22	2.87	5.21	3.42	6.20
1.23	2.25	1.78	3.24	2.33	4.24	2.88	5.23	3.43	6.22
1.24	2.27	1.79	3.26	2.34	4.25	2.89	5.25	3.44	6.24
1.25	2.29	1.80	3.28	2.35	4.27	2.90	5.26	3.45	6.26
1.26	2.30	1.81	3.30	2.36	4.29	2.91	5.28	3.46	6.28
1.27	2.32	1.82	3.32	2.37	4.31	2.92	5.30	3.47	6.29
1.28	2.34	1.83	3.33	2.38	4.33	2.93	5.32	3.48	6.31
1.29	2.36	1.84	3.35	2.39	4.34	2.94	5.34	3.49	6.33
1.30	2.38	1.85	3.37	2.40	4.36	2.95	5.35	3.50	6.35
1.31	2.39	1.86	3.39	2.41	4.38	2.96	5.37	3.51	6.37
1.32	2.41	1.87	3.41	2.42	4.40	2.97	5.39	3.52	6.38
1.33	2.43	1.88	3.42	2.43	4.42	2.98	5.41	3.53	6.40
1.34	2.45	1.89	3.44	2.44	4.43	2.99	5.43	3.54	6.42
1.35	2.47	1.90	3.46	2.45	4.45	3.00	5.45	3.55	6.44
1.36	2.48	1.91	3.48	2.46	4.47	3.01	5.46	3.56	6.46
1.37	2.50	1.92	3.50	2.47	4.49	3.02	5.48	3.57	6.47
1.38	2.52	1.93	3.51	2.48	4.51	3.03	5.50	3.58	6.49
1.39	2.54	1.94	3.53	2.49	4.52	3.04	5.52	3.59	6.51
1.40	2.56	1.95	3.55	2.50	4.54	3.05	5.54	3.60	6.53
1.41	2.58	1.96	3.57	2.51	4.56	3.06	5.55	3.61	6.55
1.42	2.59	1.97	3.59	2.52	4.58	3.07	5.57	3.62	6.56
1.43	2.61	1.98	3.60	2.53	4.60	3.08	5.59	3.63	6.58
1.44	2.63	1.99	3.62	2.54	4.61	3.09	5.61	3.64	6.60
1.45	2.65	2.00	3.64	2.55	4.63	3.10	5.63	3.65	6.62
1.46	2.67	2.01	3.66	2.56	4.65	3.11	5.64	3.66	6.64
1.47	2.68	2.02	3.68	2.57	4.67	3.12	5.66	3.67	6.65
1.48	2.70	2.03	3.69	2.58	4.69	3.13	5.68	3.68	6.67
1.49	2.72	2.04	3.71	2.59	4.70	3.14	5.70	3.69	6.69
1.50	2.74	2.05	3.73	2.60	4.72	3.15	5.72	3.70	6.71
1.51	2.76	2.06	3.75	2.61	4.74	3.16	5.73	3.71	6.73
1.52	2.77	2.07	3.77	2.62	4.76	3.17	5.75	3.72	6.74
1.53	2.79	2.08	3.78	2.63	4.78	3.18	5.77	3.73	6.76
1.54	2.81	2.09	3.80	2.64	4.80	3.19	5.79	3.74	6.78

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
3.75	6.80	4.30	7.79	4.85	8.78	5.40	9.78	5.95	10.77
3.76	6.82	4.31	7.81	4.86	8.80	5.41	9.80	5.96	10.79
3.77	6.83	4.32	7.83	4.87	8.82	5.42	9.81	5.97	10.81
3.78	6.85	4.33	7.85	4.88	8.84	5.43	9.83	5.98	10.82
3.79	6.87	4.34	7.86	4.89	8.86	5.44	9.85	5.99	10.84
3.80	6.89	4.35	7.88	4.90	8.87	5.45	9.87	6.00	10.86
3.81	6.91	4.36	7.90	4.91	8.89	5.46	9.89	6.01	10.88
3.82	6.93	4.37	7.92	4.92	8.91	5.47	9.90	6.02	10.90
3.83	6.94	4.38	7.94	4.93	8.93	5.48	9.92	6.03	10.91
3.84	6.96	4.39	7.95	4.94	8.95	5.49	9.94	6.04	10.93
3.85	6.98	4.40	7.97	4.95	8.96	5.50	9.96	6.05	10.95
3.86	7.00	4.41	7.99	4.96	8.98	5.51	9.98	6.06	10.97
3.87	7.02	4.42	8.01	4.97	9.00	5.52	9.99	6.07	10.99
3.88	7.03	4.43	8.03	4.98	9.02	5.53	10.01	6.08	11.00
3.89	7.05	4.44	8.04	4.99	9.04	5.54	10.03	6.09	11.02
3.90	7.07	4.45	8.06	5.00	9.06	5.55	10.05	6.10	11.04
3.91	7.09	4.46	8.08	5.01	9.07	5.56	10.07	6.11	11.06
3.92	7.11	4.47	8.10	5.02	9.09	5.57	10.08	6.12	11.08
3.93	7.12	4.48	8.12	5.03	9.11	5.58	10.10	6.13	11.09
3.94	7.14	4.49	8.13	5.04	9.13	5.59	10.12	6.14	11.11
3.95	7.16	4.50	8.15	5.05	9.15	5.60	10.14	6.15	11.13
3.96	7.18	4.51	8.17	5.06	9.16	5.61	10.16	6.16	11.15
3.97	7.20	4.52	8.19	5.07	9.18	5.62	10.17	6.17	11.17
3.98	7.21	4.53	8.21	5.08	9.20	5.63	10.19	6.18	11.18
3.99	7.23	4.54	8.22	5.09	9.22	5.64	10.21	6.19	11.20
4.00	7.25	4.55	8.24	5.10	9.24	5.65	10.23	6.20	11.22
4.01	7.27	4.56	8.26	5.11	9.25	5.66	10.25	6.21	11.24
4.02	7.29	4.57	8.28	5.12	9.27	5.67	10.26	6.22	11.26
4.03	7.30	4.58	8.30	5.13	9.29	5.68	10.28	6.23	11.28
4.04	7.32	4.59	8.31	5.14	9.31	5.69	10.30	6.24	11.29
4.05	7.34	4.60	8.33	5.15	9.33	5.70	10.32	6.25	11.31
4.06	7.36	4.61	8.35	5.16	9.34	5.71	10.34	6.26	11.33
4.07	7.38	4.62	8.37	5.17	9.36	5.72	10.35	6.27	11.35
4.08	7.39	4.63	8.39	5.18	9.38	5.73	10.37	6.28	11.37
4.09	7.41	4.64	8.41	5.19	9.40	5.74	10.39	6.29	11.38
4.10	7.43	4.65	8.42	5.20	9.42	5.75	10.41	6.30	11.40
4.11	7.45	4.66	8.44	5.21	9.43	5.76	10.43	6.31	11.42
4.12	7.47	4.67	8.46	5.22	9.45	5.77	10.44	6.32	11.44
4.13	7.48	4.68	8.48	5.23	9.47	5.78	10.46	6.33	11.46
4.14	7.50	4.69	8.50	5.24	9.49	5.79	10.48	6.34	11.47
4.15	7.52	4.70	8.51	5.25	9.51	5.80	10.50	6.35	11.49
4.16	7.54	4.71	8.53	5.26	9.52	5.81	10.52	6.36	11.51
4.17	7.56	4.72	8.55	5.27	9.54	5.82	10.54	6.37	11.53
4.18	7.57	4.73	8.57	5.28	9.56	5.83	10.55	6.38	11.55
4.19	7.59	4.74	8.59	5.29	9.58	5.84	10.57	6.39	11.56
4.20	7.61	4.75	8.60	5.30	9.60	5.85	10.59	6.40	11.58
4.21	7.63	4.76	8.62	5.31	9.61	5.86	10.61	6.41	11.60
4.22	7.65	4.77	8.64	5.32	9.63	5.87	10.63	6.42	11.62
4.23	7.67	4.78	8.66	5.33	9.65	5.88	10.64	6.43	11.64
4.24	7.68	4.79	8.68	5.34	9.67	5.89	10.66	6.44	11.65
4.25	7.70	4.80	8.69	5.35	9.69	5.90	10.68	6.45	11.67
4.26	7.72	4.81	8.71	5.36	9.70	5.91	10.70	6.46	11.69
4.27	7.74	4.82	8.73	5.37	9.72	5.92	10.72	6.47	11.71
4.28	7.76	4.83	8.75	5.38	9.74	5.93	10.73	6.48	11.73
4.29	7.77	4.84	8.77	5.39	9.76	5.94	10.75	6.49	11.74

