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INSTRUCTION MANUAL

FOR

OBTAINING OCEANOGRAPHIC DATA

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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.

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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 $\frac{5}{32}$- or $\frac{3}{16}$-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

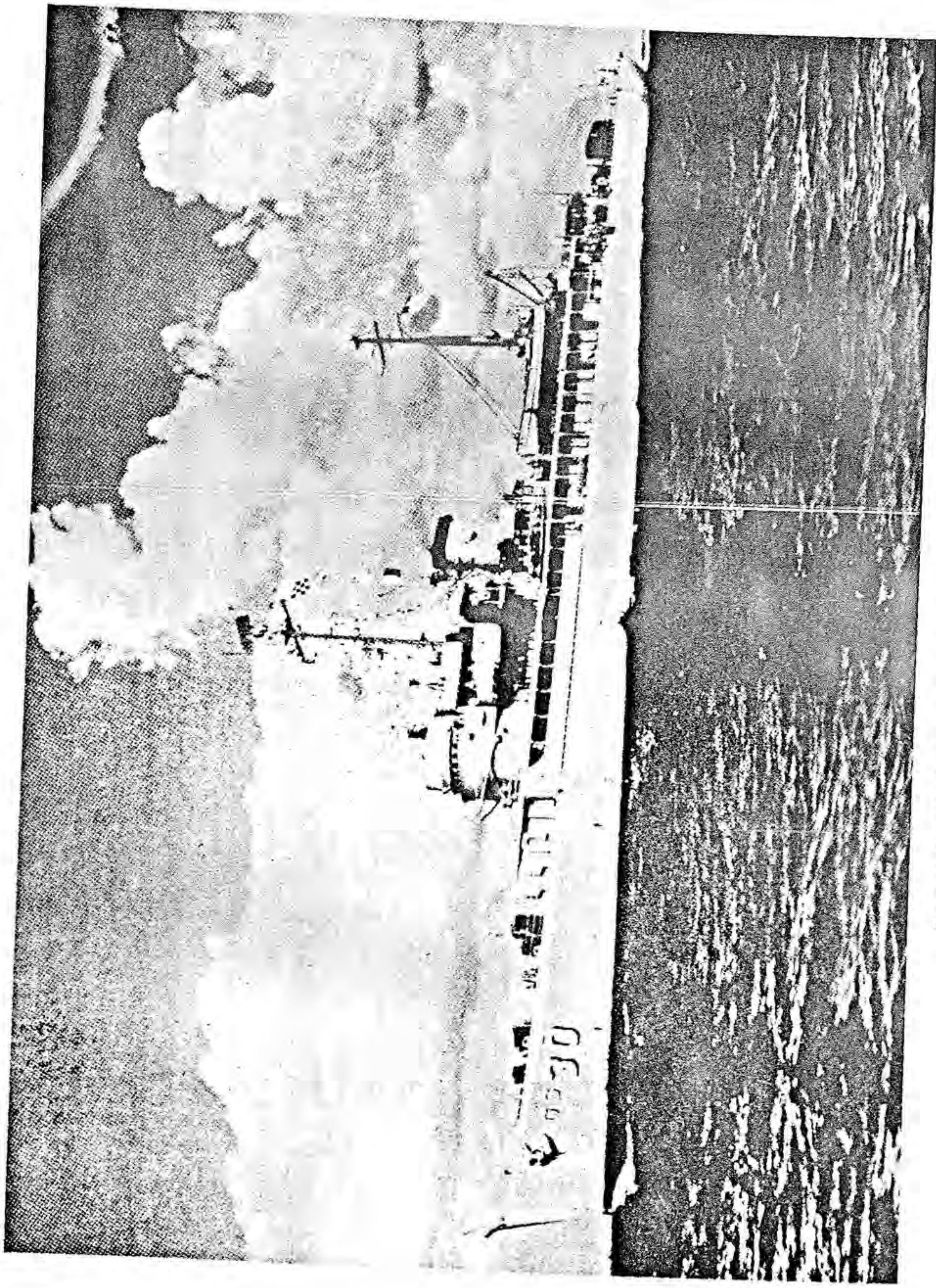

Figure A–1. USS *San Pablo* (AGS–30) Oceanographic survey ship.

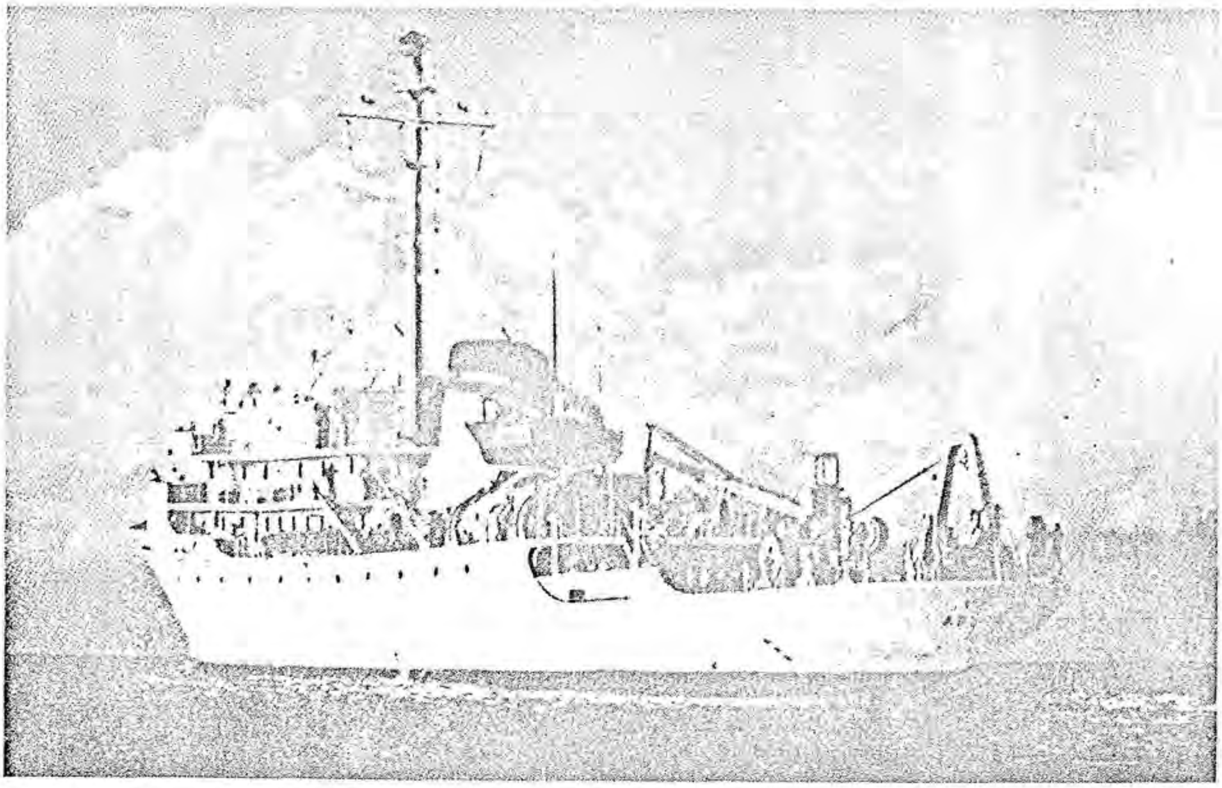

Figure A–2. USNS *Silas Bent* (AGS–26) Oceanographic survey ship.

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

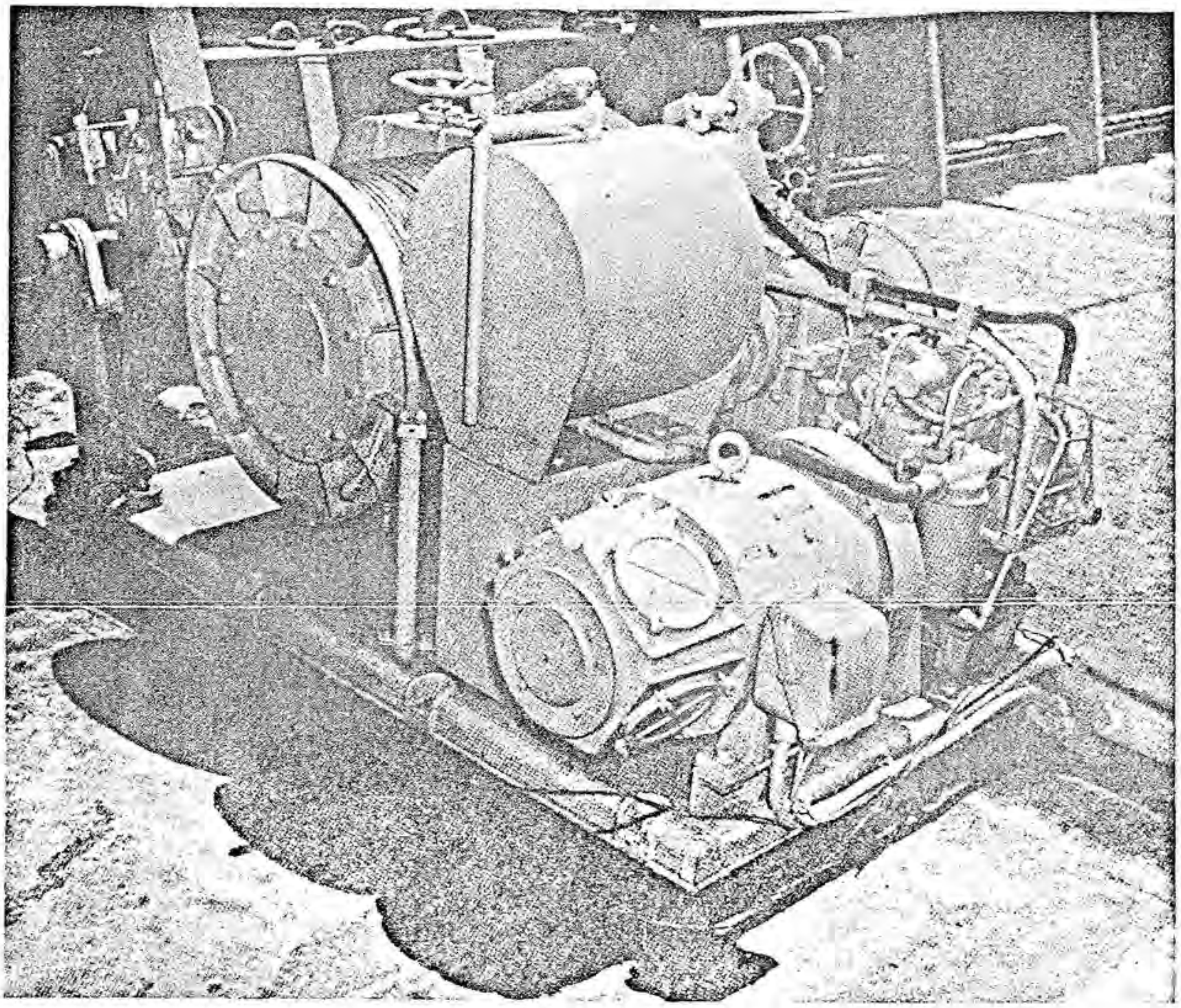

Figure A–3. Oceanographic-hydrographic winch.

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.

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-

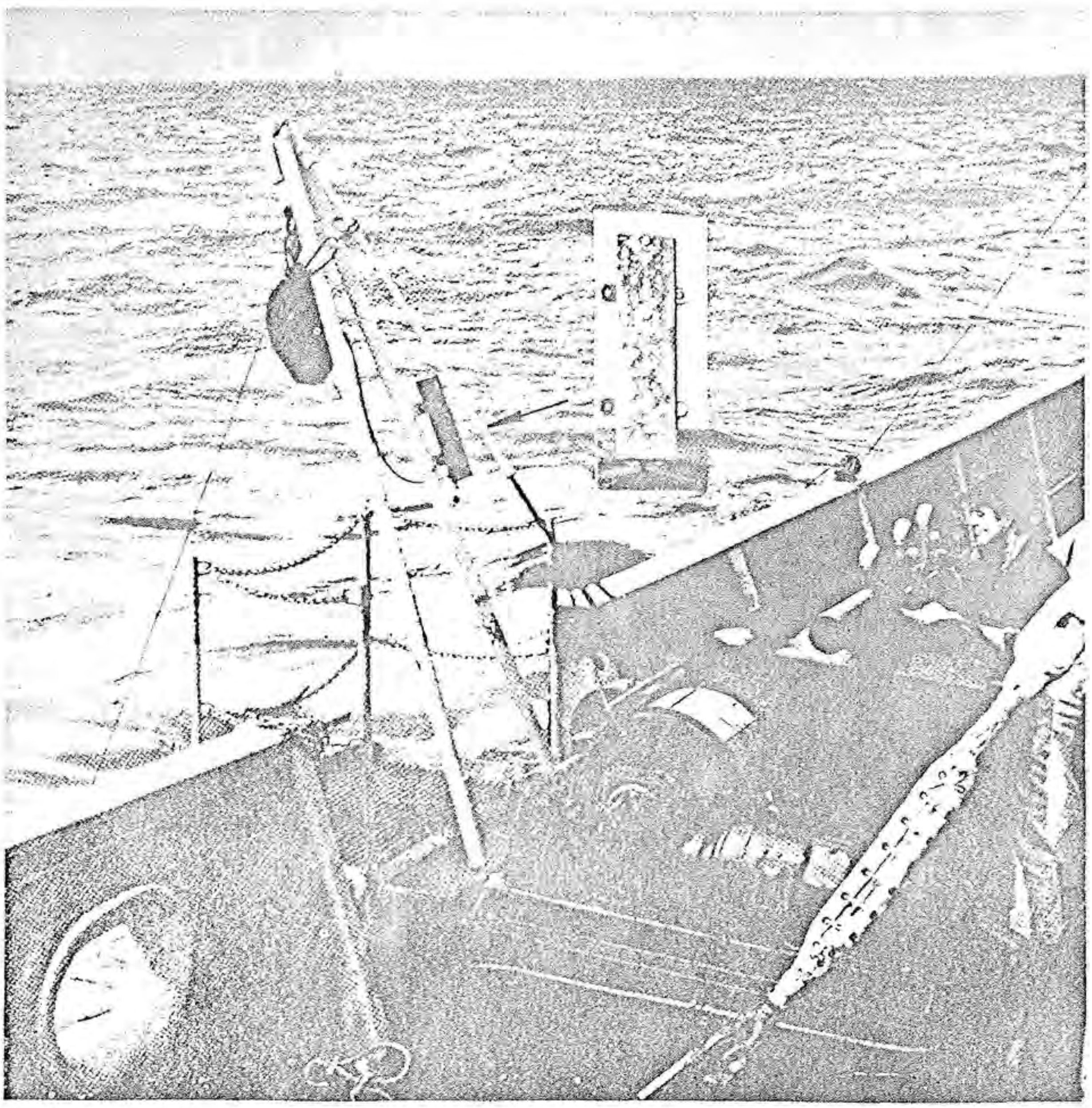

Figure A-4. **Platform, A-Frame, meter wheel, and counter block.**

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 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 $\frac{1}{10}$ 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	slight at time of observation
52	Drizzle, not freezing, intermittent	moderate at time of observation
53	Drizzle, not freezing, continuous	moderate at time of observation
54	Drizzle, not freezing, intermittent	thick at time of observation
55	Drizzle, not freezing, continuous	thick at time of observation
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	slight at time of observation
62	Rain, not freezing, intermittent	moderate at time of observation
63	Rain, not freezing, continuous	moderate at time of observation
64	Rain, not freezing, intermittent	heavy at time of observation
65	Rain, not freezing, continuous	heavy at time of observation
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	slight at time of observation
72	Intermittent fall of snow flakes	moderate at time of observation
73	Continuous fall of snow flakes	moderate at time of observation
74	Intermittent fall of snow flakes	heavy at time of observation
75	Continuous fall of snow flakes	heavy at time of observation
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), with or without rain or rain and snow mixed	—slight
88	Shower(s) of snow pellets or ice pellets, type (b), 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 the preceding hour but not at time of observation
92	Moderate or heavy rain at time of observation	thunderstorm during the preceding hour but not at time of observation
93	Slight snow, or rain and snow mixed or hail** at time of observation	thunderstorm during the preceding hour but not at time of observation
94	Moderate or heavy snow, or rain and snow mixed or hail** at time of observation	thunderstorm during the preceding hour but not 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	thunderstorm at time of observation
97	Thunderstorm, heavy without hail**, but with rain and/or snow at time of observation	thunderstorm at time of observation
98	Thunderstorm combined with duststorm or sandstorm at time of observation	thunderstorm at time of observation
99	Thunderstorm, heavy, with hail** at time of observation	thunderstorm 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).

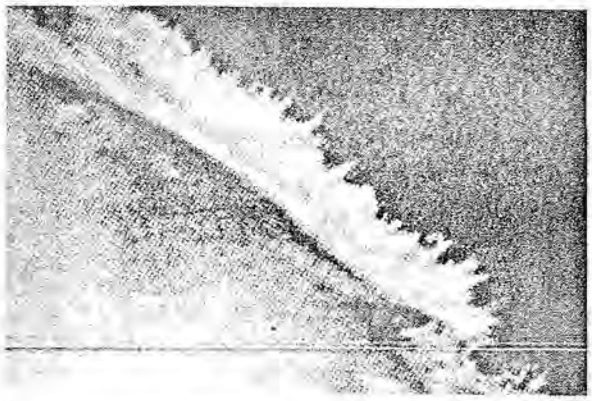

Figure B-1. Cirrus.

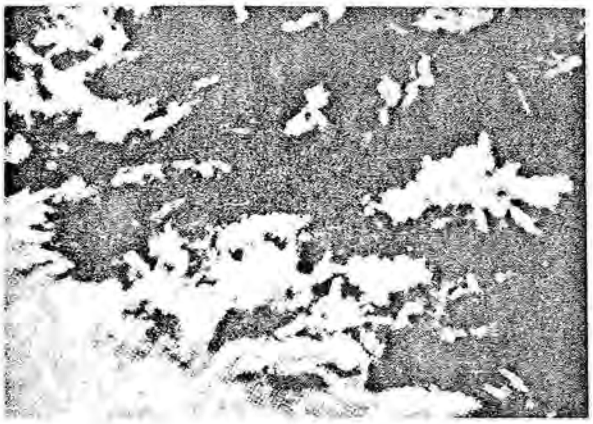

Figure B-2. Filaments or strands of cirrus scattered and not increasing.

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.

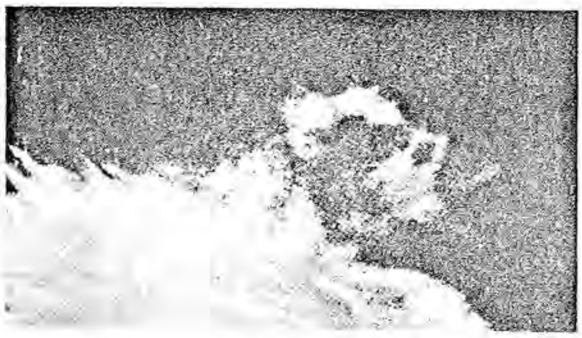

Figure B–7. Cirrus and cirrostratus often in bands converging toward the horizon.

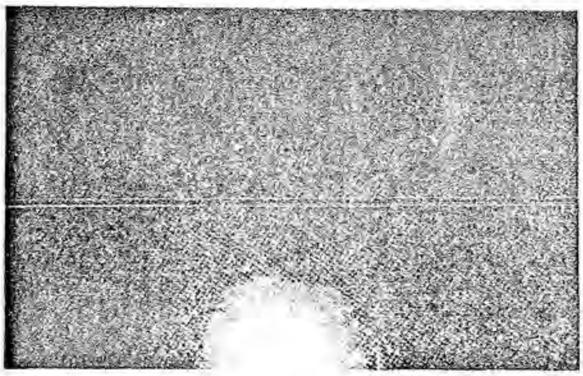

Figure B–8. Cirrostratus covering the entire sky.

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.

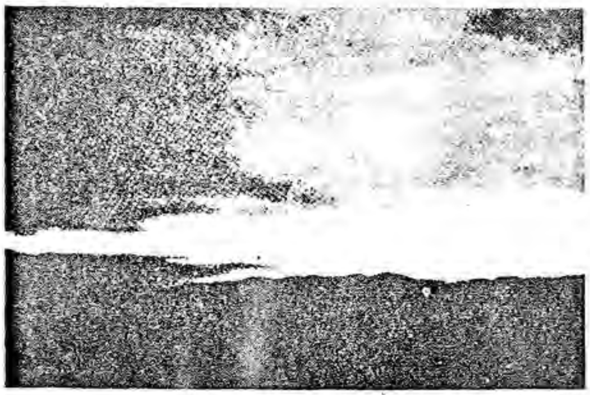

Figure B–12. Thick altostratus or nimbostratus.

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.

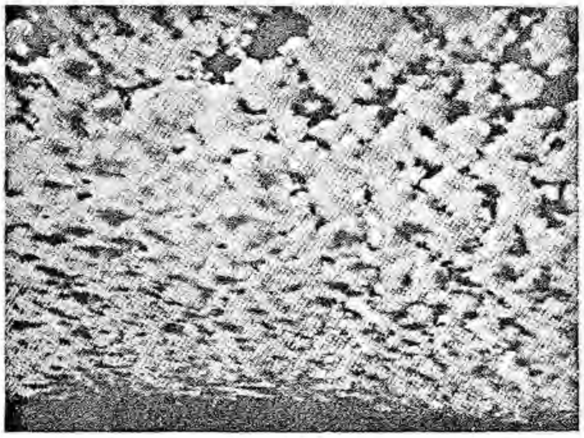

Figure B-13. Thin (semitransparent) altocumulus.

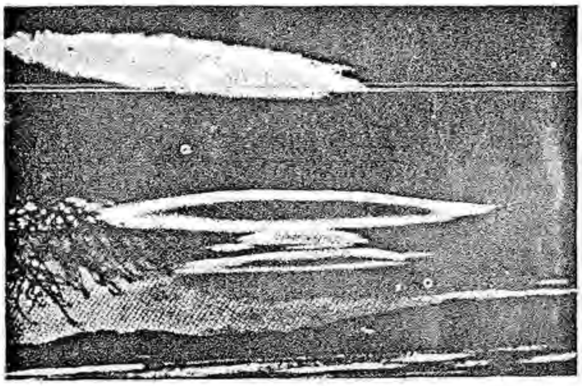

Figure B-14. Altocumulus in patches.

Figure B-15. Altocumulus in bands.

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

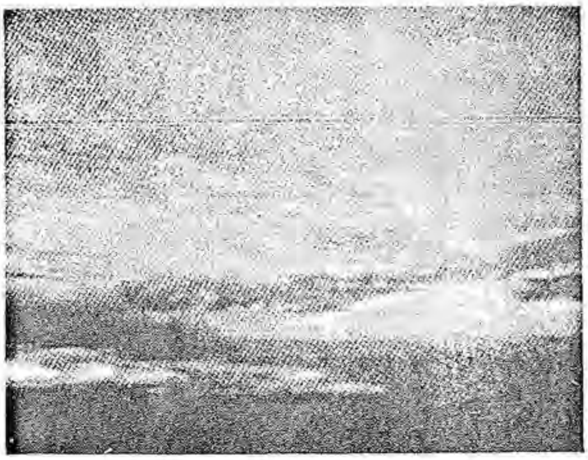

Figure B-17. Altostratus and altocumulus.

Figure B-18. Altostratus and altocumulus.

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 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.