Table 16.—CHLORINITY (Cl. °/₀₀) TO SALINITY (S. °/₀₀) CONVERSION—Continued

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
6.50	11.76	7.05	12.76	7.60	13.75	8.15	14.74	8.70	15.73
6.51	11.78	7.06	12.77	7.61	13.77	8.16	14.76	8.71	15.75
6.52	11.80	7.07	12.79	7.62	13.78	8.17	14.78	8.72	15.77
6.53	11.82	7.08	12.81	7.63	13.80	8.18	14.79	8.73	15.79
6.54	11.83	7.09	12.83	7.64	13.82	8.19	14.81	8.74	15.81
6.55	11.85	7.10	12.85	7.65	13.84	8.20	14.83	8.75	15.82
6.56	11.87	7.11	12.86	7.66	13.86	8.21	14.85	8.76	15.84
6.57	11.89	7.12	12.88	7.67	13.87	8.22	14.87	8.77	15.86
6.58	11.91	7.13	12.90	7.68	13.89	8.23	14.89	8.78	15.88
6.59	11.92	7.14	12.92	7.69	13.91	8.24	14.90	8.79	15.90
6.60	11.94	7.15	12.94	7.70	13.93	8.25	14.92	8.80	15.91
6.61	11.96	7.16	12.95	7.71	13.95	8.26	14.94	8.81	15.93
6.62	11.98	7.17	12.97	7.72	13.96	8.27	14.96	8.82	15.95
6.63	12.00	7.18	12.99	7.73	13.98	8.28	14.98	8.83	15.97
6.64	12.02	7.19	13.01	7.74	14.00	8.29	14.99	8.84	15.99
6.65	12.03	7.20	13.03	7.75	14.02	8.30	15.01	8.85	16.00
6.66	12.05	7.21	13.04	7.76	14.04	8.31	15.03	8.86	16.02
6.67	12.07	7.22	13.06	7.77	14.05	8.32	15.05	8.87	16.04
6.68	12.09	7.23	13.08	7.78	14.07	8.33	15.07	8.88	16.06
6.69	12.11	7.24	13.10	7.79	14.09	8.34	15.08	8.89	16.08
6.70	12.12	7.25	13.12	7.80	14.11	8.35	15.10	8.90	16.09
6.71	12.14	7.26	13.13	7.81	14.13	8.36	15.12	8.91	16.11
6.72	12.16	7.27	13.15	7.82	14.15	8.37	15.14	8.92	16.13
6.73	12.18	7.28	13.17	7.83	14.16	8.38	15.16	8.93	16.15
6.74	12.20	7.29	13.19	7.84	14.18	8.39	15.17	8.94	16.17
6.75	12.21	7.30	13.21	7.85	14.20	8.40	15.19	8.95	16.18
6.76	12.23	7.31	13.22	7.86	14.22	8.41	15.21	8.96	16.20
6.77	12.25	7.32	13.24	7.87	14.24	8.42	15.23	8.97	16.22
6.78	12.27	7.33	13.26	7.88	14.25	8.43	15.25	8.98	16.24
6.79	12.29	7.34	13.28	7.89	14.27	8.44	15.26	8.99	16.26
6.80	12.30	7.35	13.30	7.90	14.29	8.45	15.28	9.00	16.28
6.81	12.32	7.36	13.31	7.91	14.31	8.46	15.30	9.01	16.29
6.82	12.34	7.37	13.33	7.92	14.33	8.47	15.32	9.02	16.31
6.83	12.36	7.38	13.35	7.93	14.34	8.48	15.34	9.03	16.33
6.84	12.38	7.39	13.37	7.94	14.36	8.49	15.35	9.04	16.35
6.85	12.39	7.40	13.39	7.95	14.38	8.50	15.37	9.05	16.37
6.86	12.41	7.41	13.41	7.96	14.40	8.51	15.39	9.06	16.38
6.87	12.43	7.42	13.42	7.97	14.42	8.52	15.41	9.07	16.40
6.88	12.45	7.43	13.44	7.98	14.43	8.53	15.43	9.08	16.42
6.89	12.47	7.44	13.46	7.99	14.45	8.54	15.44	9.09	16.44
6.90	12.48	7.45	13.48	8.00	14.47	8.55	15.46	9.10	16.46
6.91	12.50	7.46	13.50	8.01	14.49	8.56	15.48	9.11	16.47
6.92	12.52	7.47	13.51	8.02	14.51	8.57	15.50	9.12	16.49
6.93	12.54	7.48	13.53	8.03	14.52	8.58	15.52	9.13	16.51
6.94	12.56	7.49	13.55	8.04	14.54	8.59	15.53	9.14	16.53
6.95	12.57	7.50	13.57	8.05	14.56	8.60	15.55	9.15	16.55
6.96	12.59	7.51	13.59	8.06	14.58	8.61	15.57	9.16	16.56
6.97	12.61	7.52	13.60	8.07	14.60	8.62	15.59	9.17	16.58
6.98	12.63	7.53	13.62	8.08	14.61	8.63	15.61	9.18	16.60
6.99	12.65	7.54	13.64	8.09	14.63	8.64	15.63	9.19	16.62
7.00	12.67	7.55	13.66	8.10	14.65	8.65	15.64	9.20	16.64
7.01	12.68	7.56	13.68	8.11	14.67	8.66	15.66	9.21	16.65
7.02	12.70	7.57	13.69	8.12	14.69	8.67	15.68	9.22	16.67
7.03	12.72	7.58	13.71	8.13	14.70	8.68	15.70	9.23	16.69
7.04	12.74	7.59	13.73	8.14	14.72	8.69	15.72	9.24	16.71