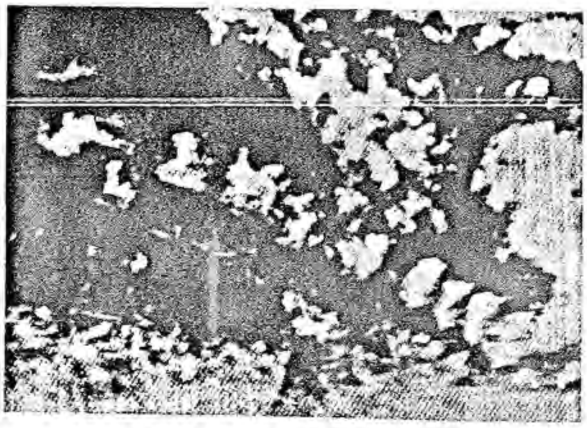

Figure B–20. Altocumulus.

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

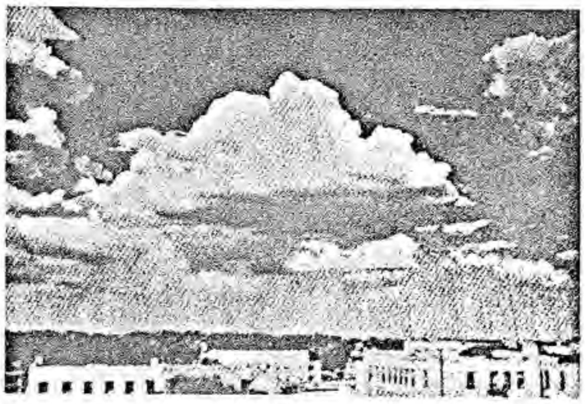

Figure B–22. Cumulus of considerable development, generally towering.

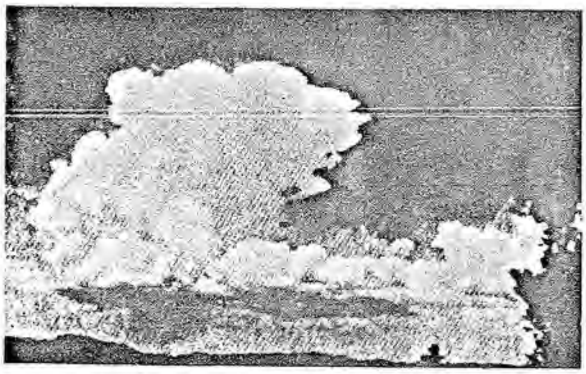

Figure B–23. Cumulonimbus.

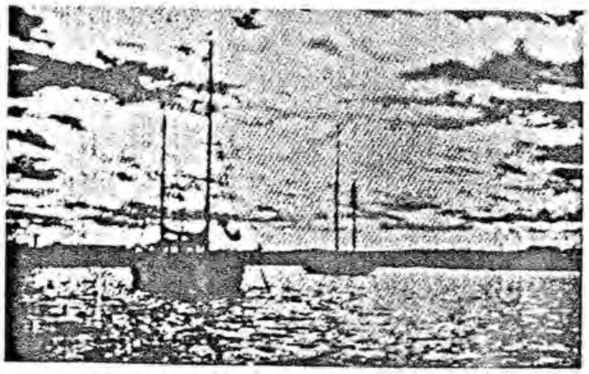

Figure B–24. Stratocumulus formed by spreading out of cumulus.

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 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

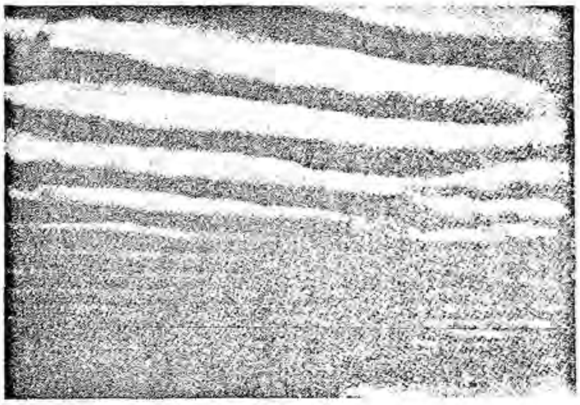

Figure B–25. Stratocumulus not formed by spreading out of cumulus.

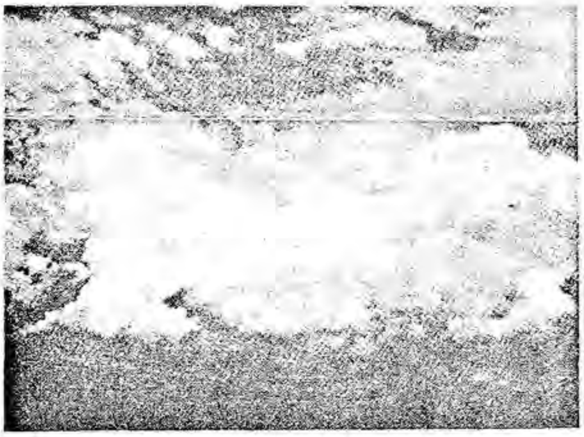

Figure B–26. Cumulus and stratocumulus.

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

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).

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.

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 columns.

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 $(\text{Period})^2$

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.

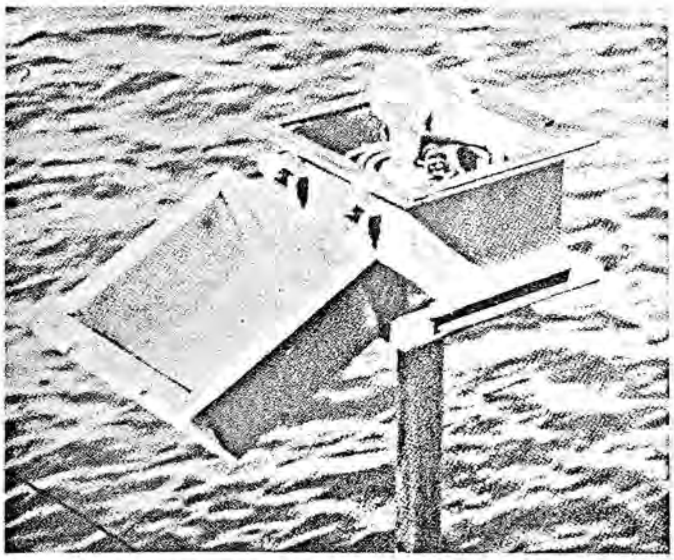
An installation for measuring total incoming solar radiation and the radiation reflected from the sea surface includes one topside pyrheliometer and two inverted (180° shielded) outboard pyrheliometers (fig. B–29).

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.

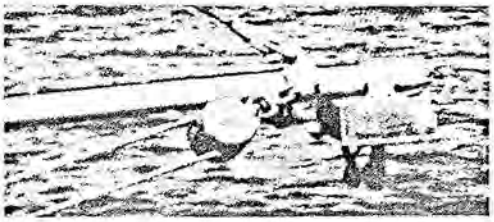
B–19 Marking the Recorder Chart.—The following information is entered on the recorder chart:

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



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 predicted.

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 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

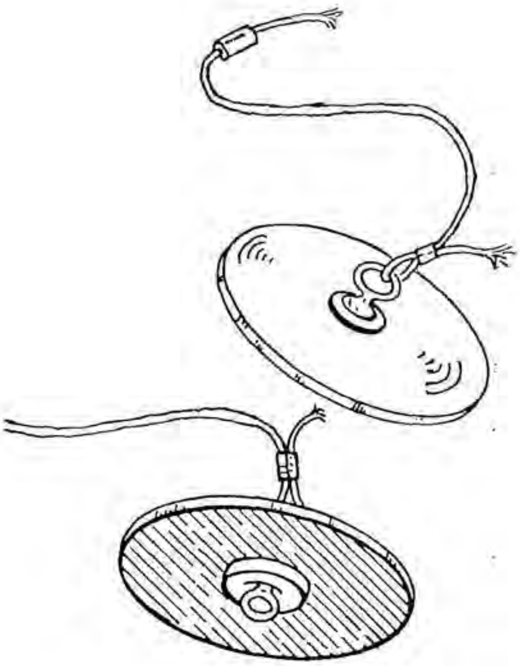


Figure B-30. The Secchi disc.

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

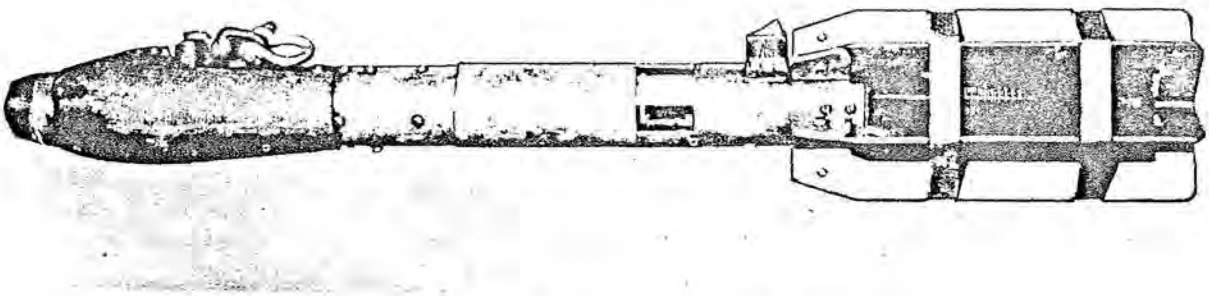


Figure C-1. The Bathythermograph (BT).

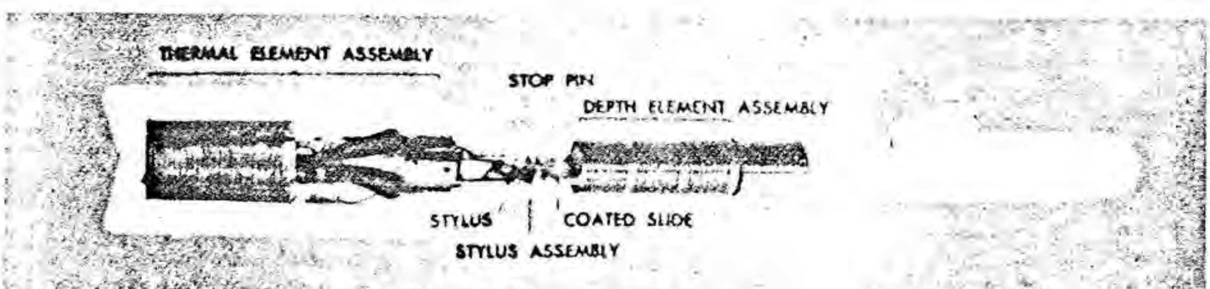


Figure C-2. BT thermal element, depth element, and styllus assemblies.

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. 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.

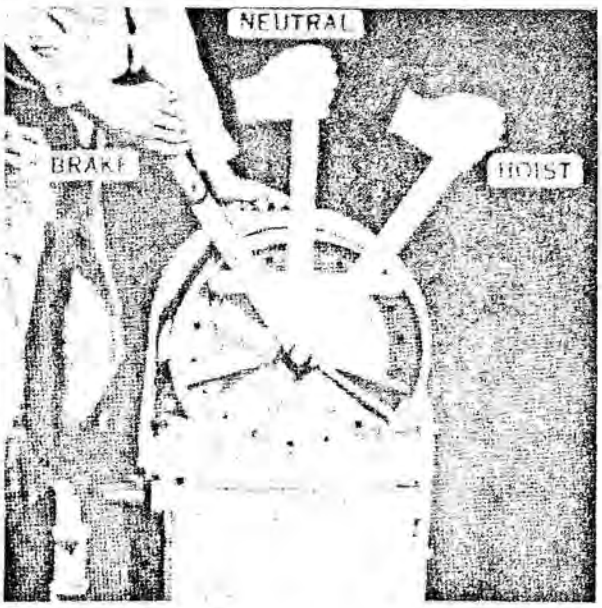


Figure C–3. E 6/S BT winch operating positions.

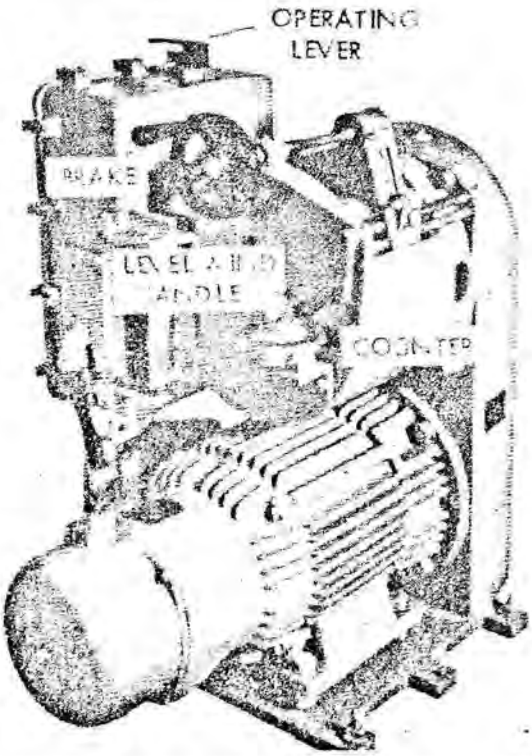


Figure C–4. ACCO Equipment Division BT winch.

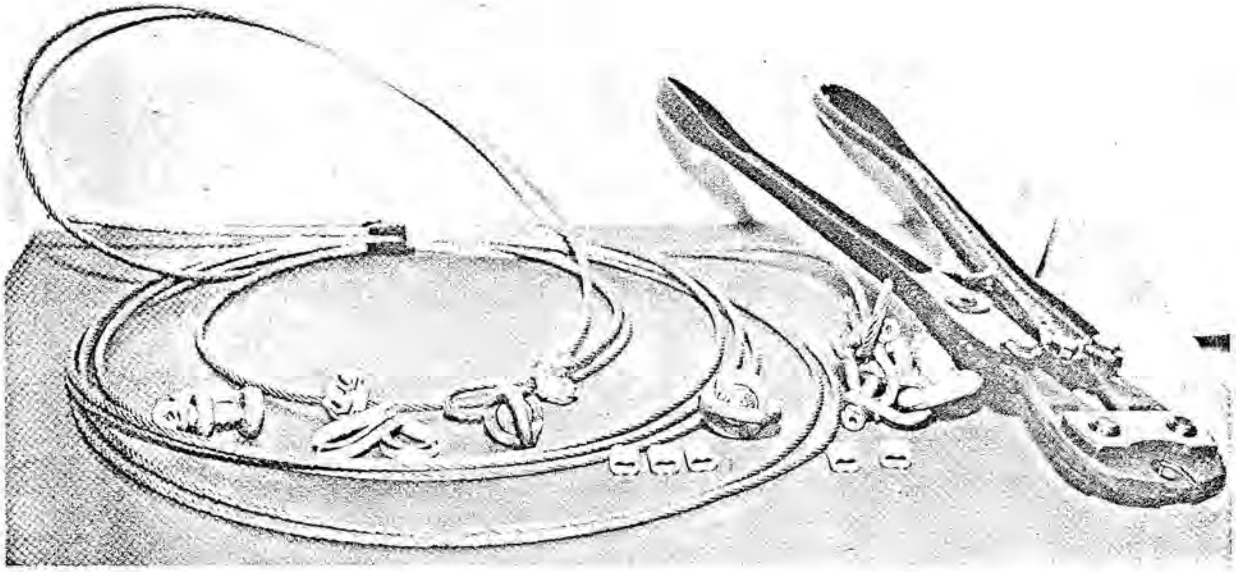


Figure C–5. The Nicopress tool and sleeves, wire rope, thimbles, swivels, wire clips, and shackles.

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.

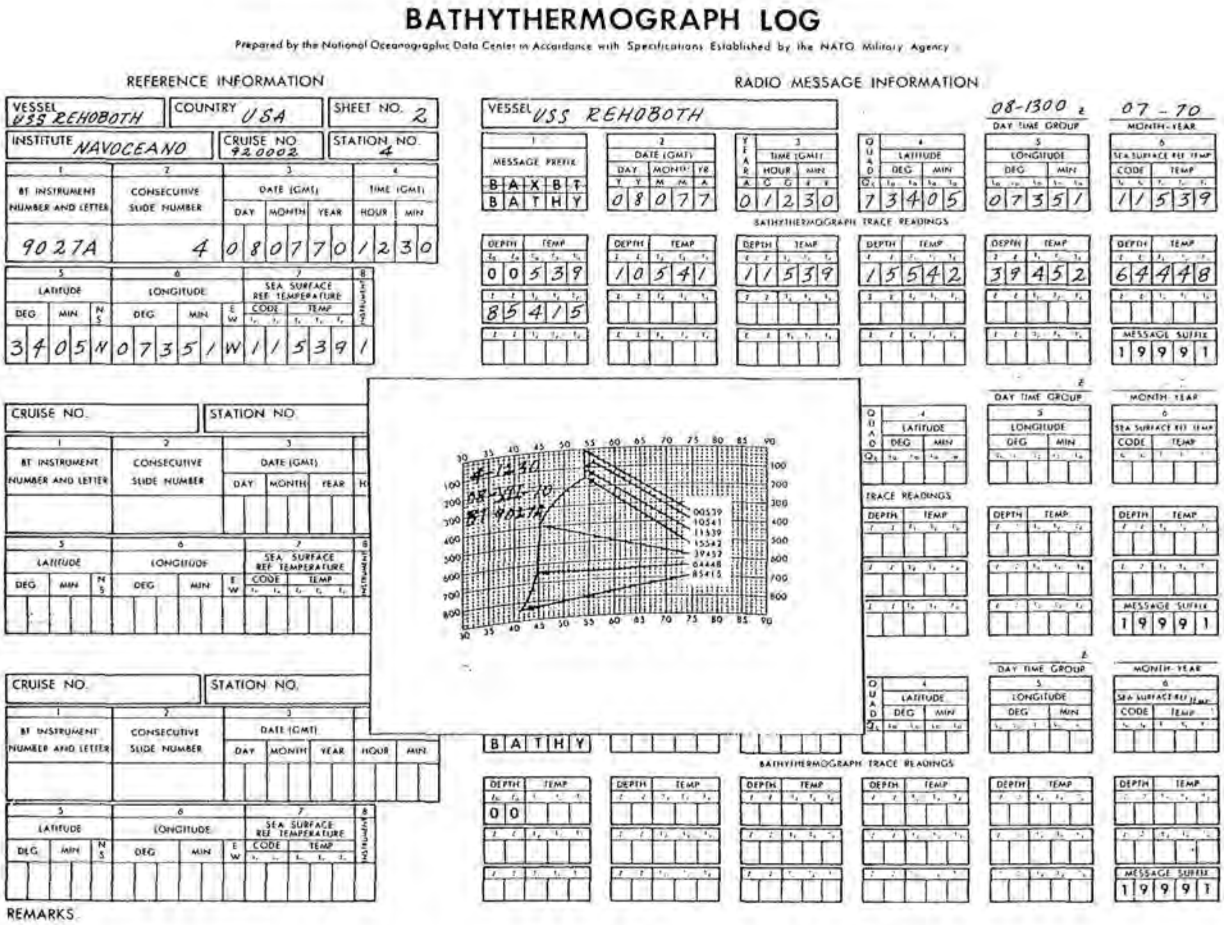


Figure C-6. Bathythermograph Log with slide and grid inset.

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

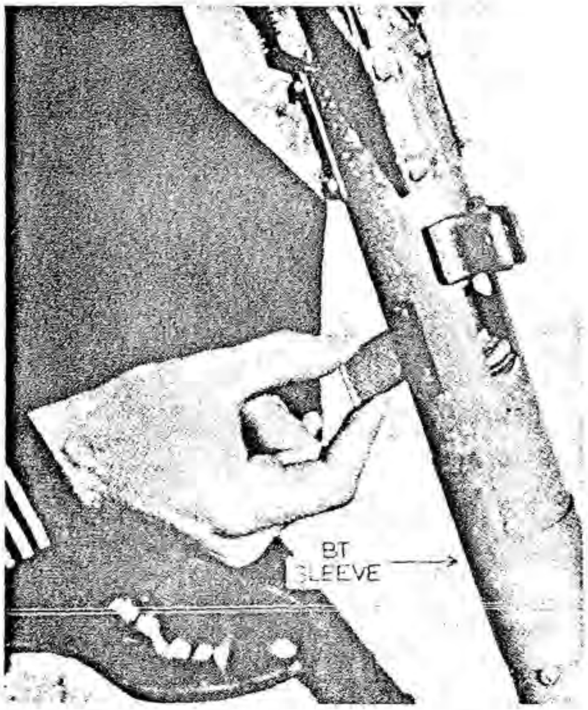


Figure C–7. Inserting glass slide into BT.

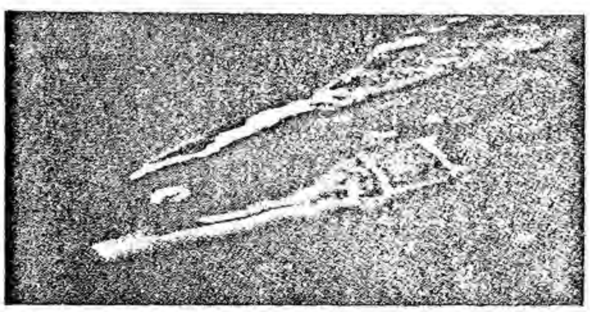


Figure C–8. BT just below the surface.

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

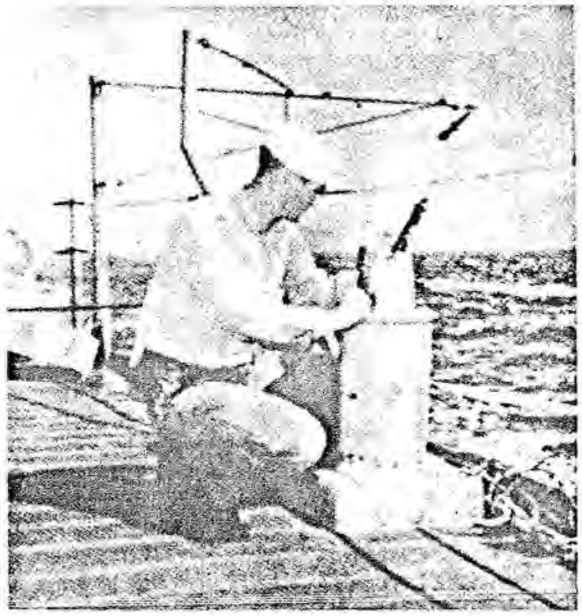


Figure C–9. Reading the sea surface reference temperature.