Table 16.—CHLORINITY (Cl. °/₀₀) TO SALINITY (S. °/₀₀) CONVERSION—Continued

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
9.25	16.73	9.80	17.72	10.35	18.71	10.90	19.70	11.45	20.70
9.26	16.74	9.81	17.74	10.36	18.73	10.91	19.72	11.46	20.72
9.27	16.76	9.82	17.76	10.37	18.75	10.92	19.74	11.47	20.73
9.28	16.78	9.83	17.77	10.38	18.77	10.93	19.76	11.48	20.75
9.29	16.80	9.84	17.79	10.39	18.78	10.94	19.78	11.49	20.77
9.30	16.82	9.85	17.81	10.40	18.80	10.95	19.79	11.50	20.79
9.31	16.83	9.86	17.83	10.41	18.82	10.96	19.81	11.51	20.81
9.32	16.85	9.87	17.85	10.42	18.84	10.97	19.83	11.52	20.82
9.33	16.87	9.88	17.86	10.43	18.86	10.98	19.85	11.53	20.84
9.34	16.89	9.89	17.88	10.44	18.87	10.99	19.87	11.54	20.86
9.35	16.91	9.90	17.90	10.45	18.89	11.00	19.89	11.55	20.88
9.36	16.92	9.91	17.92	10.46	18.91	11.01	19.90	11.56	20.90
9.37	16.94	9.92	17.94	10.47	18.93	11.02	19.92	11.57	20.91
9.38	16.96	9.93	17.95	10.48	18.95	11.03	19.94	11.58	20.93
9.39	16.98	9.94	17.97	10.49	18.96	11.04	19.96	11.59	20.95
9.40	17.00	9.95	17.99	10.50	18.98	11.05	19.98	11.60	20.97
9.41	17.02	9.96	18.01	10.51	19.00	11.06	19.99	11.61	20.99
9.42	17.03	9.97	18.03	10.52	19.02	11.07	20.01	11.62	21.00
9.43	17.05	9.98	18.04	10.53	19.04	11.08	20.03	11.63	21.02
9.44	17.07	9.99	18.06	10.54	19.05	11.09	20.05	11.64	21.04
9.45	17.09	10.00	18.08	10.55	19.07	11.10	20.07	11.65	21.06
9.46	17.11	10.01	18.10	10.56	19.09	11.11	20.08	11.66	21.08
9.47	17.12	10.02	18.12	10.57	19.11	11.12	20.10	11.67	21.09
9.48	17.14	10.03	18.13	10.58	19.13	11.13	20.12	11.68	21.11
9.49	17.16	10.04	18.15	10.59	19.14	11.14	20.14	11.69	21.13
9.50	17.18	10.05	18.17	10.60	19.16	11.15	20.16	11.70	21.15
9.51	17.20	10.06	18.19	10.61	19.18	11.16	20.17	11.71	21.17
9.52	17.21	10.07	18.21	10.62	19.20	11.17	20.19	11.72	21.18
9.53	17.23	10.08	18.22	10.63	19.22	11.18	20.21	11.73	21.20
9.54	17.25	10.09	18.24	10.64	19.24	11.19	20.23	11.74	21.22
9.55	17.27	10.10	18.26	10.65	19.25	11.20	20.25	11.75	21.24
9.56	17.29	10.11	18.28	10.66	19.27	11.21	20.26	11.76	21.26
9.57	17.30	10.12	18.30	10.67	19.29	11.22	20.28	11.77	21.27
9.58	17.32	10.13	18.31	10.68	19.31	11.23	20.30	11.78	21.29
9.59	17.34	10.14	18.33	10.69	19.33	11.24	20.32	11.79	21.31
9.60	17.36	10.15	18.35	10.70	19.34	11.25	20.34	11.80	21.33
9.61	17.38	10.16	18.37	10.71	19.36	11.26	20.35	11.81	21.35
9.62	17.39	10.17	18.39	10.72	19.38	11.27	20.37	11.82	21.37
9.63	17.41	10.18	18.40	10.73	19.40	11.28	20.39	11.83	21.38
9.64	17.43	10.19	18.42	10.74	19.42	11.29	20.41	11.84	21.40
9.65	17.45	10.20	18.44	10.75	19.43	11.30	20.43	11.85	21.42
9.66	16.47	10.21	18.46	10.76	19.45	11.31	20.44	11.86	21.44
9.67	17.48	10.22	18.48	10.77	19.47	11.32	20.46	11.87	21.46
9.68	17.50	10.23	18.50	10.78	19.49	11.33	20.48	11.88	21.47
9.69	17.52	10.24	18.51	10.79	19.51	11.34	20.50	11.89	21.49
9.70	17.54	10.25	18.53	10.80	19.52	11.35	20.52	11.90	21.51
9.71	17.56	10.26	18.55	10.81	19.54	11.36	20.53	11.91	21.53
9.72	17.57	10.27	18.57	10.82	19.56	11.37	20.55	11.92	21.55
9.73	17.59	10.28	18.59	10.83	19.58	11.38	20.57	11.93	21.56
9.74	17.61	10.29	18.60	10.84	19.60	11.39	20.59	11.94	21.58
9.75	17.63	10.30	18.62	10.85	19.61	11.40	20.61	11.95	21.60
9.76	17.65	10.31	18.64	10.86	19.63	11.41	20.63	11.96	21.62
9.77	17.66	10.32	18.66	10.87	19.65	11.42	20.64	11.97	21.64
9.78	17.68	10.33	18.68	10.88	19.67	11.43	20.66	11.98	21.65
9.79	17.70	10.34	18.69	10.89	19.69	11.44	20.68	11.99	21.67

Table 16.—CHLORINITY (Cl. $^{\circ}/_{\circ\circ}$) TO SALINITY (S. $^{\circ}/_{\circ\circ}$) CONVERSION—Continued

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
12. 00	21. 69	12. 55	22. 68	13. 10	23. 68	13. 65	24. 67	14. 20	25. 66
12. 01	21. 71	12. 56	22. 70	13. 11	23. 69	13. 66	24. 69	14. 21	25. 68
12. 02	21. 73	12. 57	22. 72	13. 12	23. 71	13. 67	24. 70	14. 22	25. 70
12. 03	21. 74	12. 58	22. 74	13. 13	23. 73	13. 68	24. 72	14. 23	25. 72
12. 04	21. 76	12. 59	22. 75	13. 14	23. 75	13. 69	24. 74	14. 24	25. 73
12. 05	21. 78	12. 60	22. 77	13. 15	23. 77	13. 70	24. 76	14. 25	25. 75
12. 06	21. 80	12. 61	22. 79	13. 16	23. 78	13. 71	24. 78	14. 26	25. 77
12. 07	21. 82	12. 62	22. 81	13. 17	23. 80	13. 72	24. 79	14. 27	25. 79
12. 08	21. 83	12. 63	22. 83	13. 18	23. 82	13. 73	24. 81	14. 28	25. 81
12. 09	21. 85	12. 64	22. 85	13. 19	23. 84	13. 74	24. 83	14. 29	25. 82
12. 10	21. 87	12. 65	22. 86	13. 20	23. 86	13. 75	24. 85	14. 30	25. 84
12. 11	21. 89	12. 66	22. 88	13. 21	23. 87	13. 76	24. 87	14. 31	25. 86
12. 12	21. 91	12. 67	22. 90	13. 22	23. 89	13. 77	24. 88	14. 32	25. 88
12. 13	21. 92	12. 68	22. 92	13. 23	23. 91	13. 78	24. 90	14. 33	25. 90
12. 14	21. 94	12. 69	22. 94	13. 24	23. 93	13. 79	24. 92	14. 34	25. 91
12. 15	21. 96	12. 70	22. 95	13. 25	23. 95	13. 80	24. 94	14. 35	25. 93
12. 16	21. 98	12. 71	22. 97	13. 26	23. 96	13. 81	24. 96	14. 36	25. 95
12. 17	22. 00	12. 72	22. 99	13. 27	23. 98	13. 82	24. 98	14. 37	25. 97
12. 18	22. 01	12. 73	23. 01	13. 28	24. 00	13. 83	24. 99	14. 38	25. 99
12. 19	22. 03	12. 74	23. 03	13. 29	24. 02	13. 84	25. 01	14. 39	26. 00
12. 20	22. 05	12. 75	23. 04	13. 30	24. 04	13. 85	25. 03	14. 40	26. 02
12. 21	22. 07	12. 76	23. 06	13. 31	24. 05	13. 86	25. 05	14. 41	26. 04
12. 22	22. 09	12. 77	23. 08	13. 32	24. 07	13. 87	25. 07	14. 42	25. 06
12. 23	22. 11	12. 78	23. 10	13. 33	24. 09	13. 88	25. 08	14. 43	26. 08
12. 24	22. 12	12. 79	23. 12	13. 34	24. 11	13. 89	25. 10	14. 44	26. 09
12. 25	22. 14	12. 80	23. 13	13. 35	24. 13	13. 90	25. 12	14. 45	26. 11
12. 26	22. 16	12. 81	23. 15	13. 36	24. 14	13. 91	25. 14	14. 46	26. 13
12. 27	22. 18	12. 82	23. 17	13. 37	24. 16	13. 92	25. 16	14. 47	26. 15
12. 28	22. 20	12. 83	23. 19	13. 38	24. 18	13. 93	25. 17	14. 48	26. 17
12. 29	22. 21	12. 84	23. 21	13. 39	24. 20	13. 94	25. 19	14. 49	26. 18
12. 30	22. 23	12. 85	23. 22	13. 40	24. 22	13. 95	25. 21	14. 50	26. 20
12. 31	22. 25	12. 86	23. 24	13. 41	24. 24	13. 96	25. 23	14. 51	26. 22
12. 32	22. 27	12. 87	23. 26	13. 42	24. 25	13. 97	25. 25	14. 52	26. 24
12. 33	22. 29	12. 88	23. 28	13. 43	24. 27	13. 98	25. 26	14. 53	26. 26
12. 34	22. 30	12. 89	23. 30	13. 44	24. 29	13. 99	25. 28	14. 54	26. 27
12. 35	22. 32	12. 90	23. 31	13. 45	24. 31	14. 00	25. 30	14. 55	26. 29
12. 36	22. 34	12. 91	23. 33	13. 46	24. 33	14. 01	25. 32	14. 56	26. 31
12. 37	22. 36	12. 92	23. 35	13. 47	24. 34	14. 02	25. 34	14. 57	26. 33
12. 38	22. 38	12. 93	23. 37	13. 48	24. 36	14. 03	25. 35	14. 58	26. 35
12. 39	22. 39	12. 94	23. 39	13. 49	24. 38	14. 04	25. 37	14. 59	26. 36
12. 40	22. 41	12. 95	23. 40	13. 50	24. 40	14. 05	25. 39	14. 60	26. 38
12. 41	22. 43	12. 96	23. 42	13. 51	24. 42	14. 06	25. 41	14. 61	26. 40
12. 42	22. 45	12 97	23. 44	13. 52	24. 43	14. 07	25. 43	14. 62	26. 42
12. 43	22. 47	12. 98	23. 46	13. 53	24. 45	14. 08	25. 44	14. 63	26. 44
12. 44	22. 48	12. 99	23. 48	13. 54	24. 47	14. 09	25. 46	14. 64	26. 46
12. 45	22. 50	13. 00	23. 50	13. 55	24. 49	14. 10	25. 48	14. 65	26. 47
12. 46	22. 52	13. 01	23. 51	13. 56	24. 51	14. 11	25. 50	14. 66	26. 49
12. 47	22. 54	13. 02	23. 53	13. 57	24. 52	14. 12	25. 52	14. 67	26. 51
12. 48	22. 56	13. 03	23. 55	13. 58	24. 54	14. 13	25. 53	14. 68	26. 53
12. 49	22. 57	13. 04	23. 57	13. 59	24. 56	14. 14	25. 55	14. 69	26. 55
12. 50	22. 59	13. 05	23. 59	13. 60	24. 58	14. 15	25. 57	14. 70	26. 56
12. 51	22. 61	13. 06	23. 60	13. 61	24. 60	14. 16	25. 59	14. 71	26. 58
12. 52	22. 63	13. 07	23. 62	13. 62	24. 61	14. 17	25. 61	14. 72	26. 60
12. 53	22. 65	13. 08	23. 64	13. 63	24. 63	14. 18	25. 62	14. 73	26. 62
12. 54	22. 66	13. 09	23. 66	13. 64	24. 65	14. 19	25. 64	14. 74	26. 64