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

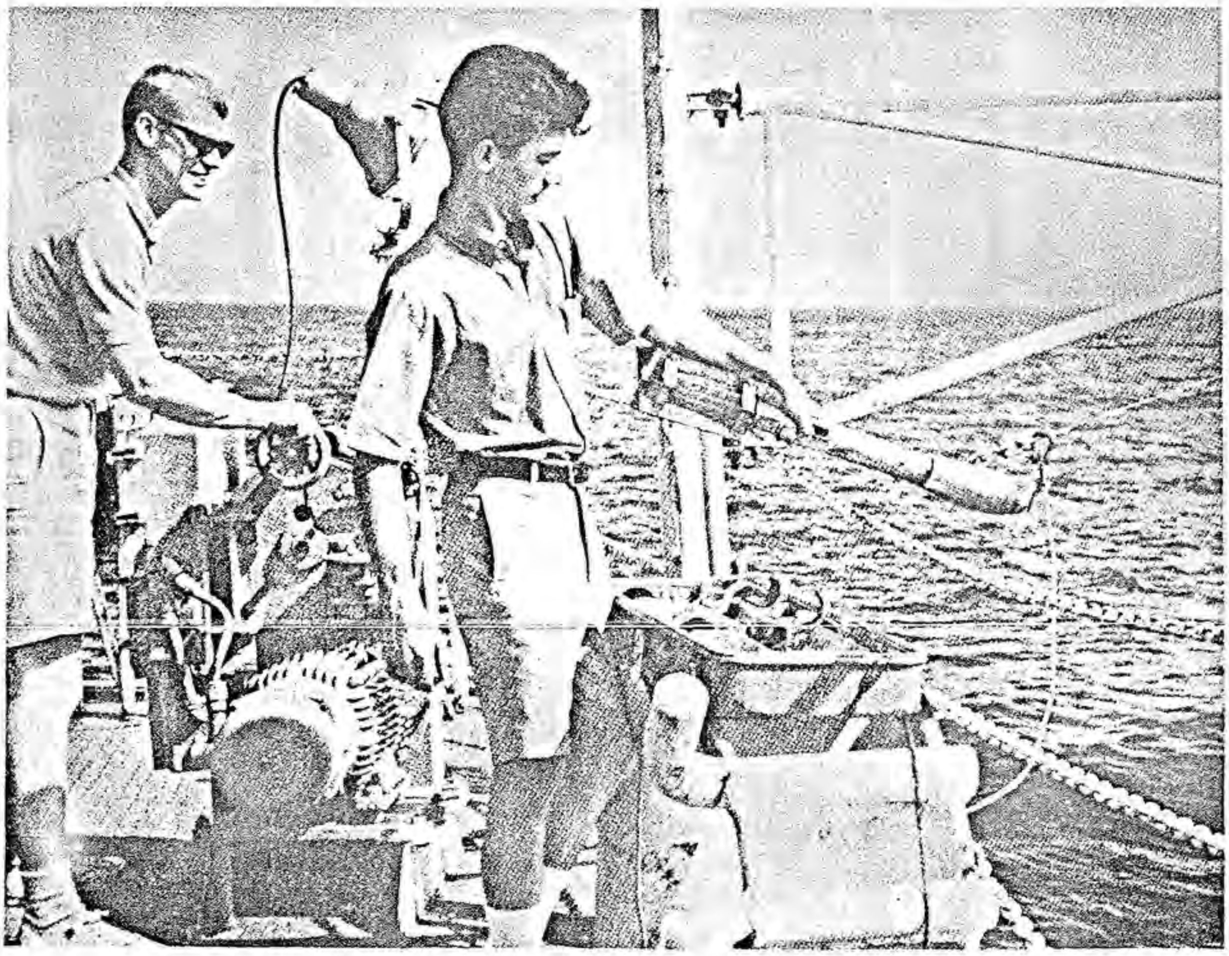


Figure C–10. Bringing BT aboard with a retrieving line and ring.

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.

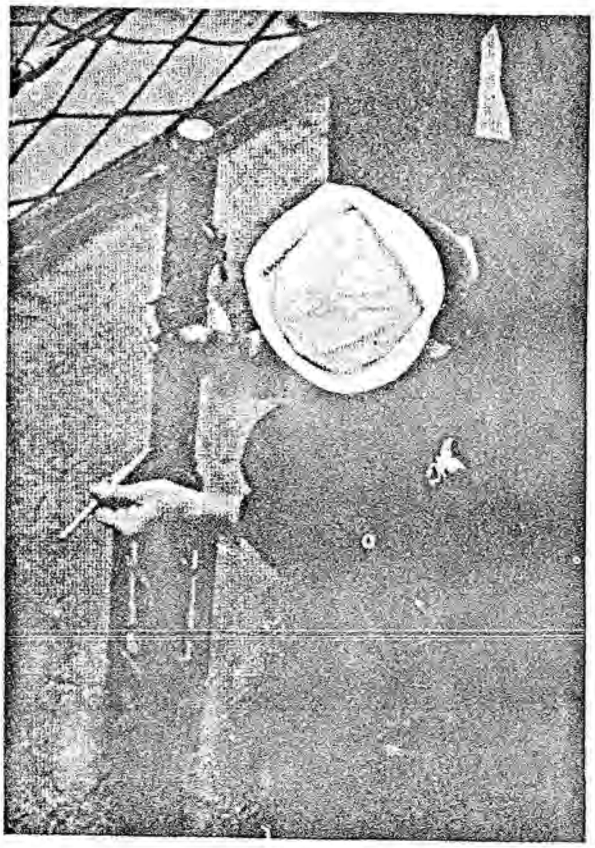


Figure C–11. Ejecting the BT slide.

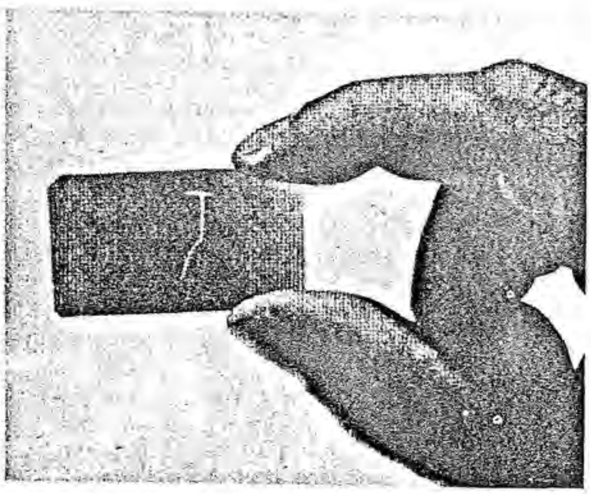


Figure C–12. Holding the BT slide.

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

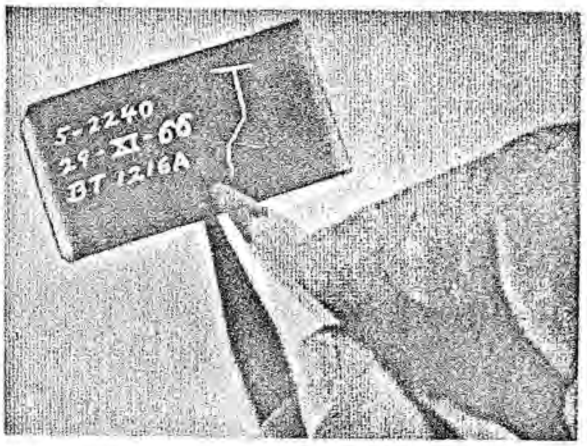


Figure C–13. Labeling the BT slide.

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.

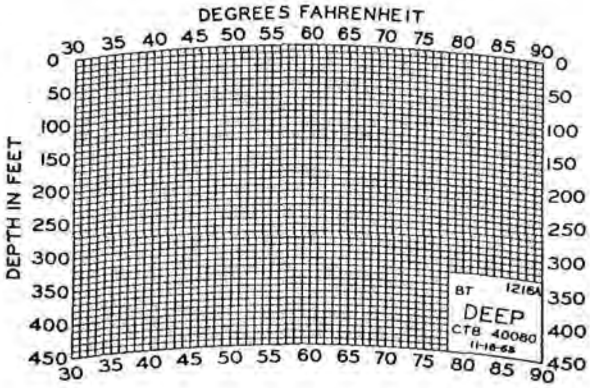


Figure C–14. BT grid.

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

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).
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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.

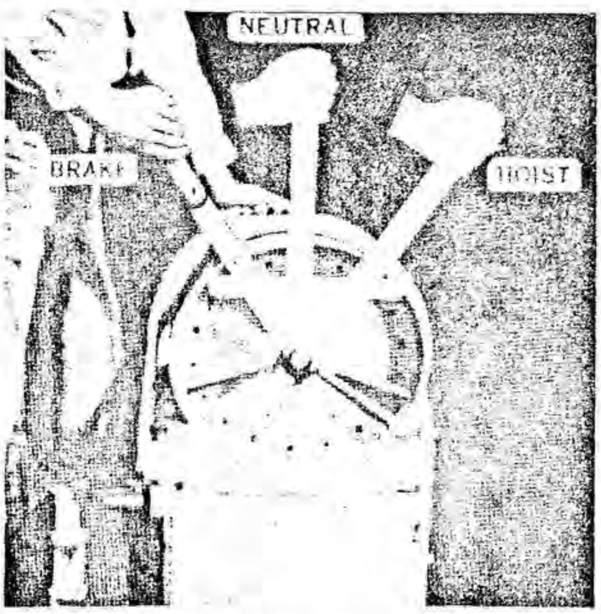

Figure C–3. E 6/S BT winch operating positions.

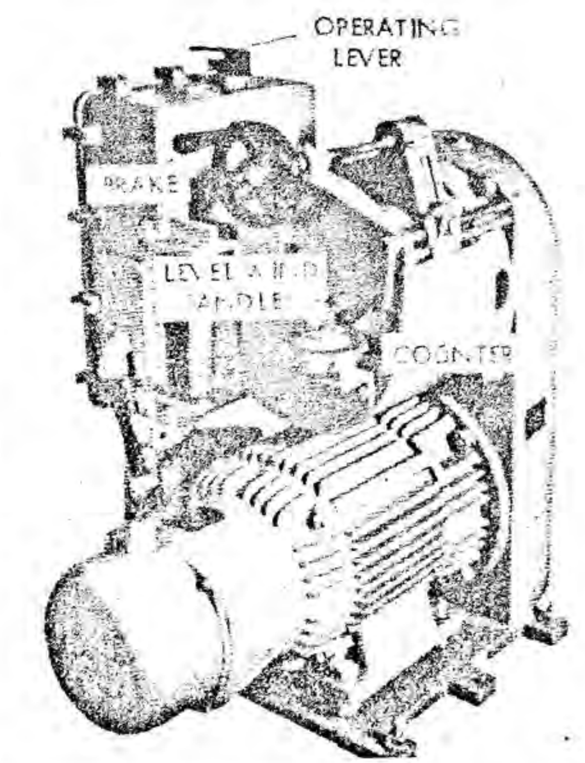

Figure C–4. ACCO Equipment Division BT winch.

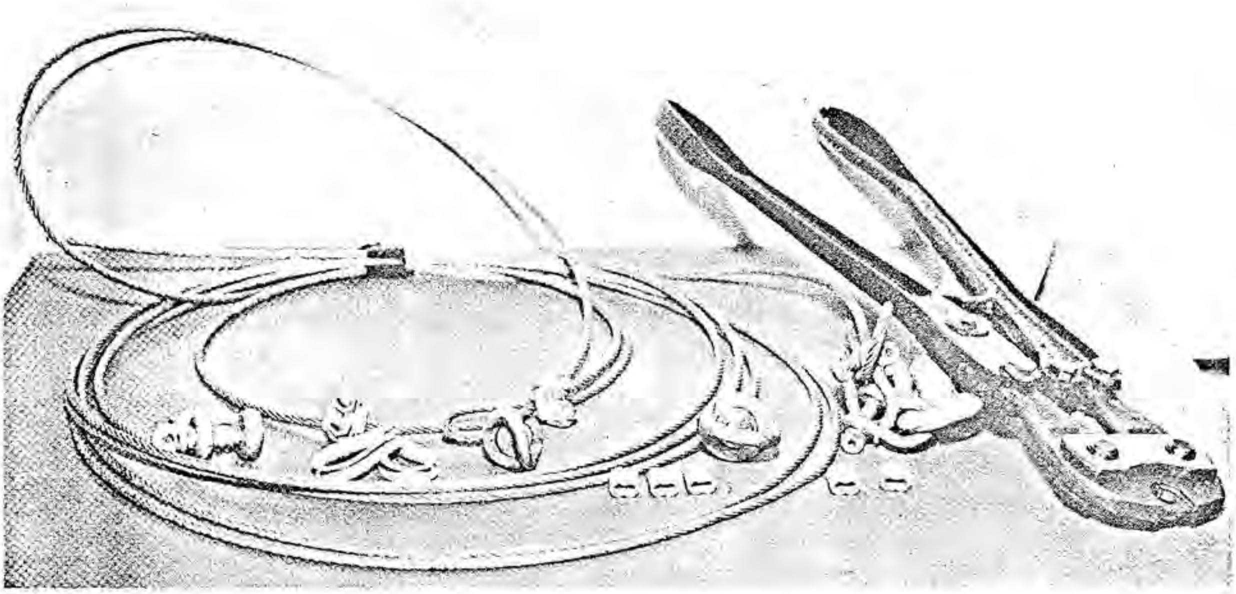

Figure C–5. The Nicopress tool and sleeves, wire rope, thimbles, swivels, wire clips, and shackles.

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.

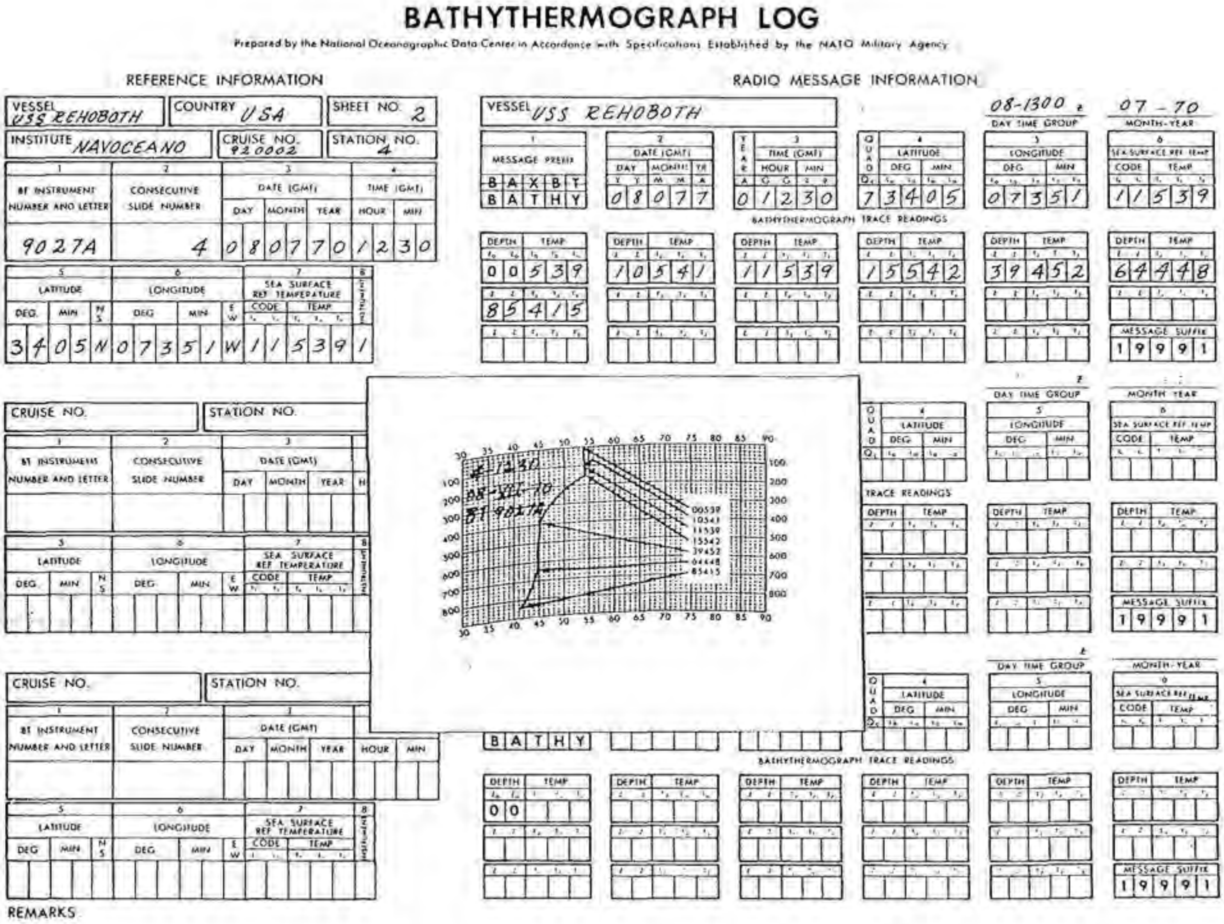

Figure C–6. Bathythermograph Log with slide and grid inset.

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:

<u>CHECK THE DEPTH OF WATER JUST BEFORE MAKING EACH LOWERING.</u>

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

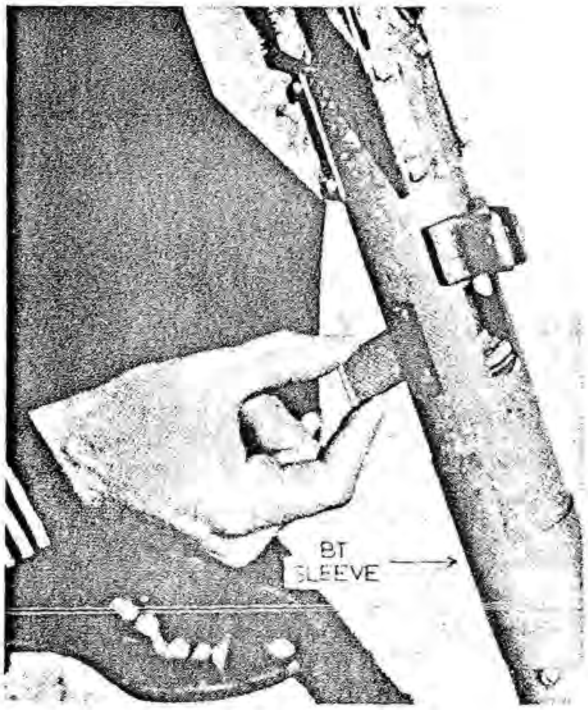

Figure C–7. Inserting glass slide into BT.

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

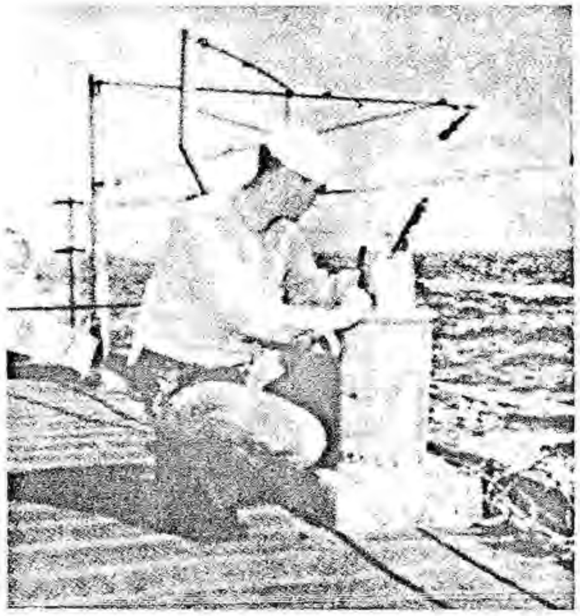

Figure C–9. Reading the sea surface reference temperature.

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

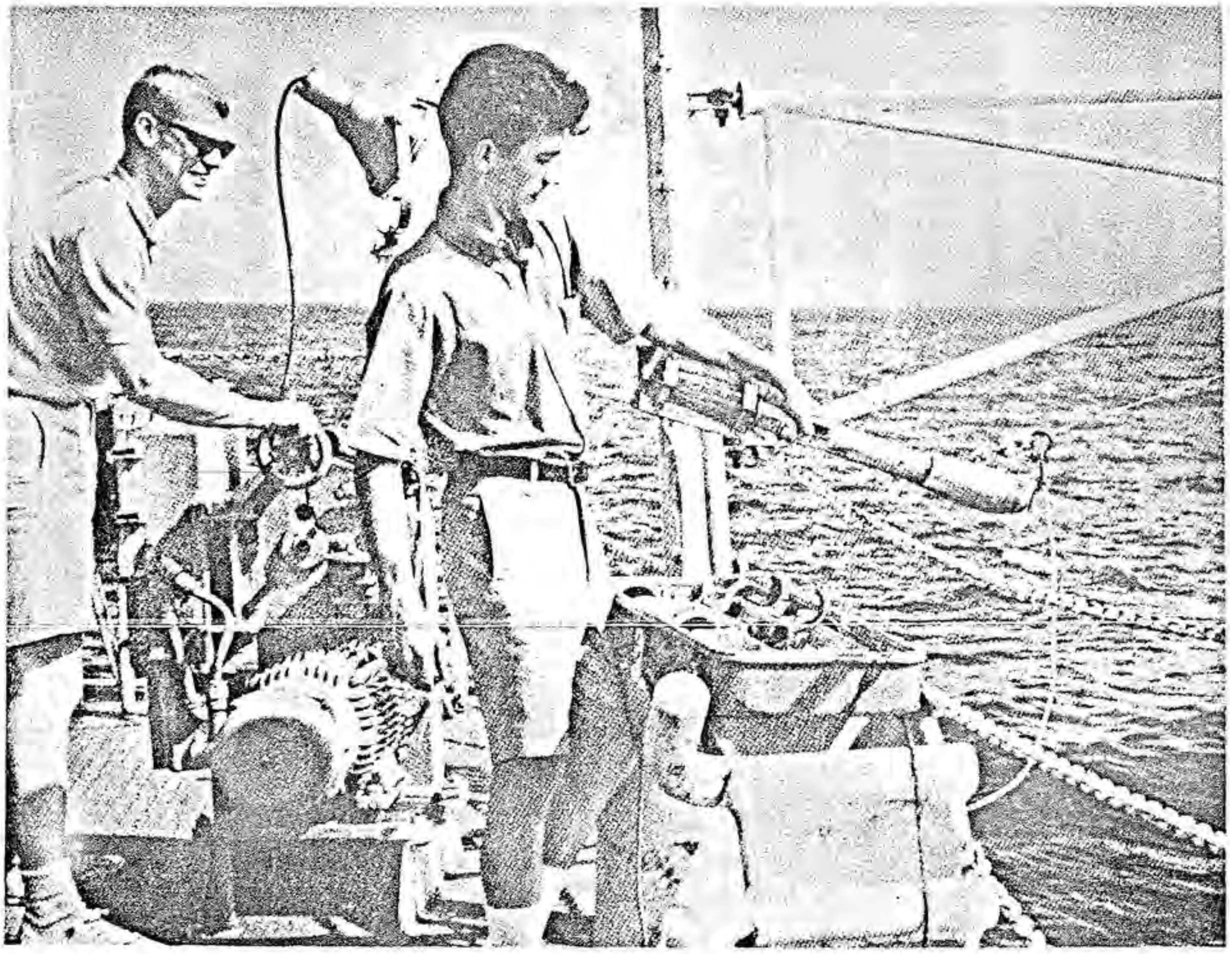

Figure C–10. Bringing BT aboard with a retrieving line and ring.

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.

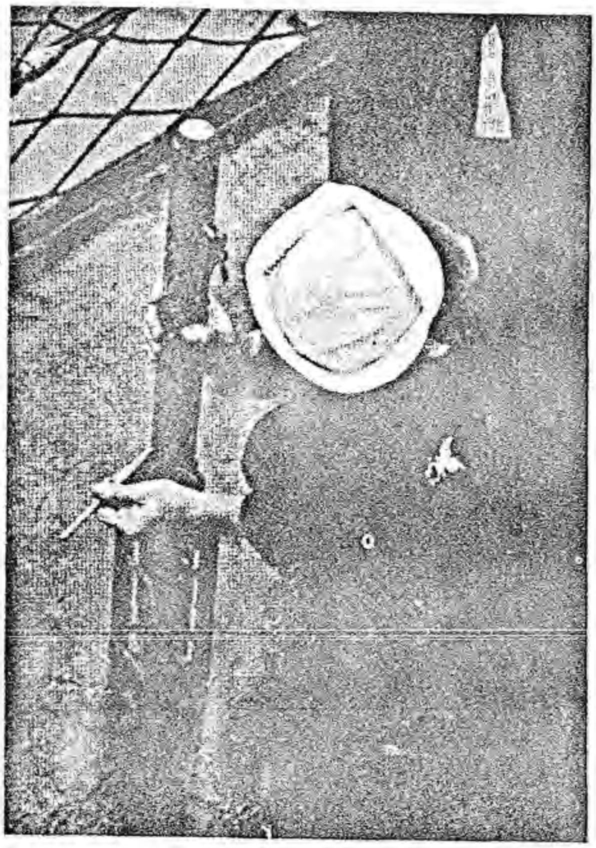

Figure C-11. Ejecting the BT slide.

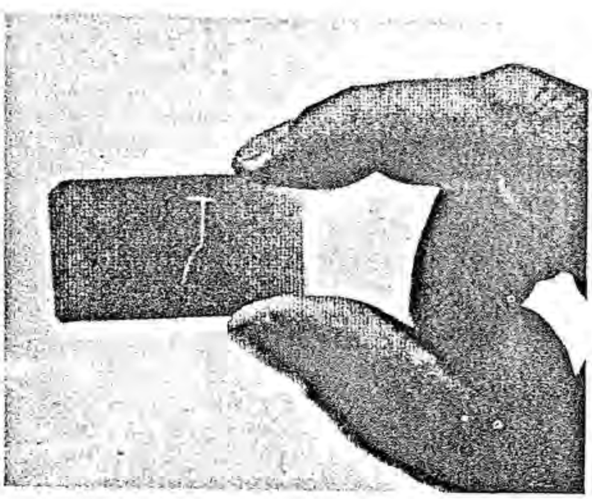

Figure C-12. Holding the BT slide.

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

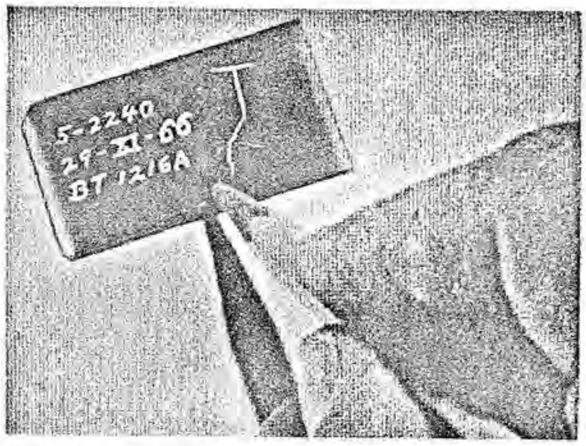

Figure C-13. Labeling the BT slide.

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.

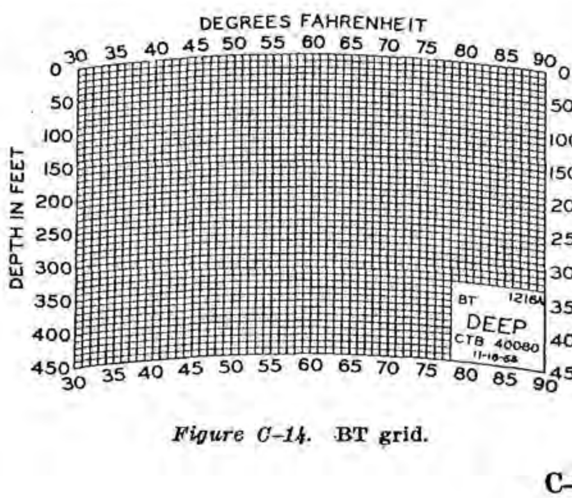

Figure C-14. BT grid.

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.

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-

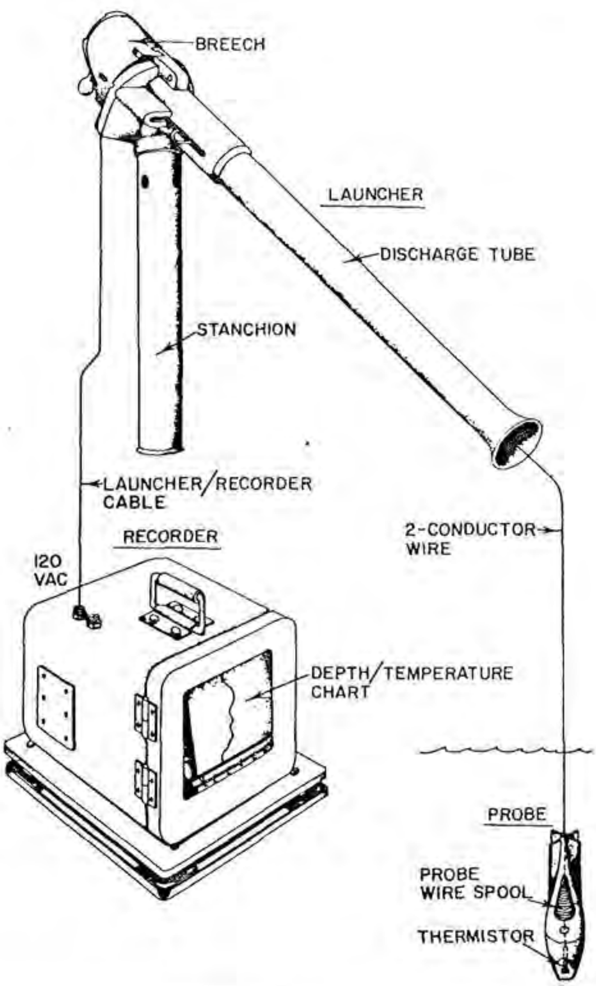

Figure C–15. Expendable bathythermograph (XBT) system.

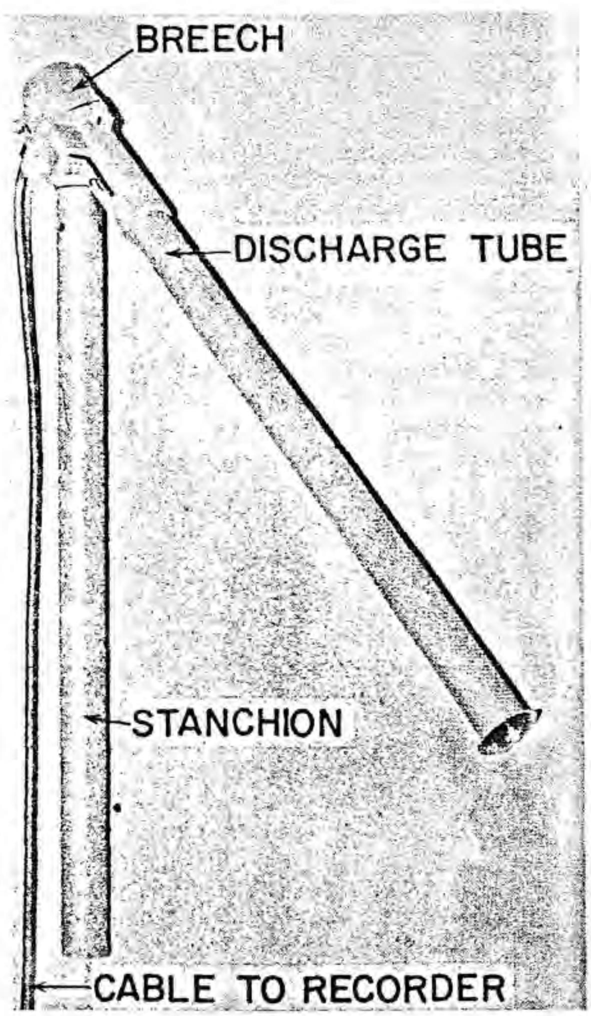

Figure C–16. XBT launcher, Sippican model LM–2A.

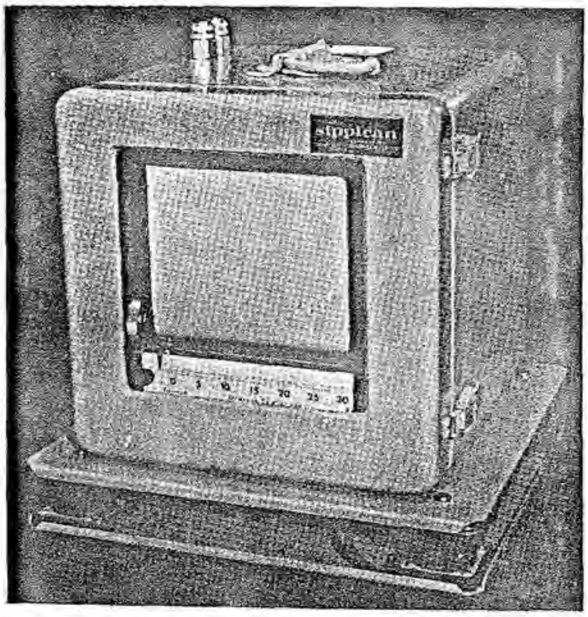

Figure C–17. Recorder, Sippican model MK–2A.

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 connected 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.

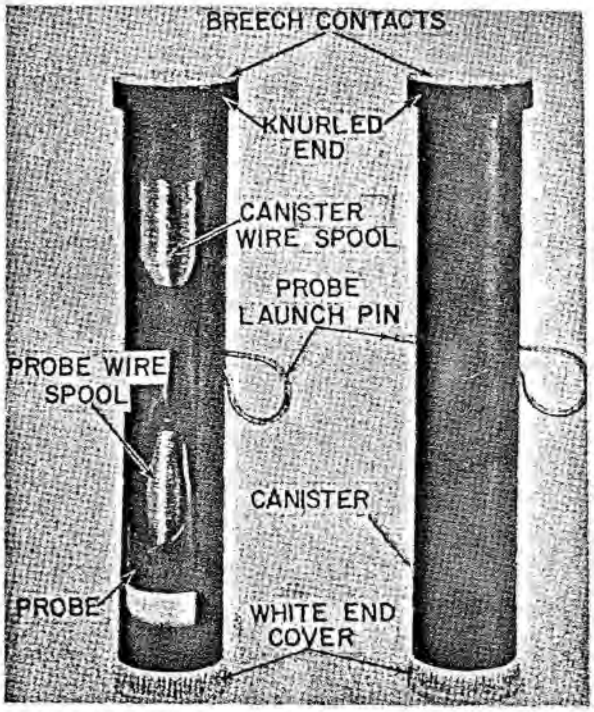

Figure C–18. Expendable probe and canister, Sippican model T–4 (cutaway view at left).

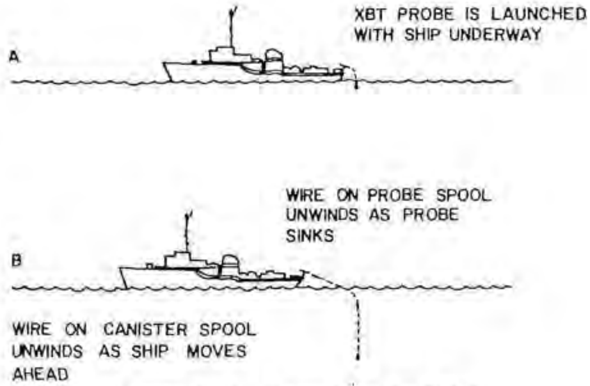

Figure C–19. Launching the XBT.

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).

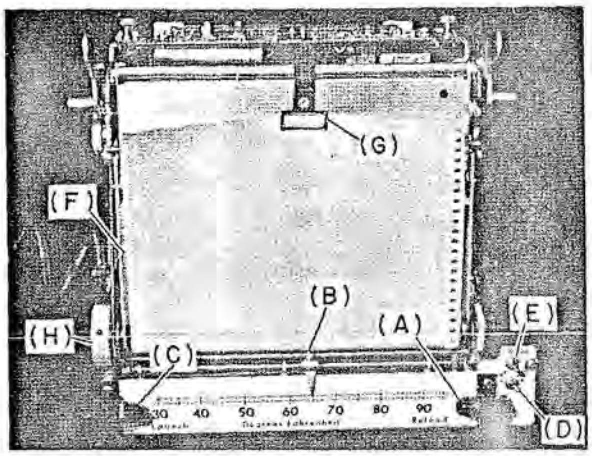

Figure C–20. XBT recorder panel.

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.

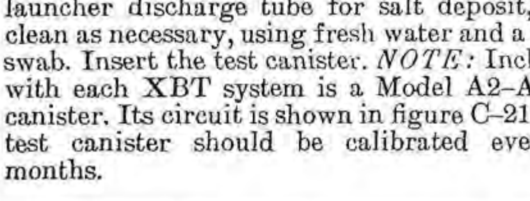

Figure C–21. Test canister circuit.

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.

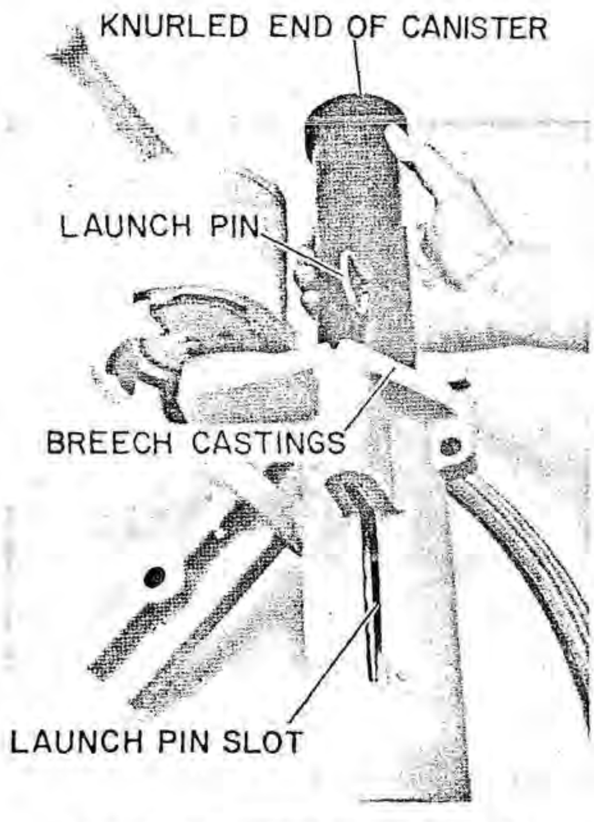

Figure C–22. Loading canister in breech.

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-

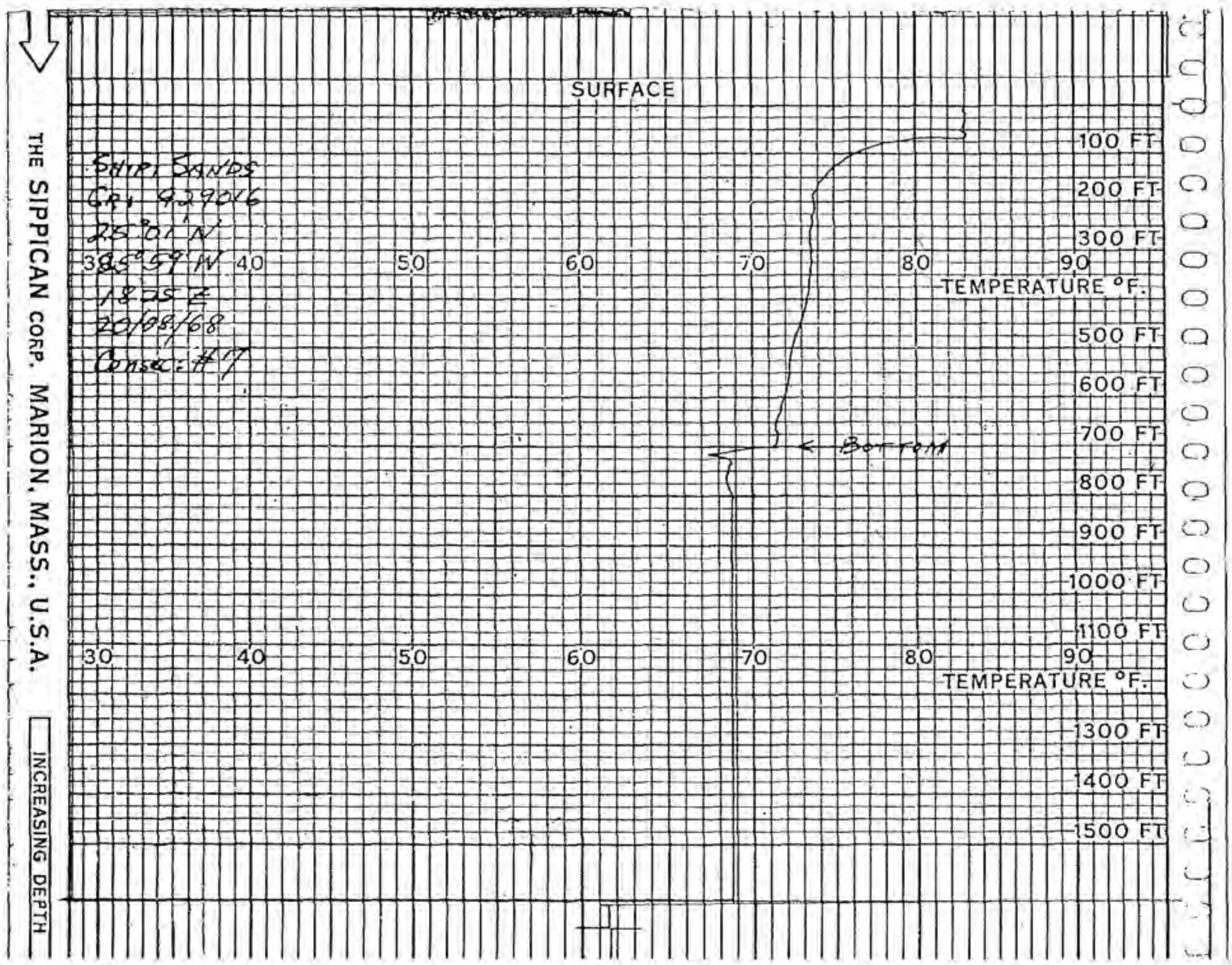

Figure C–23. XBT chart annotated.

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.

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

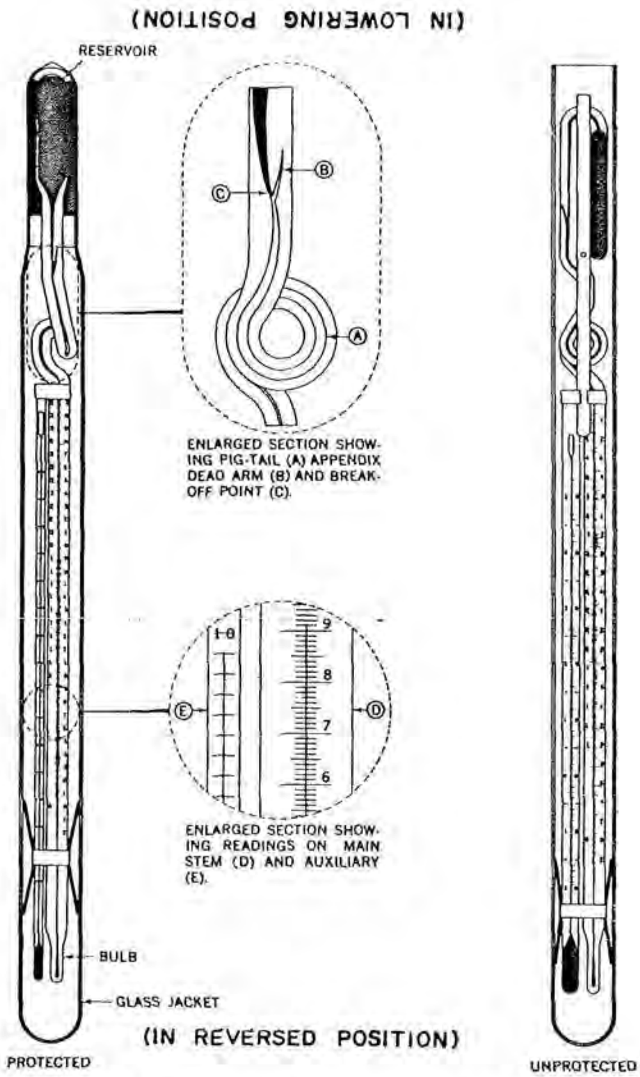

Figure D–1. Protected and unprotected deep sea reversing thermometers.

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.

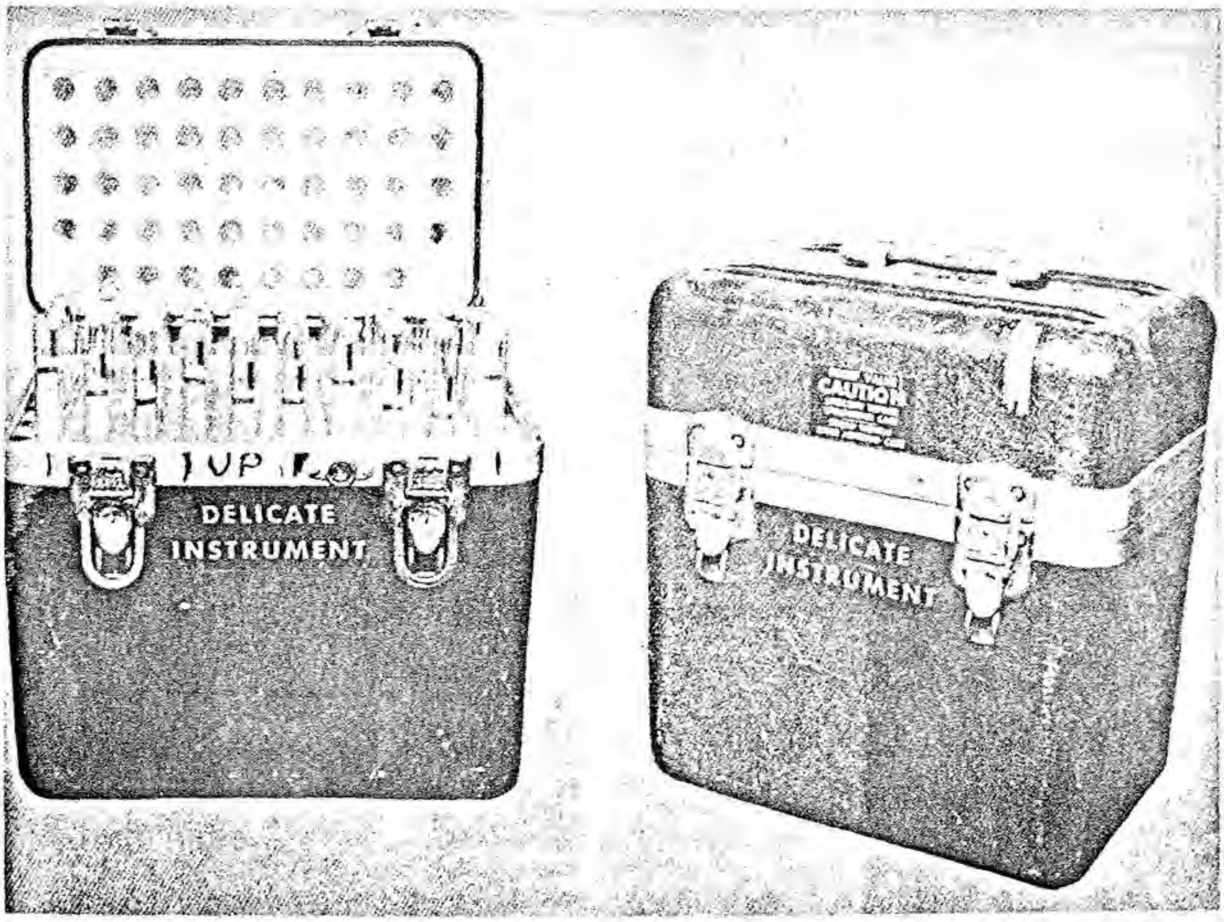

Figure D–2. Special carrying cases for storing and transporting thermometers.