Table 16.—CHLORINITY (Cl. °/₀₀) TO SALINITY (S. °/₀₀) CONVERSION—Continued

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
14. 75	26. 65	15. 30	27. 65	15. 85	28. 64	16. 40	29. 63	16. 95	30. 62
14. 76	26. 67	15. 31	27. 66	15. 86	28. 66	16. 41	29. 65	16. 96	30. 64
14. 77	26. 69	15. 32	27. 68	15. 87	28. 68	16. 42	29. 67	16. 97	30. 66
14. 78	26. 71	15. 33	27. 70	15. 88	28. 69	16. 43	29. 69	16. 98	30. 68
14. 79	26. 73	15. 34	27. 72	15. 89	28. 71	16. 44	29. 70	16. 99	30. 70
14. 80	26. 74	15. 35	27. 74	15. 90	28. 73	16. 45	29. 72	17. 00	30. 72
14. 81	26. 76	15. 36	27. 75	15. 91	28. 75	16. 46	29. 74	17. 01	30. 73
14. 82	26. 78	15. 37	27. 77	15. 92	28. 77	16. 47	29. 76	17. 02	30. 75
14. 83	26. 80	15. 38	27. 79	15. 93	28. 78	16. 48	29. 78	17. 03	30. 77
14. 84	26. 82	15. 39	27. 81	15. 94	28. 80	16. 49	29. 79	17. 04	30. 79
14. 85	26. 83	15. 40	27. 83	15. 95	28. 82	16. 50	29. 81	17. 05	30. 81
14. 86	26. 85	15. 41	27. 85	15. 96	28. 84	16. 51	29. 83	17. 06	30. 82
14. 87	26. 87	15. 42	27. 86	15. 97	28. 86	16. 52	29. 85	17. 07	30. 84
14. 88	26. 89	15. 43	27. 88	15. 98	28. 87	16. 53	29. 87	17. 08	30. 86
14. 89	26. 91	15. 44	27. 90	15. 99	28. 89	16. 54	29. 88	17. 09	30. 88
14. 90	26. 92	15. 45	27. 92	16. 00	28. 91	16. 55	29. 90	17. 10	30. 90
14. 91	26. 94	15. 46	27. 94	16. 01	28. 93	16. 56	29. 92	17. 11	30. 91
14. 92	26. 96	15. 47	27. 95	16. 02	28. 95	16. 57	29. 94	17. 12	30. 93
14. 93	26. 98	15. 48	27. 97	16. 03	28. 96	16. 58	29. 96	17. 13	30. 95
14. 94	27. 00	15. 49	27. 99	16. 04	28. 98	16. 59	29. 97	17. 14	30. 97
14. 95	27. 01	15. 50	28. 01	16. 05	29. 00	16. 60	29. 99	17. 15	30. 99
14. 96	27. 03	15. 51	28. 03	16. 06	29. 02	16. 61	30. 01	17. 16	31. 00
14. 97	27. 05	15. 52	28. 04	16. 07	29. 04	16. 62	30. 03	17. 17	31. 02
14. 98	27. 07	15. 53	28. 06	16. 08	29. 05	16. 63	30. 05	17. 18	31. 04
14. 99	27. 09	15. 54	28. 08	16. 09	29. 07	16. 64	30. 07	17. 19	31. 06
15. 00	27. 11	15. 55	28. 10	16. 10	29. 09	16. 65	30. 08	17. 20	31. 08
15. 01	27. 12	15. 56	28. 12	16. 11	29. 11	16. 66	30. 10	17. 21	31. 09
15. 02	27. 14	15. 57	28. 13	16. 12	29. 13	16. 67	30. 12	17. 22	31. 11
15. 03	27. 16	15. 58	28. 15	16. 13	29. 14	16. 68	30. 14	17. 23	31. 13
15. 04	27. 18	15. 59	28. 17	16. 14	29. 16	16. 69	30. 16	17. 24	31. 15
15. 05	27. 20	15. 60	28. 19	16. 15	29. 18	16. 70	30. 17	17. 25	31. 17
15. 06	27. 21	15. 61	28. 21	16. 16	29. 20	16. 71	30. 19	17. 26	31. 18
15. 07	27. 23	15. 62	28. 22	16. 17	29. 22	16. 72	30. 21	17. 27	31. 20
15. 08	27. 25	15. 63	28. 24	16. 18	29. 23	16. 73	30. 23	17. 28	31. 22
15. 09	27. 27	15. 64	28. 26	16. 19	29. 25	16. 74	30. 25	17. 29	31. 24
15. 10	27. 29	15. 65	28. 28	16. 20	29. 27	16. 75	30. 26	17. 30	31. 26
15. 11	27. 30	15. 66	28. 30	16. 21	29. 29	16. 76	30. 28	17. 31	31. 27
15. 12	27. 32	15. 67	28. 31	16. 22	29. 31	16. 77	30. 30	17. 32	31. 29
15. 13	27. 34	15. 68	28. 33	16. 23	29. 33	16. 78	30. 32	17. 33	31. 31
15. 14	27. 36	15. 69	28. 35	16. 24	29. 34	16. 79	30. 34	17. 34	31. 33
15. 15	27. 38	15. 70	28. 37	16. 25	29. 36	16. 80	30. 35	17. 35	31. 35
15. 16	27. 39	15. 71	28. 39	16. 26	29. 38	16. 81	30. 37	17. 36	31. 36
15. 17	27. 41	15. 72	28. 40	16. 27	29. 40	16. 82	30. 39	17. 37	31. 38
15. 18	27. 43	15. 73	28. 42	16. 28	29. 42	16. 83	30. 41	17. 38	31. 40
15. 19	27. 45	15. 74	28. 44	16. 29	29. 43	16. 84	30. 43	17. 39	31. 42
15. 20	27. 47	15. 75	28. 46	16. 30	29. 45	16. 85	30. 44	17. 40	31. 44
15. 21	27. 48	15. 76	28. 48	16. 31	29. 47	16. 86	30. 46	17. 41	31. 46
15. 22	27. 50	15. 77	28. 49	16. 32	29. 49	16. 87	30. 48	17. 42	31. 47
15. 23	27. 52	15. 78	28. 51	16. 33	29 51	16. 88	30. 50	17. 43	31. 49
15. 24	27. 54	15. 79	28. 53	16. 34	29. 52	16. 89	30. 52	17. 44	31. 51
15. 25	27. 56	15. 80	28. 55	16. 35	29. 54	16. 90	30. 53	17. 45	31. 53
15. 26	27. 57	15. 81	28. 57	16. 36	29. 56	16. 91	30. 55	17. 46	31. 55
15. 27	27. 59	15. 82	28. 59	16. 37	29. 58	16. 92	30. 57	17. 47	31. 56
15. 28	27. 61	15. 83	28. 60	16. 38	29. 60	16. 93	30. 59	17. 48	31. 58
15. 29	27. 63	15. 84	28. 62	16. 39	29. 61	16. 94	30. 61	17. 49	31. 60

Table 16.—CHLORINITY (Cl. °/₀₀) TO SALINITY (S. °/₀₀) CONVERSION—Continued

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
17. 50	31. 62	18. 05	32. 61	18. 60	33. 60	19. 15	34. 60	19. 70	35. 59
17. 51	31. 64	18. 06	32. 63	18. 61	33. 62	19. 16	34. 61	19. 71	35. 61
17. 52	31. 65	18. 07	32. 65	18. 62	33. 64	19. 17	34. 63	19. 72	35. 62
17. 53	31. 67	18. 08	32. 66	18. 63	33. 66	19. 18	34. 65	19. 73	35. 64
17. 54	31. 69	18. 09	32. 68	18. 64	33. 68	19. 19	34. 67	19. 74	35. 66
17. 55	31. 71	18. 10	32. 70	18. 65	33. 69	19. 20	34. 69	19. 75	35. 68
17. 56	31. 73	18. 11	32. 72	18. 66	33. 71	19. 21	34. 70	19. 76	35. 70
17. 57	31. 74	18. 12	32. 74	18. 67	33. 73	19. 22	34. 72	19. 77	35. 71
17. 58	31. 76	18. 13	32. 75	18. 68	33. 75	19. 23	34. 74	19. 78	35. 73
17. 59	31. 78	18. 14	32. 77	18. 69	33. 77	19. 24	34. 76	19. 79	35. 75
17. 60	31. 80	18. 15	32. 79	18. 70	33. 78	19. 25	34. 78	19. 80	35. 77
17. 61	31. 82	18. 16	32. 81	18. 71	33. 80	19. 26	34. 79	19. 81	35. 79
17. 62	31. 83	18. 17	32. 83	18. 72	33. 82	19. 27	34. 81	19. 82	35. 81
17. 63	31. 85	18. 18	32. 84	18. 73	33. 84	19. 28	34. 83	19. 83	35. 82
17. 64	31. 87	18. 19	32. 86	18. 74	33. 86	19. 29	34. 85	19. 84	35. 84
17. 65	31. 89	18. 20	32. 88	18. 75	33. 87	19. 30	34. 87	19. 85	35. 86
17. 66	31. 91	18. 21	32. 90	18. 76	33. 89	19. 31	34. 88	19. 86	35. 88
17. 67	31. 92	18. 22	32. 92	18. 77	33. 91	19. 32	34. 90	19. 87	35. 90
17. 68	31. 94	18. 23	32. 94	18. 78	33. 93	19. 33	34. 92	19. 88	35. 91
17. 69	31. 96	18. 24	32. 95	18. 79	33. 95	19. 34	34. 94	19. 89	35. 93
17. 70	31. 98	18. 25	32. 97	18. 80	33. 96	19. 35	34. 96	19. 90	35. 95
17. 71	32. 00	18. 26	32. 99	18. 81	33. 98	19. 36	34. 97	19. 91	35. 97
17. 72	32. 01	18. 27	33. 01	18. 82	34. 00	19. 37	34. 99	19. 92	35. 99
17. 73	32. 03	18. 28	33. 03	18. 83	34. 02	19. 38	35. 01	19. 93	36. 00
17. 74	32. 05	18. 29	33. 04	18. 84	34. 04	19. 39	35. 03	19. 94	36. 02
17. 75	32. 07	18. 30	33. 06	18. 85	34. 05	19. 40	35. 05	19. 95	36. 04
17. 76	32. 09	18. 31	33. 08	18. 86	34. 07	19. 41	35. 07	19. 96	36. 06
17. 77	32. 10	18. 32	33. 10	18. 87	34. 09	19. 42	35. 08	19. 97	36. 08
17. 78	32. 12	18. 33	33. 12	18. 88	34. 11	19. 43	35. 10	19. 98	36. 09
17. 79	32. 14	18. 34	33. 13	18. 89	34. 13	19. 44	35. 12	19. 99	36. 11
17. 80	32. 16	18. 35	33. 15	18. 90	34. 14	19. 45	35. 14	20. 00	36. 13
17. 81	32. 18	18. 36	33. 17	18. 91	34. 16	19. 46	35. 16	20. 01	36. 15
17. 82	32. 20	18. 37	33. 19	18. 92	34. 18	19. 47	35. 17	20. 02	36. 17
17. 83	32. 21	18. 38	33. 21	18. 93	34. 20	19. 48	35. 19	20. 03	36. 18
17. 84	32. 23	18. 39	33. 22	18. 94	34. 22	19. 49	35. 21	20. 04	36. 20
17. 85	32. 25	18. 40	33. 24	18. 95	34. 23	19. 50	35. 23	20. 05	36. 22
17. 86	32. 27	18. 41	33. 26	18. 96	34. 25	19. 51	35. 25	20. 06	36. 24
17. 87	32. 29	18. 42	33. 28	18. 97	34. 27	19. 52	35. 26	20. 07	36. 26
17. 88	32. 30	18. 43	33. 30	18. 98	34. 29	19. 53	35. 28	20. 08	36. 27
17. 89	32. 32	18. 44	33. 31	18. 99	34. 31	19. 54	35. 30	20. 09	36. 29
17. 90	32. 24	18. 45	33. 33	19. 00	34. 33	19. 55	35. 32	20. 10	36. 31
17. 91	32. 36	18. 46	33. 35	19. 01	34. 34	19. 56	35. 34	20. 11	36. 33
17. 92	32. 38	18. 47	33. 37	19. 02	34. 36	19. 57	35. 35	20. 12	36. 35
17. 93	32. 39	18. 48	33. 39	19. 03	34. 38	19. 58	35. 37	20. 13	36. 36
17. 94	32. 41	18. 49	33. 40	19. 04	34. 40	19. 59	35. 39	20. 14	36. 38
17. 95	32. 43	18. 50	33. 42	19. 05	34. 42	19. 60	35. 41	20. 15	36. 40
17. 96	32. 45	18. 51	33. 44	19. 06	34. 43	19. 61	35. 43	20. 16	36. 42
17. 97	32. 47	15. 52	33. 46	19. 07	34. 45	19. 62	35. 44	20. 17	36. 44
17. 98	32. 48	18. 53	33. 48	19. 08	34. 47	19. 63	35. 46	20. 18	36. 45
17. 99	32. 50	18. 54	33. 49	19. 09	34. 49	19. 64	35. 48	20. 19	36. 47
18. 00	32. 52	18. 55	33. 51	19. 10	34. 51	19. 65	35. 50	20. 20	36. 49
18. 01	32. 54	18. 56	33. 53	19. 11	34. 52	19. 66	35. 52	20. 21	36. 51
18. 02	32. 56	18. 57	33. 55	19. 12	34. 54	19. 67	35. 53	20. 22	36. 53
18. 03	32. 57	18. 58	33. 57	19. 13	34. 56	19. 68	35. 55	20. 23	36. 55
18. 04	32. 59	18. 59	33. 58	19. 14	34. 58	19. 69	35. 57	20. 24	36. 56