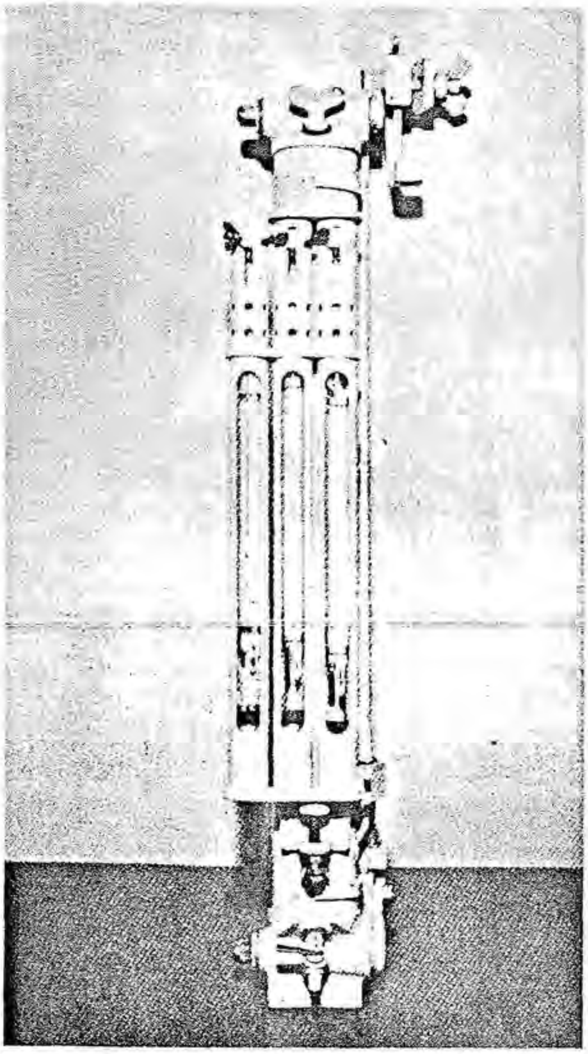

Figure D-3. Nansen bottle with reversing thermometers.

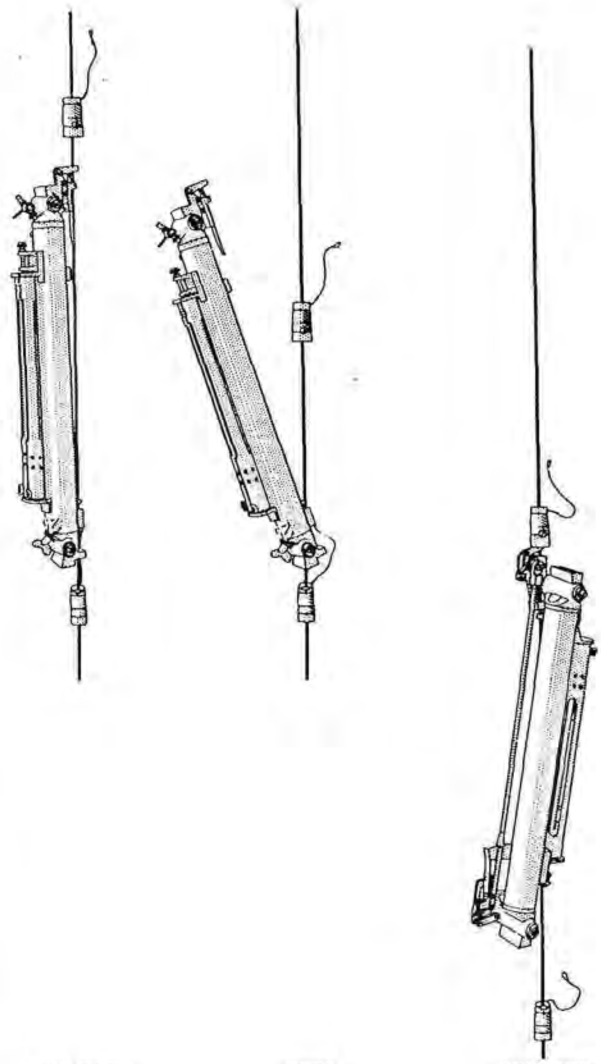

Figure D-4. Nansen bottle in three positions—before tripping, during tripping, and after tripping.

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

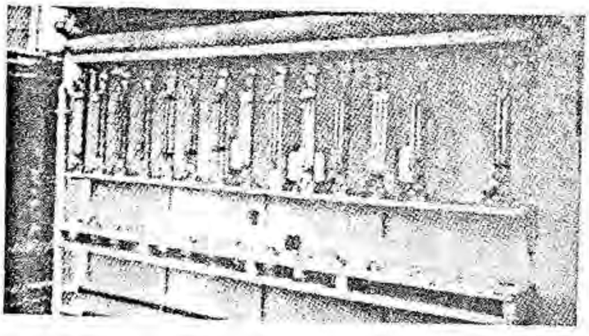

Figure D-5. Nansen bottle rack.

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.

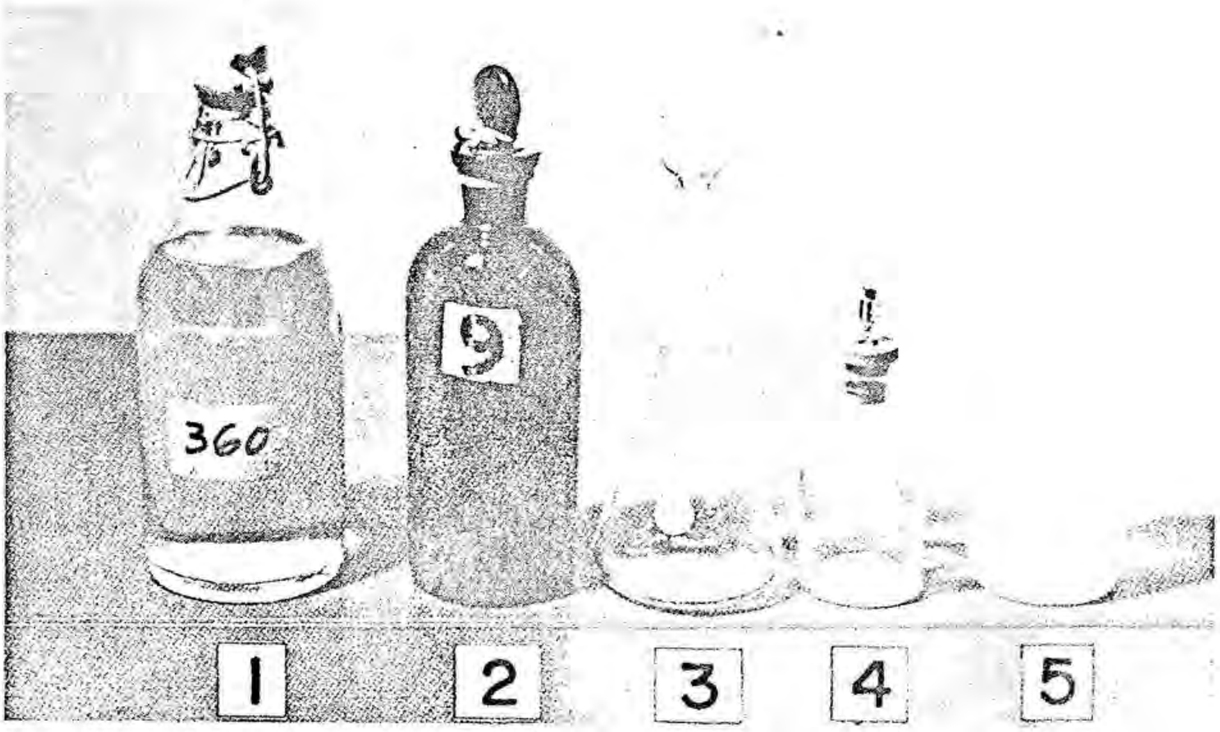

Figure D–6. Water sample bottles.

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.	201 - 01
ASSIGNED STATION NO.	4A
VESSEL	USS San Pablo
DATE (GMT)	24 April 1965
TIME ZONE	+4
LATITUDE	30° 30′ 0″ N.
LONGITUDE	69° 04′ 2″ W.
NAVIGATION	LORAN C
WEATHER	Partly Cloudy
BAROMETER	1017.9 MBS
WIND SPEED	07
WIND DIR	300
ICE COVERAGE	—
AIR TEMP. DRY	20.1°C
AIR TEMP. WET	16.7°C
CLOUDS TYPE	Cumulus
CLOUDS AMT.	4/10
VISIBILITY	7 miles
SEA DIR	280
SEA HEIGHT (ft)	1
SWELL DIR	—
SWELL HEIGHT (ft)	—
SWELL LENGTH (ft)	—
WATER COLOR	III
WATER TRANSPARENCY	15 white
REMARKS	
CONSECUTIVE STATION NO.	3
STATION OBSERVERS	LE JORDAN
COMPUTED BY	KBP
CHECKED BY	FD

HANSEN CAST	WIRE ANGLE (1)	WIRE ANGLE (2)	GMT 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

Meter wheel reading down: 604

Left Thermometer

CAST	SERIAL NO. SALINITY SAMPLE BOTTLE NO.	SAMPLE BOTTLE (1) O₂	(2)	(3)	HANSEN BOTTLE NO.	METER WHEEL DOWN	METER WHEEL UP	WIRE LENGTH DEPTH (L)	THERM. NO.	MAIN (T′)	AUX. (t)	V_0	I	C_p / C_u	T_w
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
	50	2	50		2	590	591	10	487-64	19.85 / 19.86	18.5 / 18.6	101.2	-.02 / .02	+.02 / +.02	19.85 / 19.86
	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
	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
	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
	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
	55	7	55		7	450	451	150	637-64	18.72 / 18.74	18.4 / 18.7	97.0	.05 / .03	.01 / .00	18.76 / 18.77
	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
	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
									WAI No 1	14° DR208					
	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
	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
									WAI No 2	5° DR210					
	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

Right Thermometer, Accepted Values and Thermometric Calculations

SERIAL NO.	THERM. NO.	MAIN (T′ OR T′u)	AUX (t OR tu)	V_0	I	C_p / C_u	T_w OR T_u	ACCEPTED OR AVERAGE T_w	DIFF. (T_u-T_w)	(T_w-T_w) DIFF / pm	Q FACTOR	THERMOMETRIC DEPTH (Z)	L-Z OBS	L-Z USED	ACCEPTED DEPTH (D)	REMARKS
49	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	RT. IDS NUMBERS 48, 49, 50
50	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	539-64	19.19 / 19.20	18.8 / 19.0	98.7	.01 / .01	.01 / .00	19.19 / 19.19	19.19		.01				1	19	
52	239-63	18.94 / 18.95	18.7 / 19.0	106.2	.00 / .00	.01 / .00	18.95 / 18.95	18.96		.03				1	29	
53	67-63	19.10 / 19.11	18.7 / 19.1	95.0	.01 / .01	.01 / .00	19.10 / 19.10	19.09		.01				2	48	
54	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	642-64	18.79 / 18.80	18.3 / 18.7	110.0	.03 / .03	.01 / .00	18.77 / 18.77	18.77		.01				5	145	
56	643-64	18.62 / 18.63	18.4 / 18.7	111.0	.04 / .04	.00 / .00	18.58 / 18.59	18.58		.00				6	194	
57	702-64	17.88 / 17.88	18.4 / 18.7	104.6	.00 / .00	.01 / .02	17.87 / 17.86	17.86		.03		↗	9	9	291	
	55-1321	20.63 / 20.64	18.1 / 18.2	106.3	.06 / .06	.00 / .01	20.57 / 20.57		2.71	.9737	.0070727	291				
58	715-65	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	18.2 / 18.3	120.8	.00 / .00	.01 / .02	21.01 / 21.00		3.49	.9733	.0087893	387				
59	157-64	16.81 / 16.82	18.4 / 18.5	103.7	.02 / .02	.03 / .03	16.80 / 16.81	16.82		.04		↗	14	14	486	
	419-63	20.96 / 20.96	18.5 / 18.6	128.8	.01 / .01	.09 / .09	20.91 / 20.91		4.09	.9730	.0081841	486				
60	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	139.6	.01 / .01	.09 / .09	19.96 / 19.97		4.84	.9727	.0080448	585				

SUMMARY T_w-T_w DIFF.

	PAIRS	TW.
TOTAL T_w =	12	
DIFF °C .00	2	
.01	4	
.02	1	
.03	2	
≥.04	2	
ONE T_w Acc	1A	
NONE Acc	X	

Figure E-1. Oceanographic Log Sheet-A.

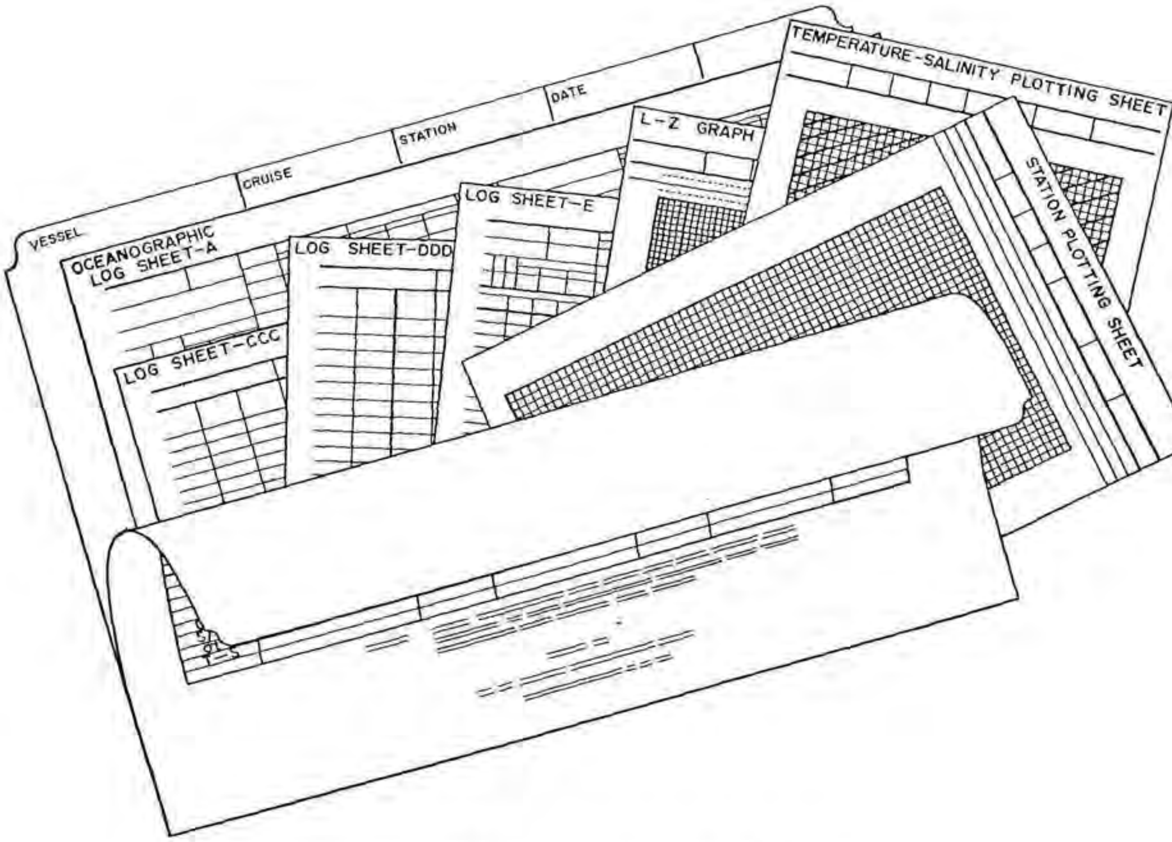

Figure E-2. Oceanographic Station Folder.

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 (3/8- to 1/2-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

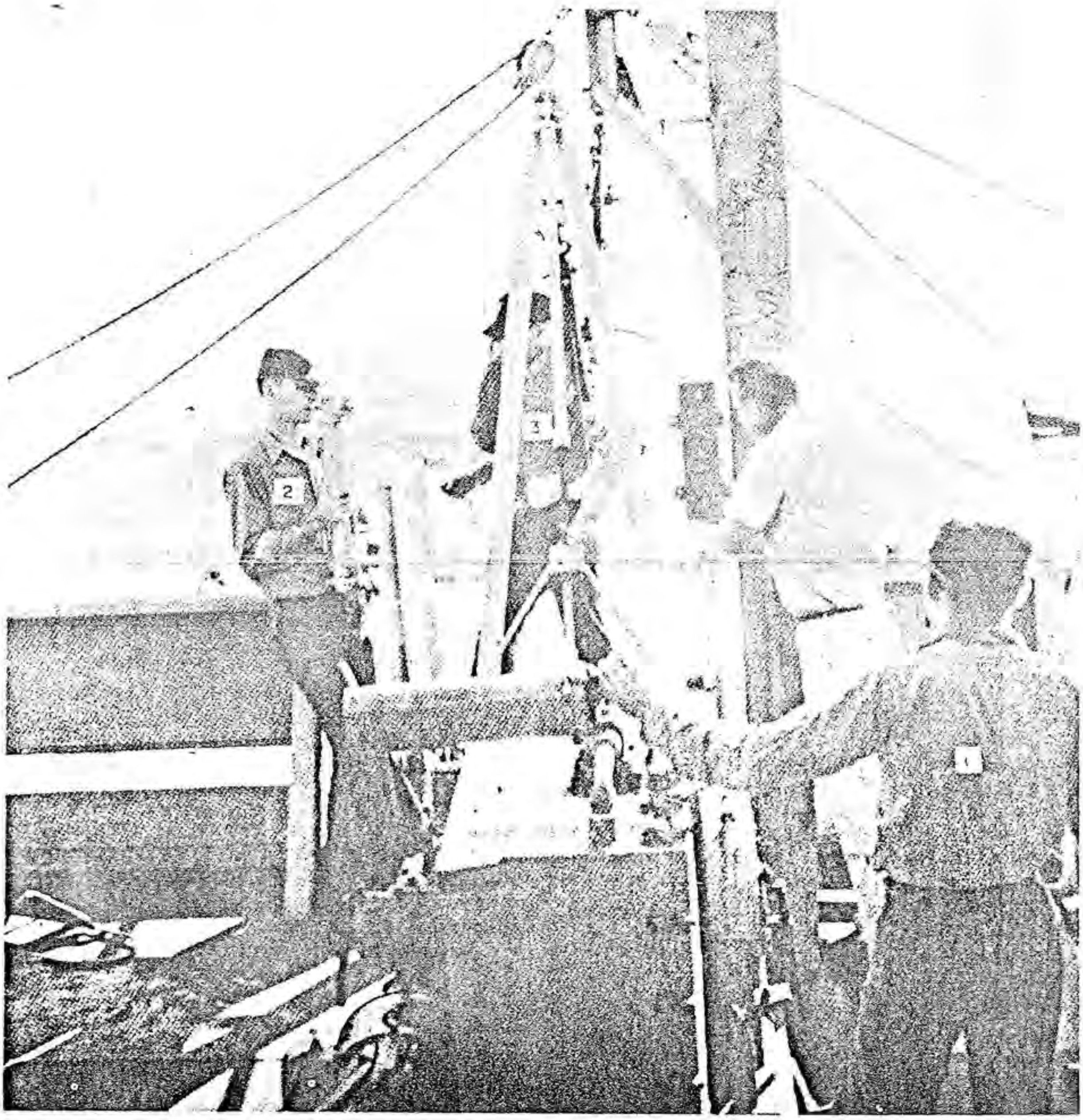

Figure E-3. Winch operator (1), bottle passer (2), and bottle hanger (3).

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.

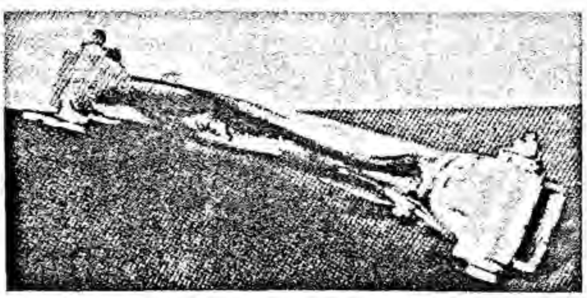

Figure E–5. A crushed Nansen bottle.

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

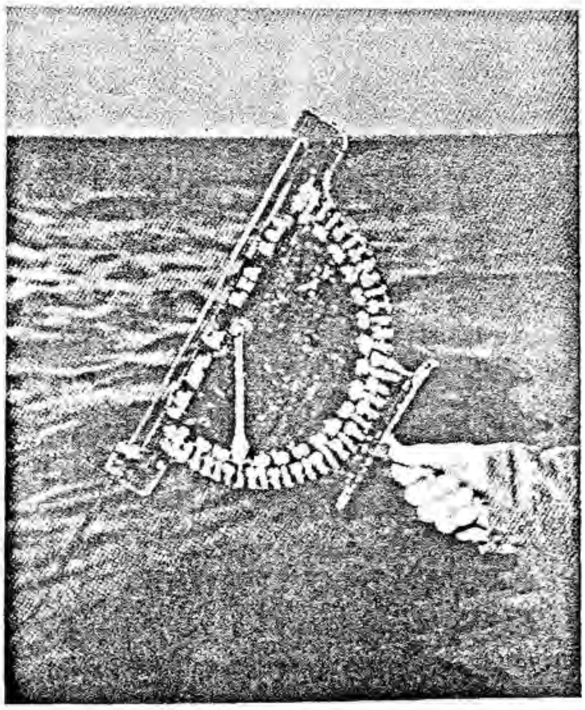

Figure E–6. Wire angle indicator.

(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.

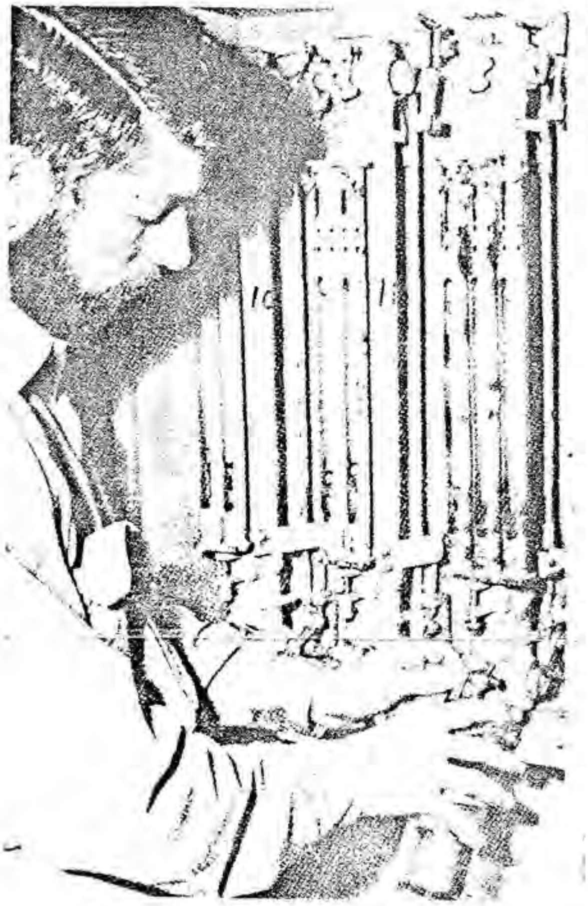

Figure E-8. Drawing water samples.

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.

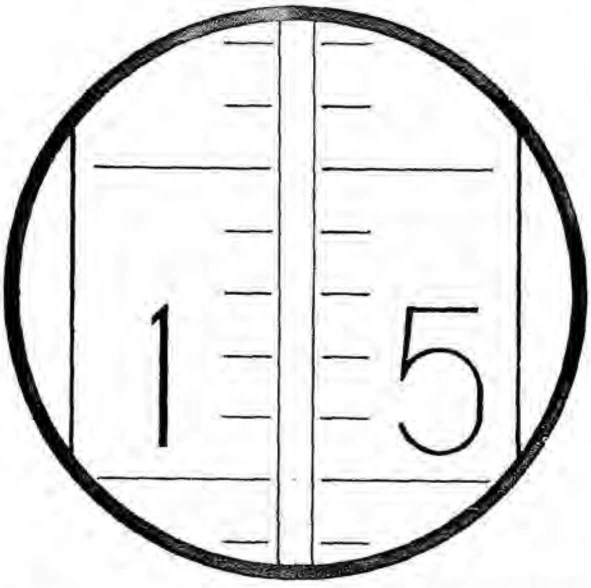

Figure E-10. The scale divisions and the mercury column of the reversing thermometer main stem as seen through the thermometer viewer. *Note:* The meniscus of the mercury column is arched. For proper reading, center the top of the mercury in the viewer, and read the top of the meniscus on the scale;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

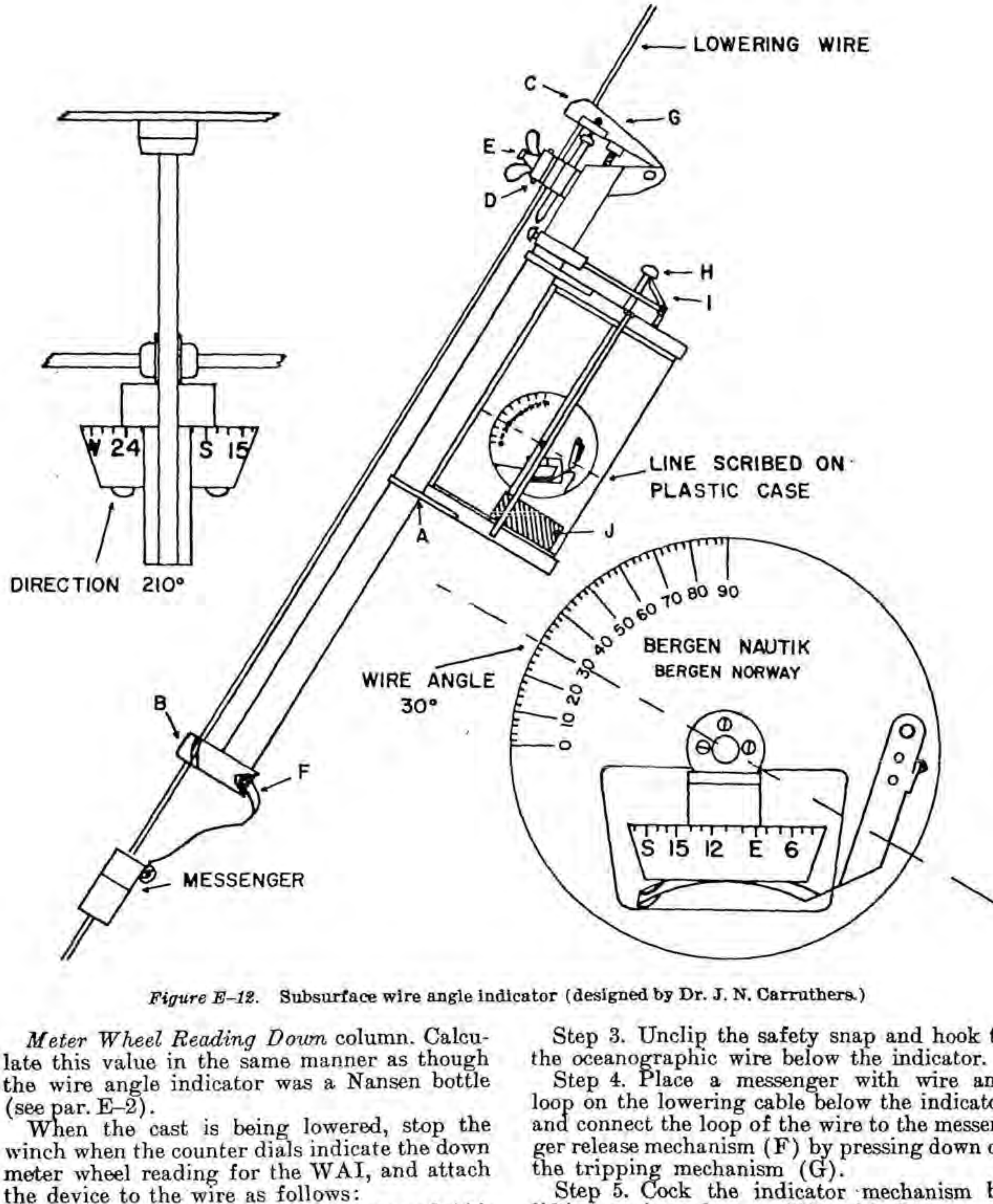

Figure E–12. Subsurface wire angle indicator (designed by Dr. J. N. Carruthers.)

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_o), 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_o in °C., makers V_o 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.

NUMBER	MAKE	V_o	"K" VALUE	RANGE	SMALLEST SCALE DIVISION	
195-64	Kessler	V_o = 139.6 °C; MAKERS V_o = 146°C	6098	-2 °C TO + 30 °C	0.1 °C	☐ PROTECTED; ☒ UNPROTECTED

OWNER			
U. S. NAVAL OCEANOGRAPHIC OFFICE		☒ PURCHASED NEW; ☐ PURCHASED USED	PURCHASED FROM: KESSLER CO.; PRICE: $92.30; DATE ACQUIRED: June 1964

DEEP SEA REVERSING THERMOMETER CORRECTIONS

MAIN THERMOMETER TEMPERATURE	MAIN THERMOMETER CORRECTION	AUXILIARY THERMOMETER TEMPERATURE	AUXILIARY THERMOMETER CORRECTION	"Q" FACTOR 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 FNHC-NAVOCEANO-3167/53 (Rev. 2-64)

Figure F-1. Reversing Thermometer Calibration and History Record.

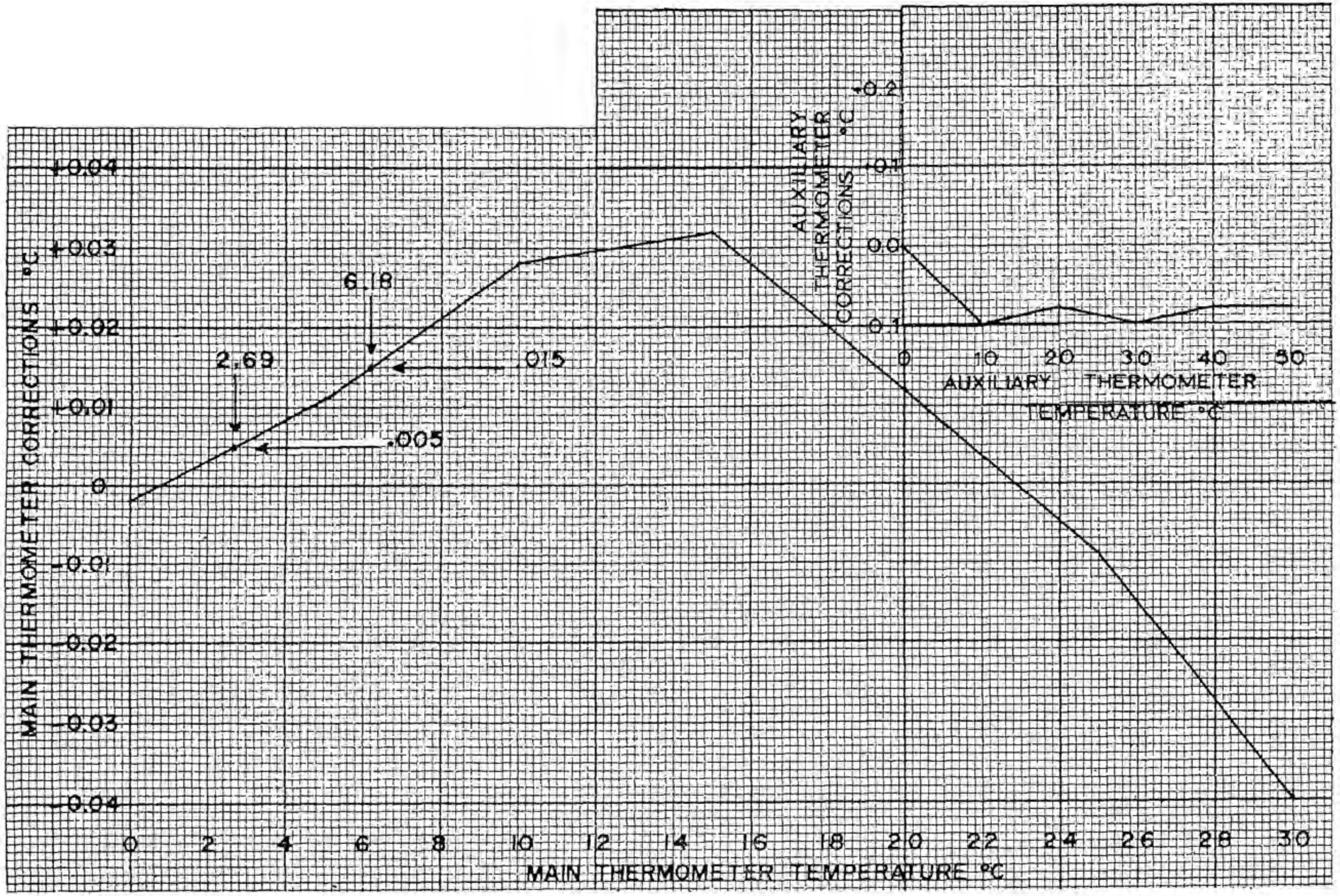

Figure F–2. Thermometer correction graphs.

NUMBER	MAKE	V_o / MAKERS V	"K" VALUE	RANGE	SMALLEST SCALE DIVISION	PROTECTED / UNPROTECTED
510-64	Kessler	V_o = 101.0 °C; MAKERS V = 100 °C	6098	-2 °C TO + 20 °C	.1 °C	[X] PROTECTED; [ ] UNPROTECTED

OWNER		PURCHASE	PURCHASED FROM / PRICE / DATE ACQUIRED
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 TEMPERATURE	MAIN THERMOMETER CORRECTION	AUXILIARY THERMOMETER TEMPERATURE	AUXILIARY THERMOMETER CORRECTION	"Q" FACTOR 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=

INTERPOLATION TABLE — APPLY THERMOMETER CORRECTIONS ALGEBRAICALLY

MAIN T°	CORR	T°	CORR	T°	CORR	T°	CORR	T°	CORR	AUXILIARY T°	CORR
-2.										0	
	-.04										-.1
2.08										1.7	
	-.05										.0
11.66										500	
	-.04										
16.40											
	.05										
20.0											

NUMBER	MAKE	V_o / MAKERS V	"K" VALUE	RANGE	SMALLEST SCALE DIVISION	PROTECTED / UNPROTECTED
157-64	Kessler	V_o = 103.7 °C; MAKERS V = 105 °C	6098	-2 °C TO + 20 °C	.1 °C	[X] PROTECTED; [ ] UNPROTECTED

OWNER		PURCHASE	PURCHASED FROM / PRICE / DATE ACQUIRED
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 TEMPERATURE	MAIN THERMOMETER CORRECTION	AUXILIARY THERMOMETER TEMPERATURE	AUXILIARY THERMOMETER CORRECTION	"Q" FACTOR 1000 METERS
0 °C	.014	0 °C	.00	1=
5 °C	.042	10 °C	-.08	2=
10 °C	.006	20 °C	-.08	3=

INTERPOLATION TABLE — APPLY THERMOMETER CORRECTIONS ALGEBRAICALLY

MAIN T°	CORR	T°	CORR	T°	CORR	T°	CORR	T°	CORR	AUXILIARY T°	CORR
0		8.75								.0	
	+.01		+.01								.0
.18		12.62								6.2	
	+.02		+.02								-.1
1.97		20.00								40.5	
	+.03										0
3.76										45.2	
	+.04										

NUMBER	MAKE	V_o / MAKERS V	"K" VALUE	RANGE	SMALLEST SCALE DIVISION	PROTECTED / UNPROTECTED
419-63	Kessler	V_o = 120.8 °C; MAKERS V = 125 °C	6098	-2 °C TO + 30 °C	.1 °C	[ ] PROTECTED; [X] UNPROTECTED

OWNER		PURCHASE	PURCHASED FROM / PRICE / DATE ACQUIRED
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 TEMPERATURE	MAIN THERMOMETER CORRECTION	AUXILIARY THERMOMETER TEMPERATURE	AUXILIARY THERMOMETER CORRECTION	"Q" FACTOR 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=

INTERPOLATION TABLE — APPLY THERMOMETER CORRECTIONS ALGEBRAICALLY

MAIN T°	CORR	T°	CORR	T°	CORR	T°	CORR	T°	CORR	AUXILIARY T°	CORR
0		24.74								0	
	+.01		+.01								.0
.75		30.00								7.0	
	.00										-.1
3.25										17.6	
	-.01										.0
7.50										31.5	
	-.02										-.1
17.50										45.0	
	-.01										-.2
22.25										50.0	
	.00										
24.75											

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	157-64	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	$\overline{18.5}$	120.8	-.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 ±.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_u.
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.
$20.91°-16.82°=4.09°$

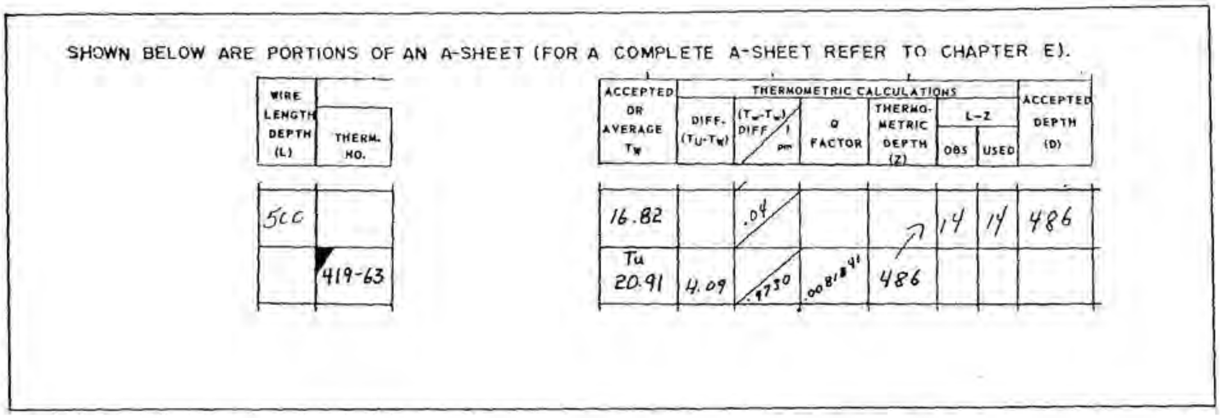

Figure F–5. Portion of A-Sheet showing thermometric calculations.

Step 3. Enter Table F–1 and determine $1/\rho m$ for wire length (L), using nearest oceanic region. Enter value in *$1/\rho m$* block.

$1/\rho m$ 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

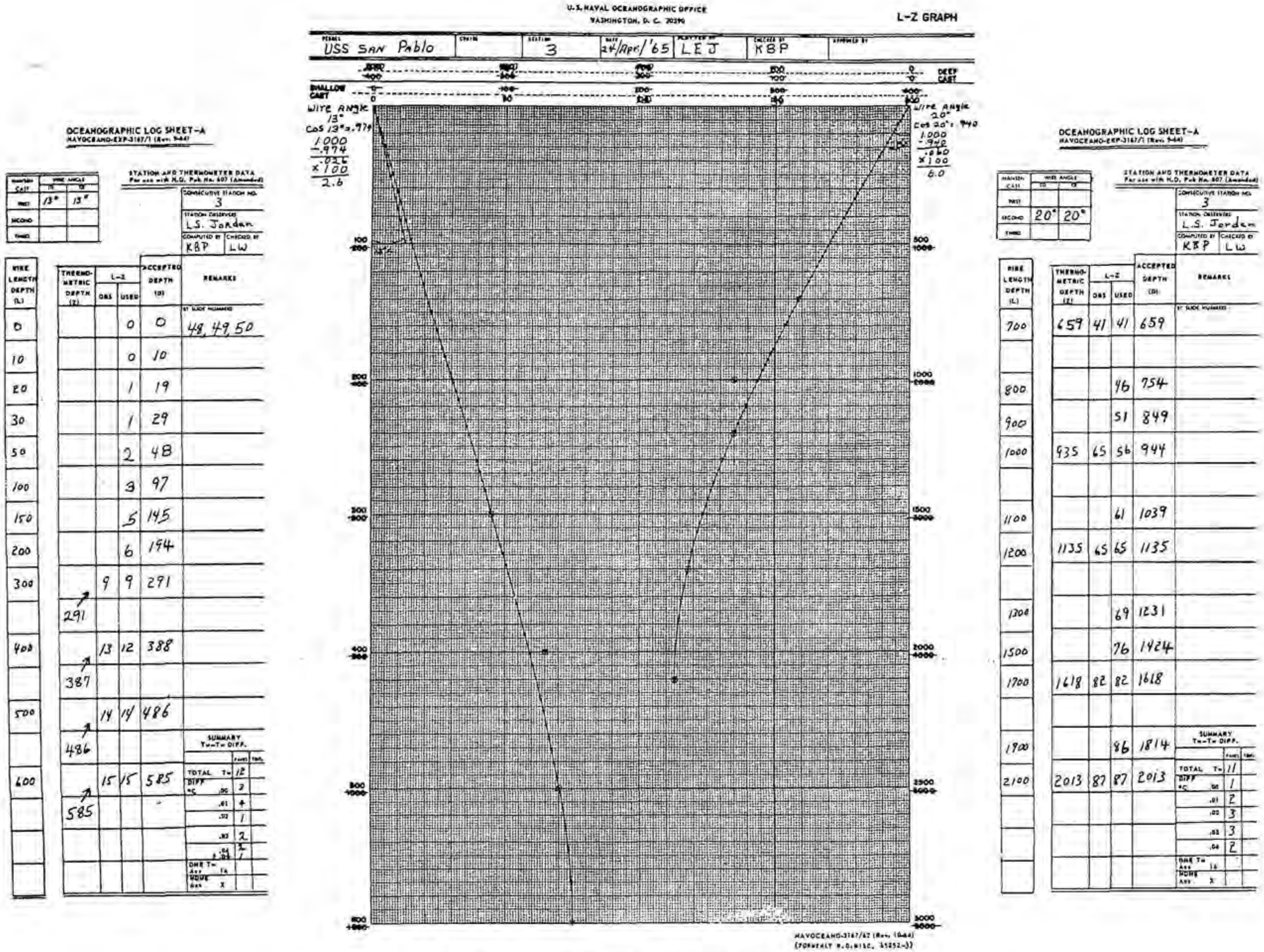

Figure F-6. The L–Z graph with typical curves.

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 Θ° 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_0+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°).

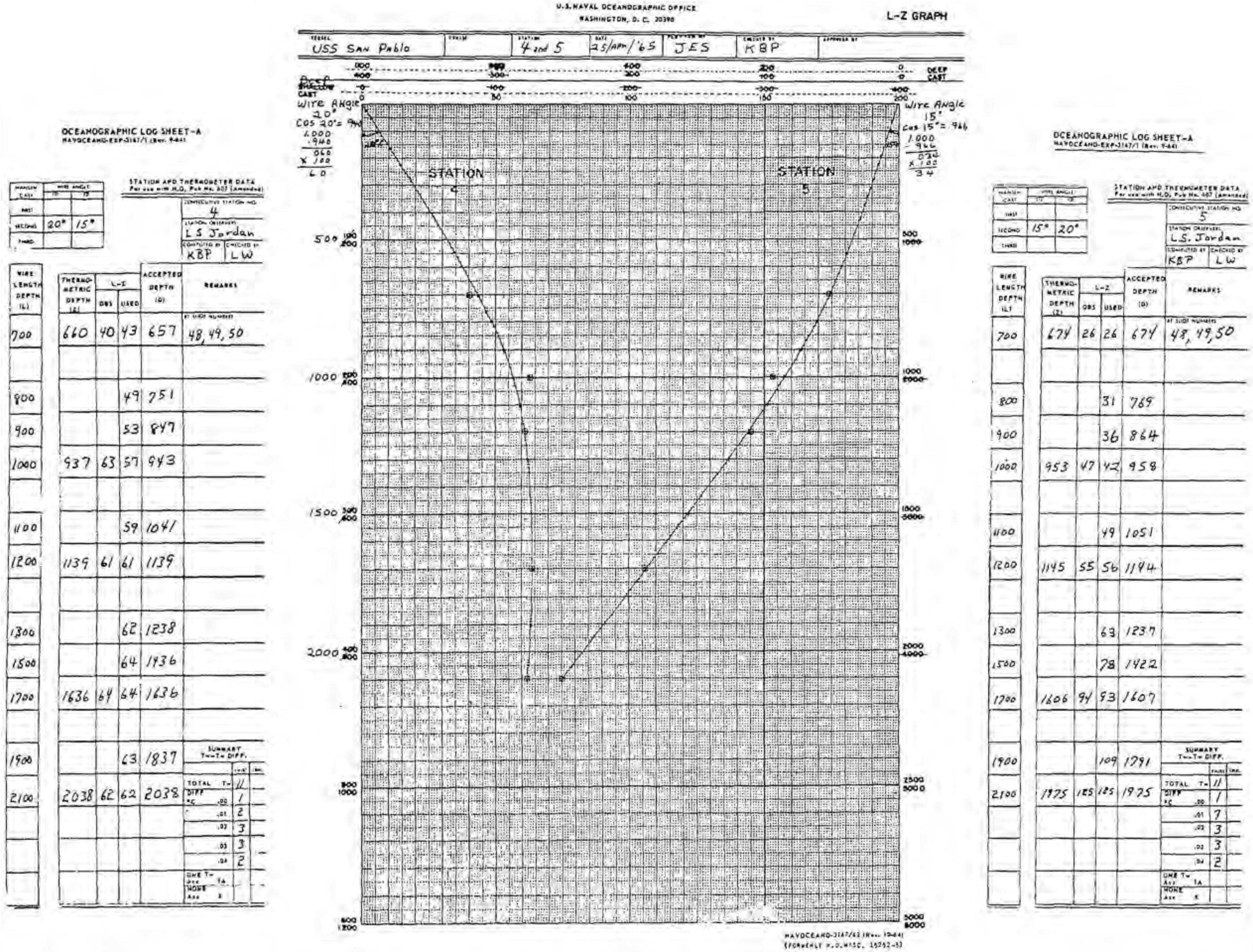

Figure F–7. The L–Z graph with atypical curves.