Table 16.—CHLORINITY (Cl. °/₀₀) TO SALINITY (S. °/₀₀) CONVERSION—Continued

Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.	Cl.	S.
20.25	36.58	20.80	37.57	21.35	38.57	21.90	39.56	22.45	40.55
20.26	36.60	20.81	37.59	21.36	38.58	21.91	39.58	22.46	40.57
20.27	36.62	20.82	37.61	21.37	38.60	21.92	39.60	22.47	40.59
20.28	36.64	20.83	37.63	21.38	38.62	21.93	39.61	22.48	40.61
20.29	36.65	20.84	37.65	21.39	38.64	21.94	39.63	22.49	40.62
20.30	36.67	20.85	37.66	21.40	38.66	21.95	39.65	22.50	40.64
20.31	36.69	20.86	37.68	21.41	38.68	21.96	39.67	22.51	40.66
20.32	36.71	20.87	37.70	21.42	38.69	21.97	39.69	22.52	40.68
20.33	36.73	20.88	37.72	21.43	38.71	21.98	39.70	22.53	40.70
20.34	36.74	20.89	37.74	21.44	38.73	21.99	39.72	22.54	40.71
20.35	36.76	20.90	37.75	21.45	38.75	22.00	39.74	22.55	40.73
20.36	36.78	20.91	37.77	21.46	38.77	22.01	39.76	22.56	40.75
20.37	36.80	20.92	37.79	21.47	38.78	22.02	39.78	22.57	40.77
20.38	36.82	20.93	37.81	21.48	38.80	22.03	39.79	22.58	40.79
20.39	36.83	20.94	37.83	21.49	38.82	22.04	39.81	22.59	40.80
20.40	36.85	20.95	37.84	21.50	38.84	22.05	39.83	22.60	40.82
20.41	36.87	20.96	37.86	21.51	38.86	22.06	39.85	22.61	40.84
20.42	36.89	20.97	37.88	21.52	38.87	22.07	39.87	22.62	40.86
20.43	36.91	20.98	37.90	21.53	38.89	22.08	39.88	22.63	40.88
20.44	36.92	20.99	37.92	21.54	38.91	22.09	39.90	22.64	40.90
20.45	36.94	21.00	37.94	21.55	38.93	22.10	39.92	22.65	40.91
20.46	36.96	21.01	37.95	21.56	38.95	22.11	39.94	22.66	40.93
20.47	36.98	21.02	37.97	21.57	38.96	22.12	39.96	22.67	40.95
20.48	37.00	21.03	37.99	21.58	38.98	22.13	39.97	22.68	40.97
20.49	37.01	21.04	38.01	21.59	39.00	22.14	39.99	22.69	40.99
20.50	37.03	21.05	38.03	21.60	39.02	22.15	40.01	22.70	41.00
20.51	37.05	21.06	38.04	21.61	39.04	22.16	40.03	22.71	41.02
20.52	37.07	21.07	38.06	21.62	39.05	22.17	40.05	22.72	41.04
20.53	37.09	21.08	38.08	21.63	39.07	22.18	40.06	22.73	41.06
20.54	37.10	21.09	38.10	21.64	39.09	22.19	40.08	22.74	41.08
20.55	37.12	21.10	38.12	21.65	39.11	22.20	40.10	22.75	41.09
20.56	37.14	21.11	38.13	21.66	39.13	22.21	40.12	22.76	41.11
20.57	37.16	21.12	38.15	21.67	39.14	22.22	40.14	22.77	41.13
20.58	37.18	21.13	38.17	21.68	39.16	22.23	40.16	22.78	41.15
20.59	37.19	21.14	38.19	21.69	39.18	22.24	40.17	22.79	41.17
20.60	37.21	21.15	38.21	21.70	39.20	22.25	40.19	22.80	41.18
20.61	37.23	21.16	38.22	21.71	39.22	22.26	40.21	22.81	41.20
20.62	37.25	21.17	38.24	21.72	39.23	22.27	40.23	22.82	41.22
20.63	37.27	21.18	38.26	21.73	39.25	22.28	40.25	22.83	41.24
20.64	37.29	21.19	38.28	21.74	39.27	22.29	40.26	22.84	41.26
20.65	37.30	21.20	38.30	21.75	39.29	22.30	40.28	22.85	41.27
20.66	37.32	21.21	38.31	21.76	39.31	22.31	40.30	22.86	41.29
20.67	37.34	21.22	38.33	21.77	39.32	22.32	40.32	22.87	41.31
20.68	37.36	21.23	38.35	21.78	39.34	22.33	40.34	22.88	41.33
20.69	37.38	21.24	38.37	21.79	39.36	22.34	40.35	22.89	41.35
20.70	37.39	21.25	38.39	21.80	39.38	22.35	40.37	22.90	41.36
20.71	37.41	21.26	38.40	21.81	39.40	22.36	40.39	22.91	41.38
20.72	37.43	21.27	38.42	21.82	39.42	22.37	40.41	22.92	41.40
20.73	37.45	21.28	38.44	21.83	39.43	22.38	40.43	22.93	41.42
20.74	37.47	21.29	38.46	21.84	39.45	22.39	40.44	22.94	41.44
20.75	37.48	21.30	38.48	21.85	39.47	22.40	40.46	22.95	41.45
20.76	37.50	21.31	38.49	21.86	39.49	22.41	40.48	22.96	41.47
20.77	37.52	21.32	38.51	21.87	39.51	22.42	40.50	22.97	41.49
20.78	37.54	21.33	38.53	21.88	39.52	22.43	40.52	22.98	41.51
20.79	37.56	21.34	38.55	21.89	39.54	22.44	40.53	22.99	41.53
								23.00	41.55

Table 17.—MEAN DENSITY OF SEA WATER COLUMN ABOVE ESTIMATED DEPTH

Estimated depth (meters)	North Atlantic		Northeast Pacific		Arctic [1]		Antarctic [2]		Mediterranean	
	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$	ρ_m	$\frac{1}{\rho_m}$
0	1. 0262	0. 9745	--------	--------	1. 0279	0. 9729	1. 0275	0. 9732	1. 0282	0. 9726
100	1. 0264	. 9743	1. 0248	0. 9758	1. 0281	. 9727	1. 0277	. 9730	1. 0286	. 9722
200	1. 0267	. 9740	1. 0255	. 9751	1. 0283	. 9725	1. 0281	. 9727	1. 0289	. 9719
300	1. 0270	. 9737	1. 0261	. 9746	1. 0285	. 9723	1. 0284	. 9724	1. 0293	. 9715
400	1. 0274	. 9733	1. 0267	. 9740	1. 0288	. 9720	1. 0287	. 9721	1. 0296	. 9712
500	1. 0278	. 9730	1. 0272	. 9735	1. 0290	. 9718	1. 0290	. 9718	1. 0300	. 9709
600	1. 0281	. 9727	1. 0276	. 9731	1. 0292	. 9716	1. 0292	. 9716	1. 0302	. 9707
700	1. 0285	. 9723	1. 0280	. 9728	1. 0295	. 9713	1. 0295	. 9713	1. 0305	. 9704
800	1. 0288	. 9720	1. 0283	. 9725	1. 0297	. 9712	1. 0297	. 9712	1. 0307	. 9702
900	1. 0291	. 9717	1. 0286	. 9722	1. 0299	. 9710	1. 0300	. 9709	1. 0310	. 9699
1,000	1. 0294	. 9714	1. 0289	. 9719	1. 0302	. 9707	1. 0302	. 9707	1. 0312	. 9697
1,500	1. 0308	. 9701	1. 0304	. 9705	1. 0314	. 9696	1. 0314	. 9696	1. 0324	. 9686
2,000	1. 0321	. 9689	1. 0318	. 9692	1. 0326	. 9684	1. 0326	. 9684	1. 0335	. 9676
2,500	1. 0334	. 9677	1. 0331	. 9680	1. 0338	. 9673	1. 0338	. 9673	1. 0346	. 9665
3,000	1. 0346	. 9666	1. 0344	. 9667	1. 0351	. 9661	1. 0350	. 9662	1. 0358	. 9655
3,500	1. 0358	. 9654	1. 0356	. 9656	1. 0363	. 9650	1. 0362	. 9651	--------	--------
4,000	1. 0370	. 9643	1. 0369	. 9644	1. 0375	. 9638	1. 0375	. 9638	--------	--------
4,500	1. 0383	. 9631	--------	--------	1. 0387	. 9627	1. 0387	. 9627	--------	--------
5,000	1. 0395	. 9620	--------	--------	1. 0400	. 9615	1. 0400	. 9615	--------	--------