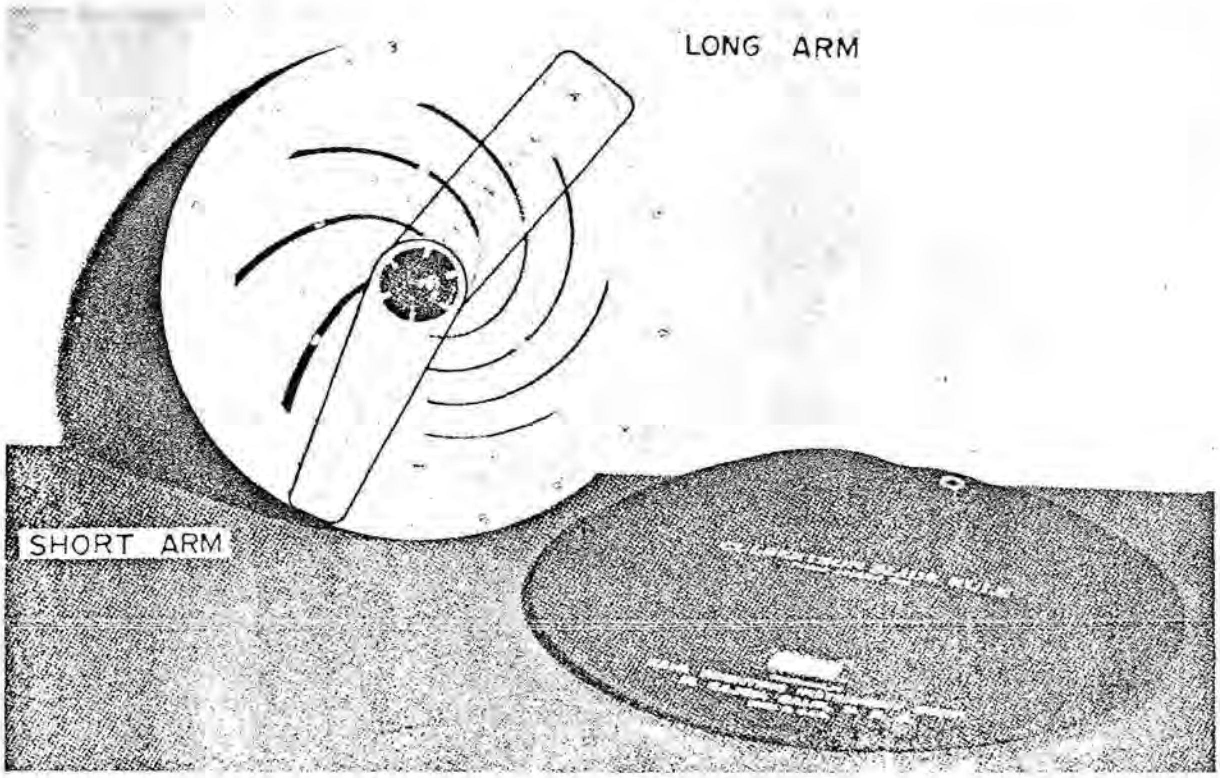

Figure F–8. Culbertson Slide Rule.

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.

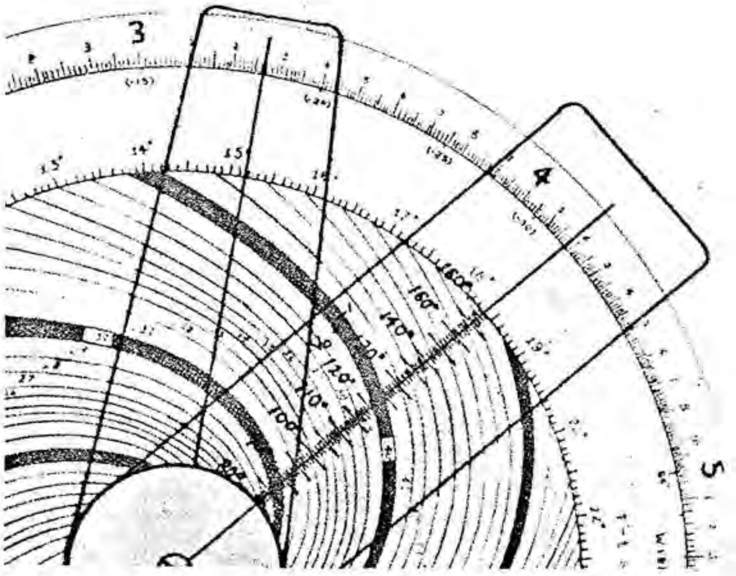

Figure F-10. Slide rule settings for correcting protected thermometer.

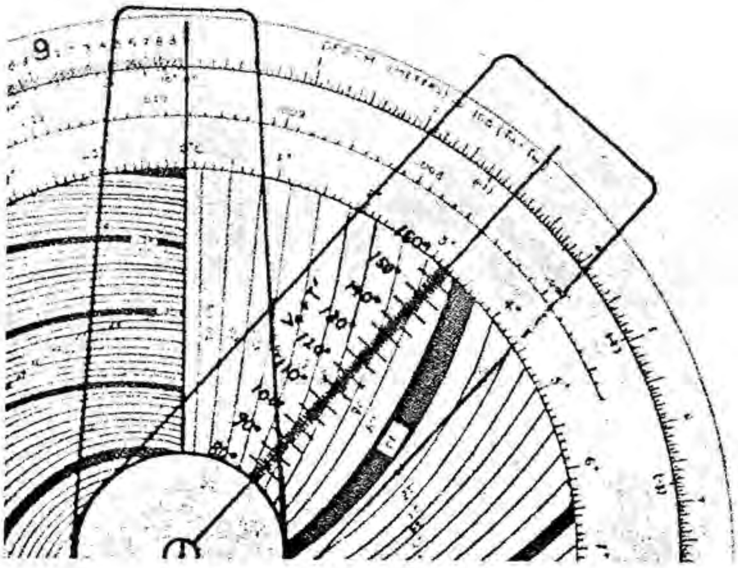

Figure F-11. Slide rule settings for obtaining C_p correction.

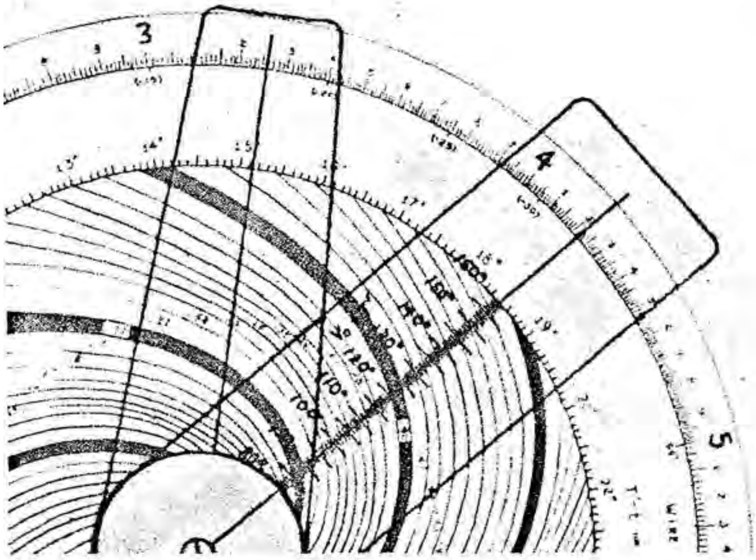

Figure F-12. Slide rule settings for correcting unprotected thermometer.

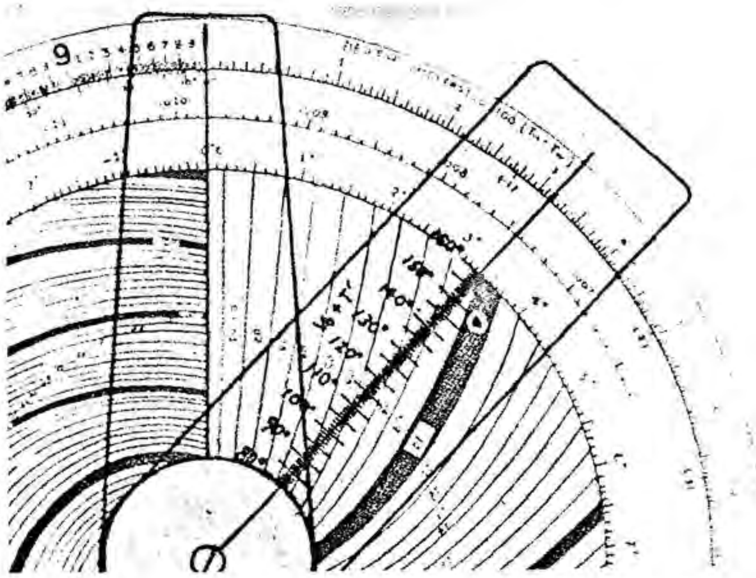

Figure F-13. Slide rule settings for obtaining C' correction.

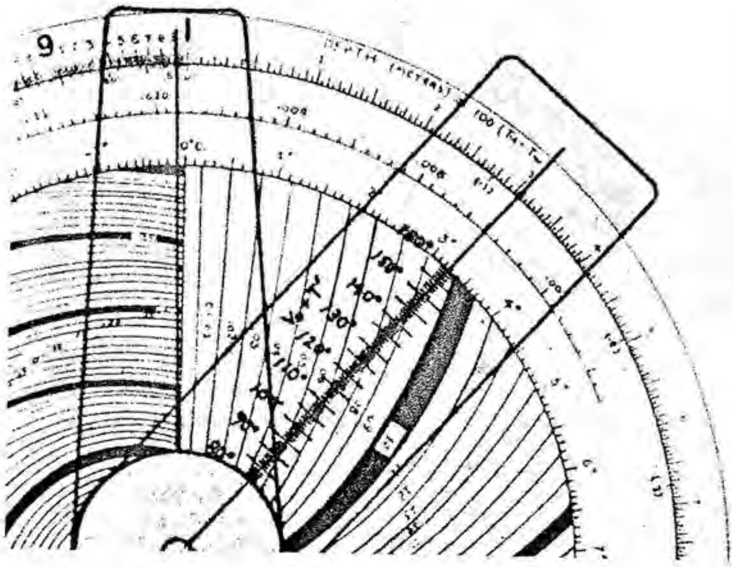

Figure F–14. Slide rule settings for obtaining C_u correction.

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-

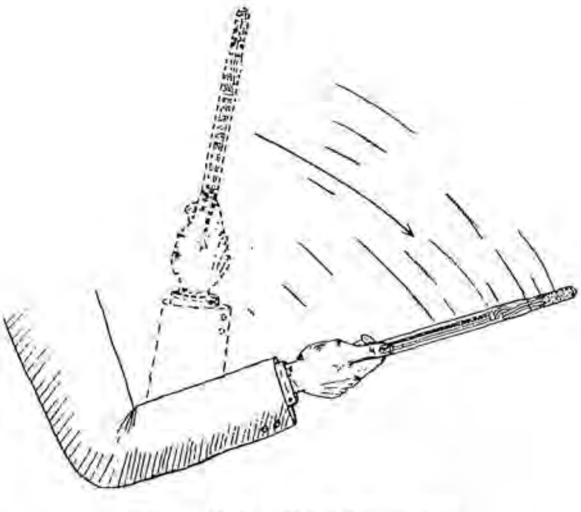

Figure G–1. Wrist-flip action.

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.

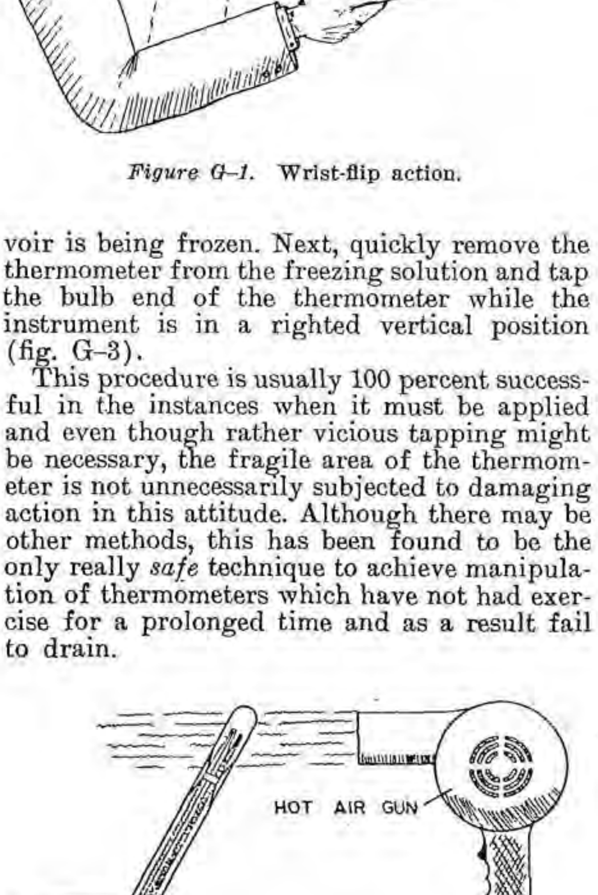

Figure G–2. Simultaneous cooling and heating action.

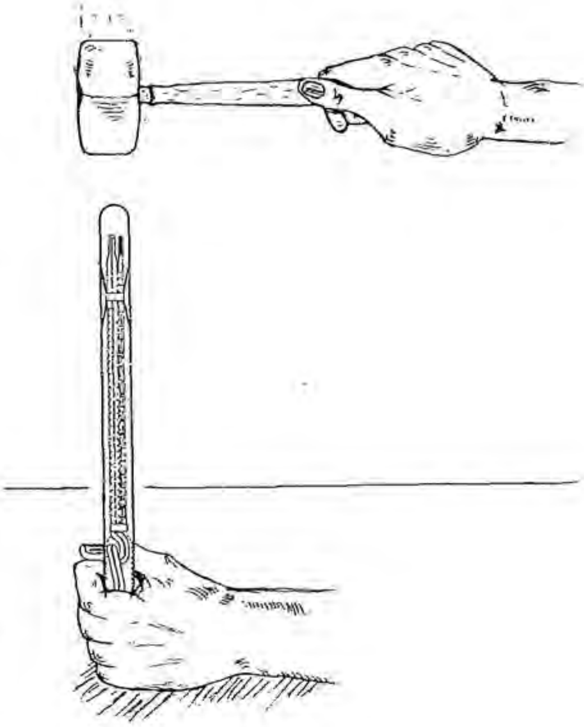

Figure G–3. Tapping action with rubber-headed hammer.

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 extensively 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
PINC-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 ‰	SALINITY ‰	TIME	STANDARDIZATION (N)-(A)=a: Cl‰ 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.

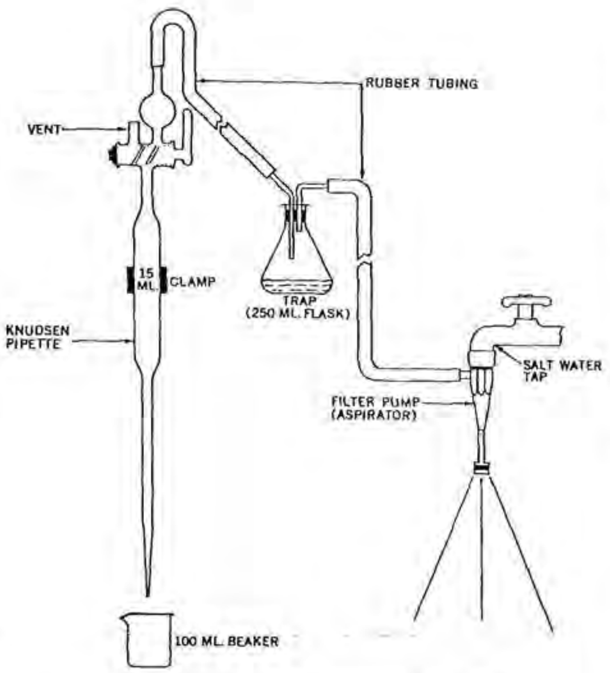

Figure I-3. Automatic-zeroing pipette.

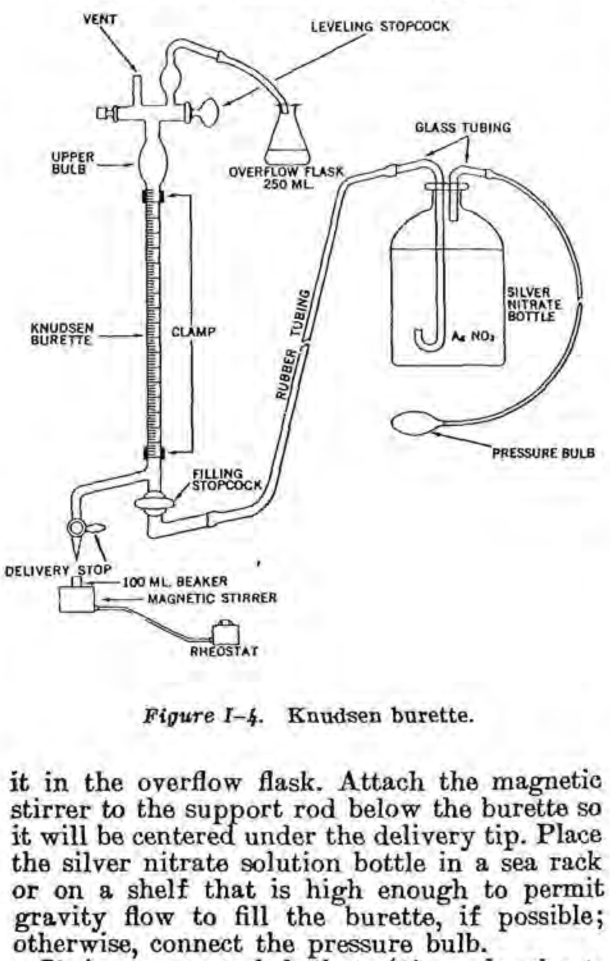

Figure I-4. Knudsen burette.

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

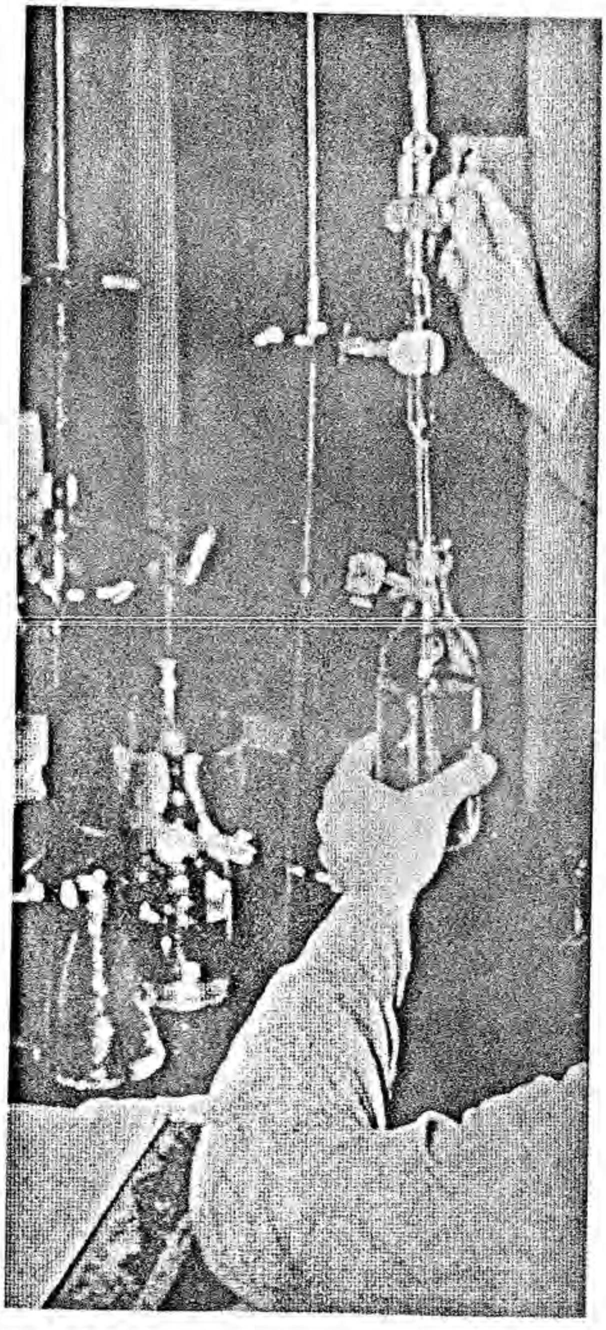

Figure I–5. Drawing the sample with the automatic pipette.

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.

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

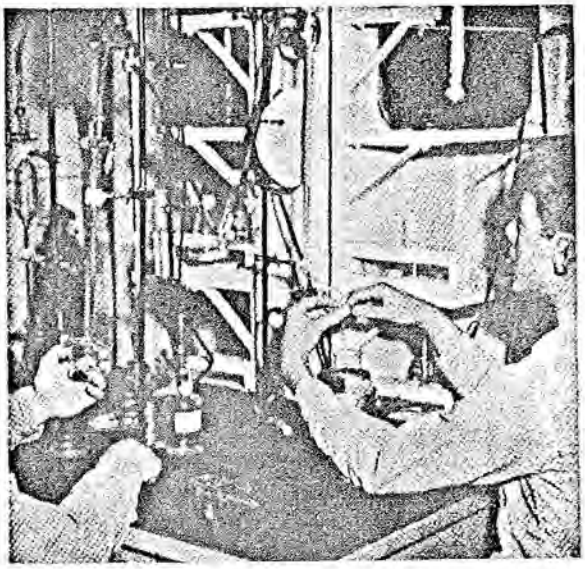

Figure I–6. Titrating a salinity sample.

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.

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.

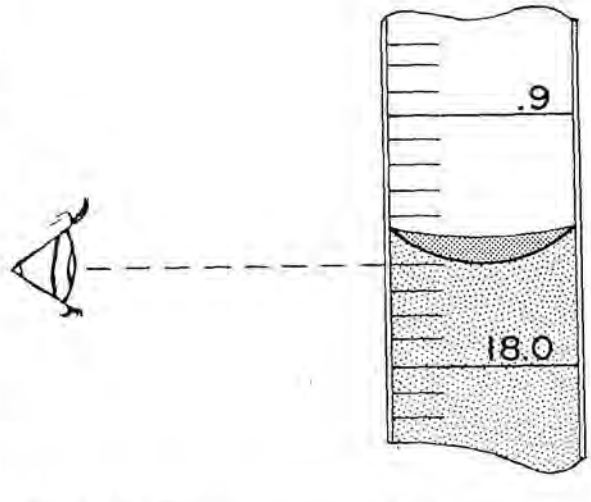

Figure I–7. The true meniscus and the observer's eye.