[1] Norwegian and Greenland Seas.
[2] Ross and Weddell Seas.

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WASHINGTON, D. C. 20390

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18 June 1964

From: Commander, U. S. Naval Oceanographic Office
To: Distribution List

Subj: Instruction Manual for Oceanographic Observations (H.O.Pub.607); revision to

Encl: (1) Supplement to H.O. Pub. 607

1. The value of oceanographic information is dependent upon the accuracy and reliability of the instruments used for its collection. The Instruction Manual for Oceanographic Observations (H.O. Pub. 607) provides a basic reference for the care and handling of selected oceanographic instruments. Closely allied with this information is the need to know more about the actual performance of oceanographic instruments that have been tested under controlled environmental conditions.

2. The results of tests conducted by the Navy's Oceanographic Instrumentation Center have been synopsized and incorporated in a prototype Instrument Fact Sheet. Enclosure (1) should be beneficial to all activities that use precise oceanographic instruments or are concerned with the validity of the data derived from them. Other fact sheets will be prepared and distributed as instruments are tested and evaluated by the Center.

3. Comments and suggestions concerning the use of the Instrument Fact Sheet are invited and should be forwarded to the Commander, U. S. Naval Oceanographic Office.

Denys W. Knoll

DENYS W. KNOLL

Distribution:
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PART III

INSTRUMENT FACT SHEETS

The accuracy and reliability of oceanographic and related instruments is of concern to all activities that make oceanographic measurements or use the data derived from these instruments.

The U. S. Navy's Oceanographic Instrumentation Center has undertaken a program of testing and calibration of the instruments and related devices that are available for making oceanographic measurements. The Fact Sheets that make up Part III are factual reports of the tests carried out by the Center. No attempt has been made to draw conclusions regarding the value of the instrument for any specific requirement; the reader must judge this for himself.

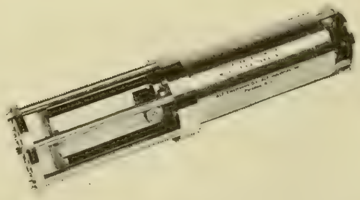
U. S. NAVY OCEANOGRAPHIC INSTRUMENTATION CENTER

INSTRUMENT FACT SHEET

MAY 1964 IFS-001-64

This document is issued to acquaint users of oceanographic instruments with the technical results of engineering evaluations conducted in the laboratory and the field by the Instrument Center.

DEEP SEA VELOCIMETER



MODEL

TR-4-A

MANUFACTURER

ACF INDUSTRIES

DESCRIPTION

THE TR-4 VELOCIMETER IS A SELF-CONTAINED INSTRUMENT DESIGNED TO DIRECTLY MEASURE THE VELOCITY OF SOUND IN WATER USING THE "SING-AROUND" TECHNIQUE. AN ACOUSTIC PULSE IS TRANSMITTED THROUGH THE WATER AND WHEN RECEIVED, TRIGGERS ANOTHER TRANSMITTED PULSE. THUS, THE RESULTING REPETITION RATE (I. E., FREQUENCY) IS PROPORTIONAL TO THE SOUND VELOCITY. THE FREQUENCY SIGNAL, AFTER TRAVELING THROUGH THE NECESSARY CABLE LENGTH IS THEN AMPLIFIED AND DOUBLED BY THE AUXILIARY FREQUENCY DOUBLER.

SPECIFICATIONS

	MFGR	CENTER
Accuracy (m/sec)	±0.15	+0.31 −0.05
Maximum Operating Pressure (psi)	20,000	10,000*
Power Supply		
Source	Ext. AC	
Source Requirements		
Voltage (VAC)	105-125V	No Effect
Frequency (cps)	50-400 cps	No Effect
Power (VA)	2 VA	
Signal Attenuation Sensitivity (3 db)	0.07	0.08
Dimensions (inches		
Maximum Length	14-5/16	
Maximum Diameter	4	
Weight (pounds)		
Less Housing	7-1/2	
With Housing	16-1/2	

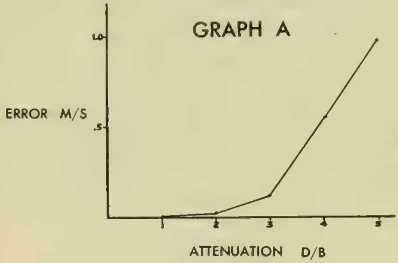
*Maximum available test pressure.

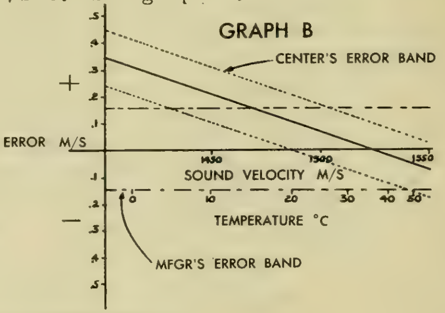
ADDITIONAL TEST DATA

The frequency doubler unit has a mercury battery power supply of 6.75 volts. The unit becomes inoperative if this voltage falls below 3.8 volts.

The errors induced by the effects of signal attenuation of up to 3 db and above are shown in graph A.

The relationship between the sound velocity (C), and the "Sing-Around" frequency (F), as stated by the manufacturer is: C = .205916F ±.15 m/sec. This equation was observed to result in an error of +.31 to −.05 m/sec. However, if the relationship for this particular instrument is changed to: C = .206451F − 3.96 m/sec, the error is within ±.1 m/sec. See graph B.





ALL TESTS WERE PERFORMED IN DISTILLED WATER AND ATMOSPHERIC PRESSURE