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)

α=0.025

a=	k=
20.15	
	+0.01
19.76	
	+0.02
19.34	
	+0.03
18.93	

a is average burette reading

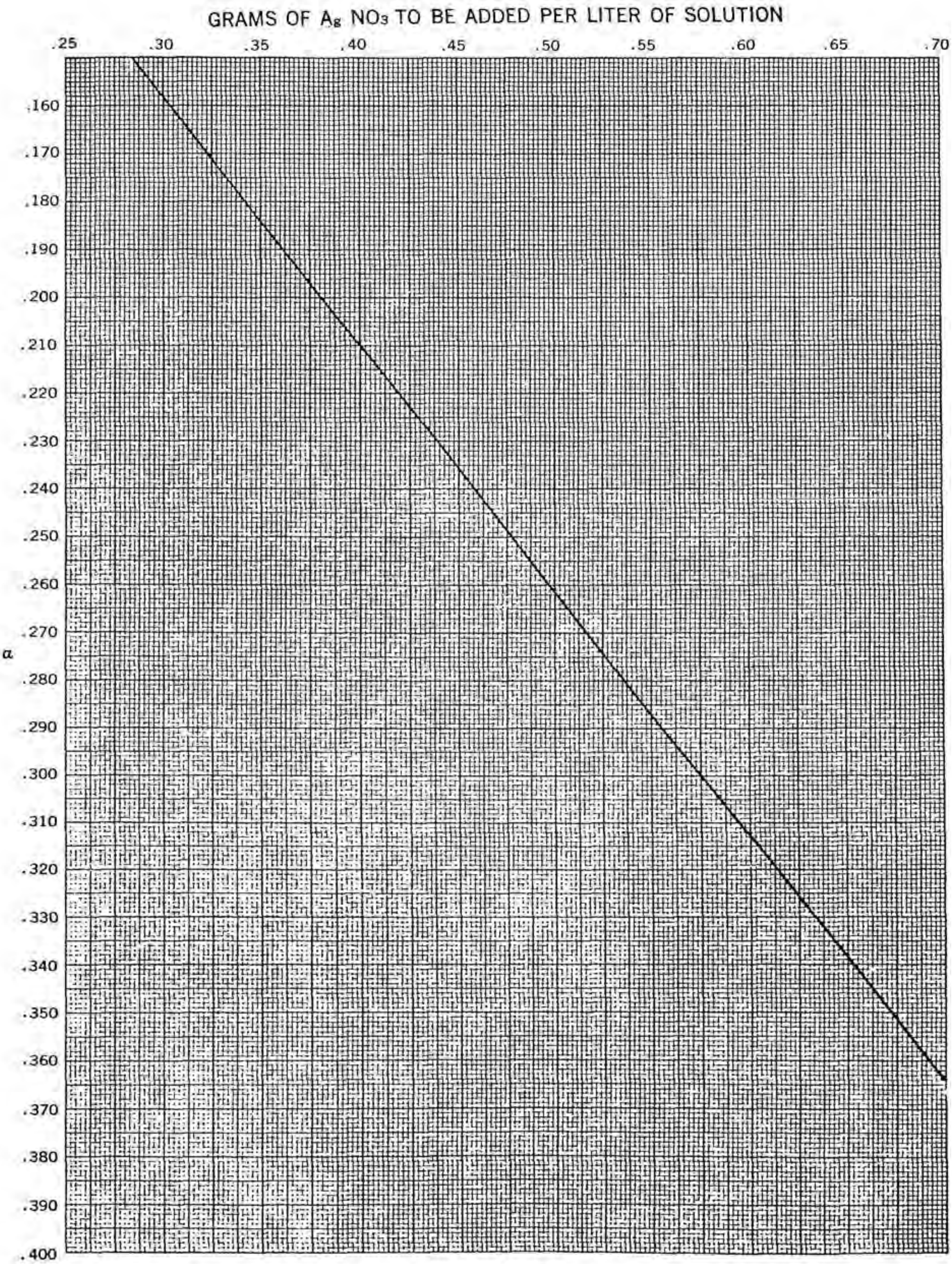

Figure I–8. **Grams of $AgNO_3$ to be added to the solution when alpha is negative.**

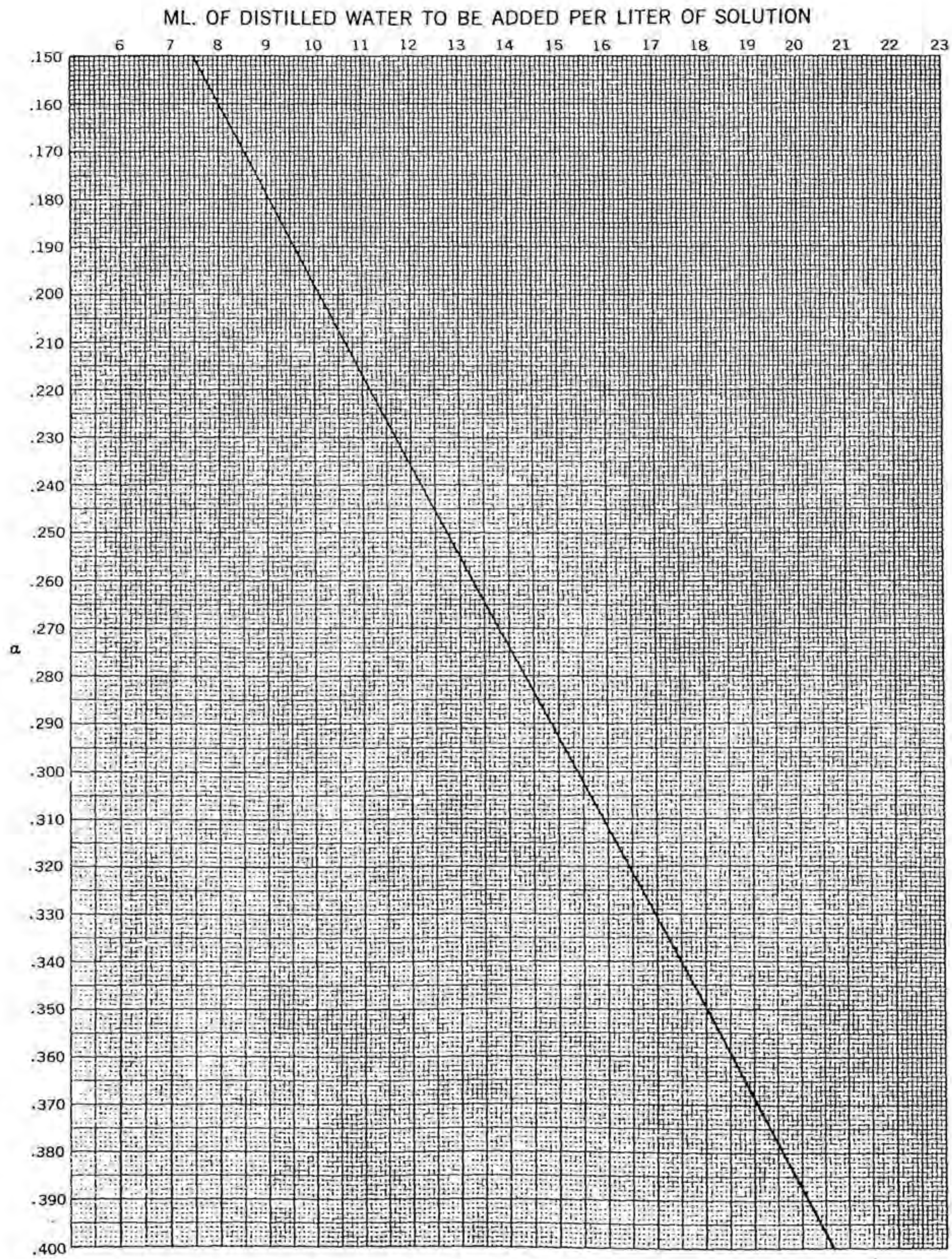

Figure I–9. **Ml. of distilled water to add to the solution when alpha is positive.**

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

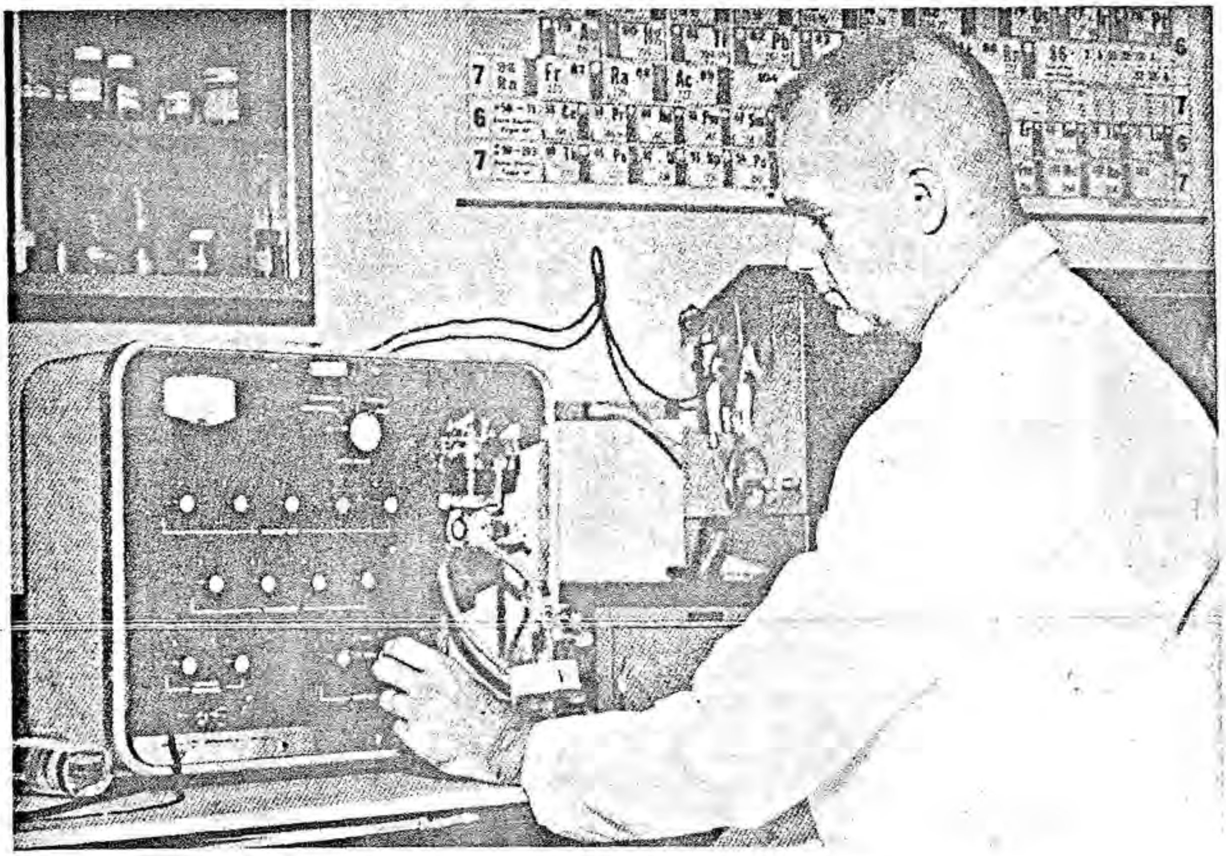

Figure I–10. Industrial Instruments Inc. Model RS–7A Portable Induction Salinometer.

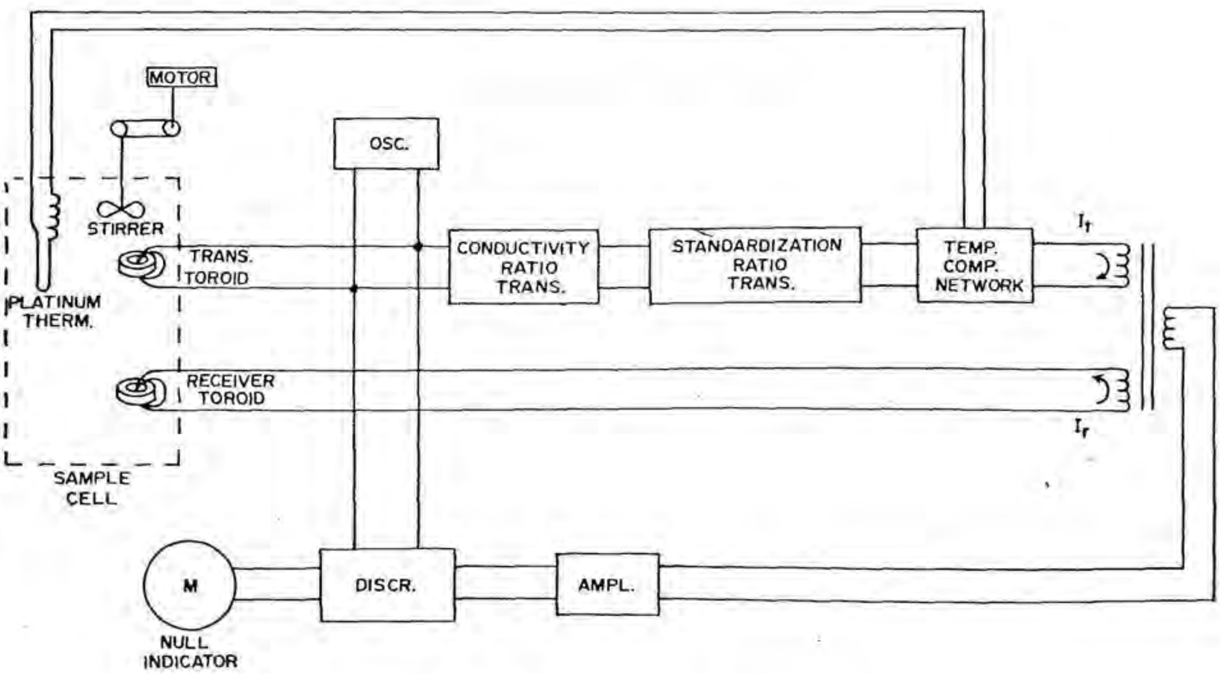

Figure I–11. Block diagram of salinometer.

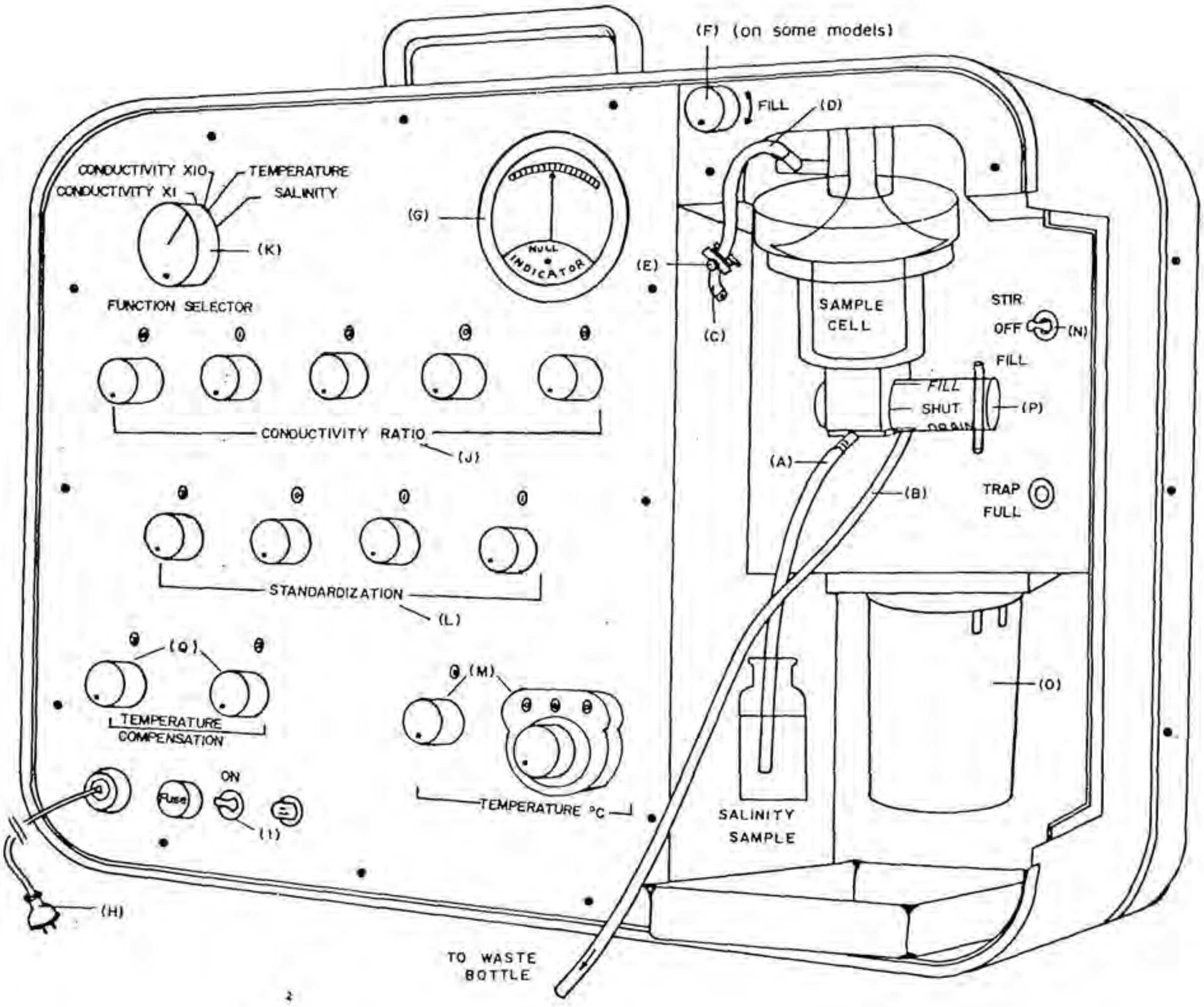

Figure I-12. Salinometer set up for operation.

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

	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.	DILTN.	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				
	Std $_1$	34.998			I-2		I-4				
	Std $_2$	34.996									
		−.002									
		Std $_1$ > Std $_2$									

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 I-4. Abstract of Temperature Corrections to Salinity table

	Sample Temperature °C.					
Salinity ‰	16	18	20	22	24	26
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,

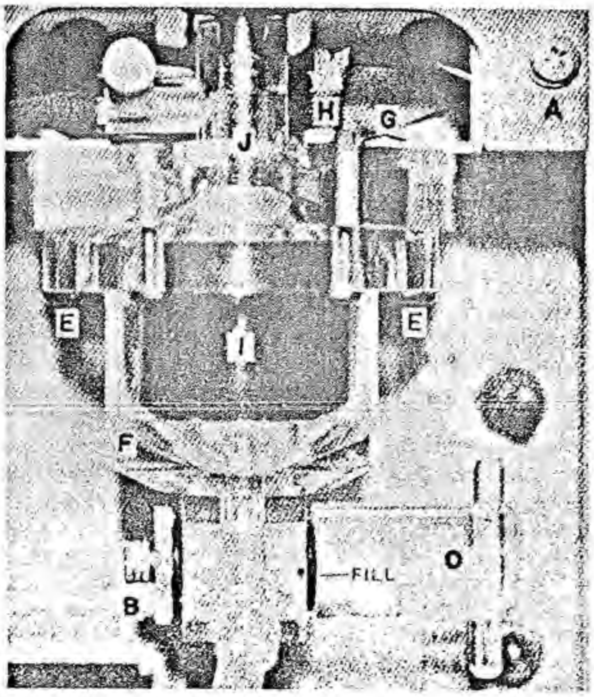

Figure I-15. Sample cell assembly.

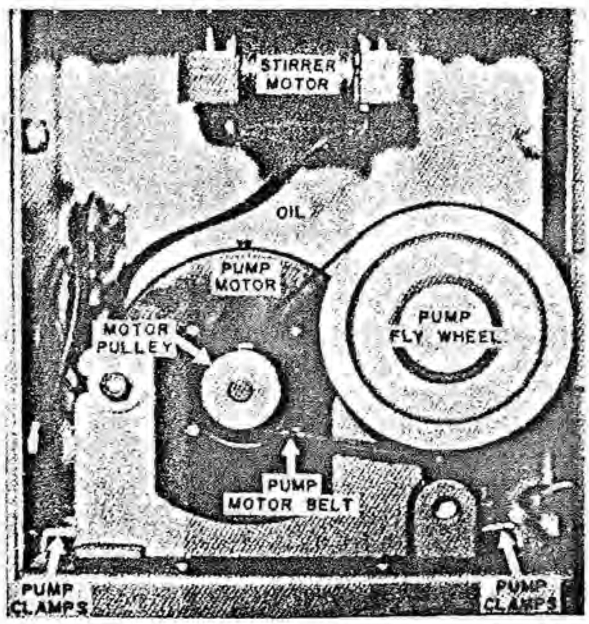

Figure I-16. Pump motor and stirrer motor.

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 3/4 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 1/8 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 1/8 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 1/8 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:

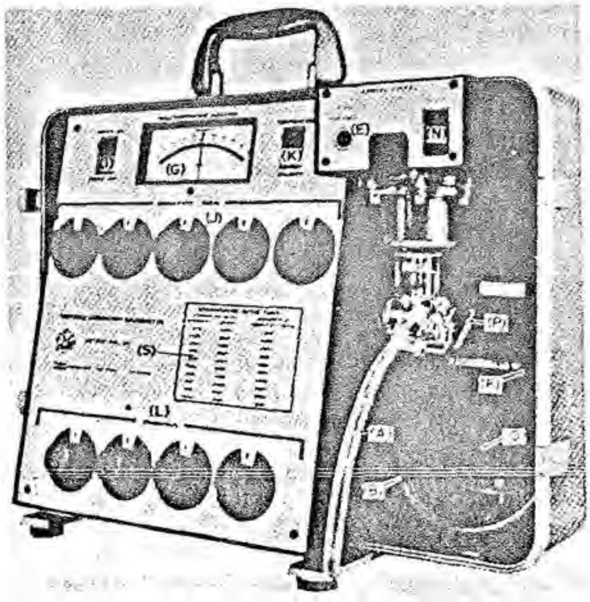

Figure I–17. Laboratory salinometer, Model 6220, Bissett-Berman Corp.

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.

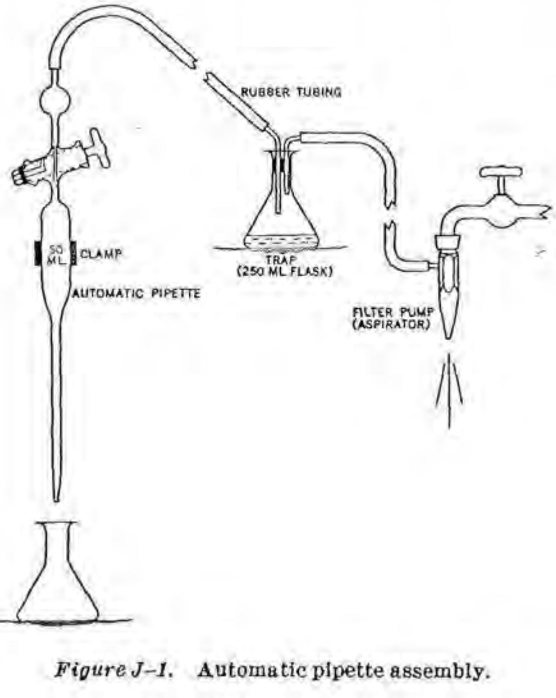

Figure J–1. Automatic pipette assembly.

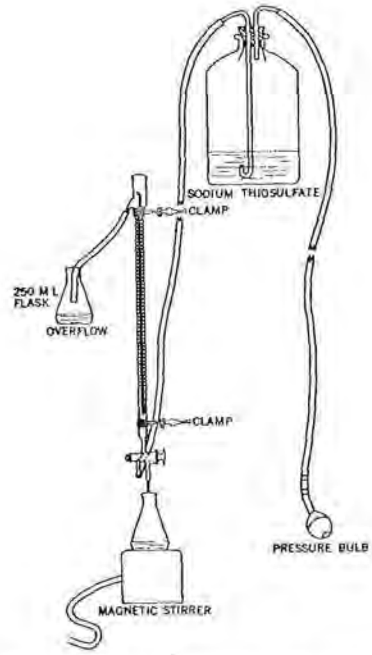

Figure J–2. Automatic self zeroing (0–10 ml.) burette assembly.

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 ± 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

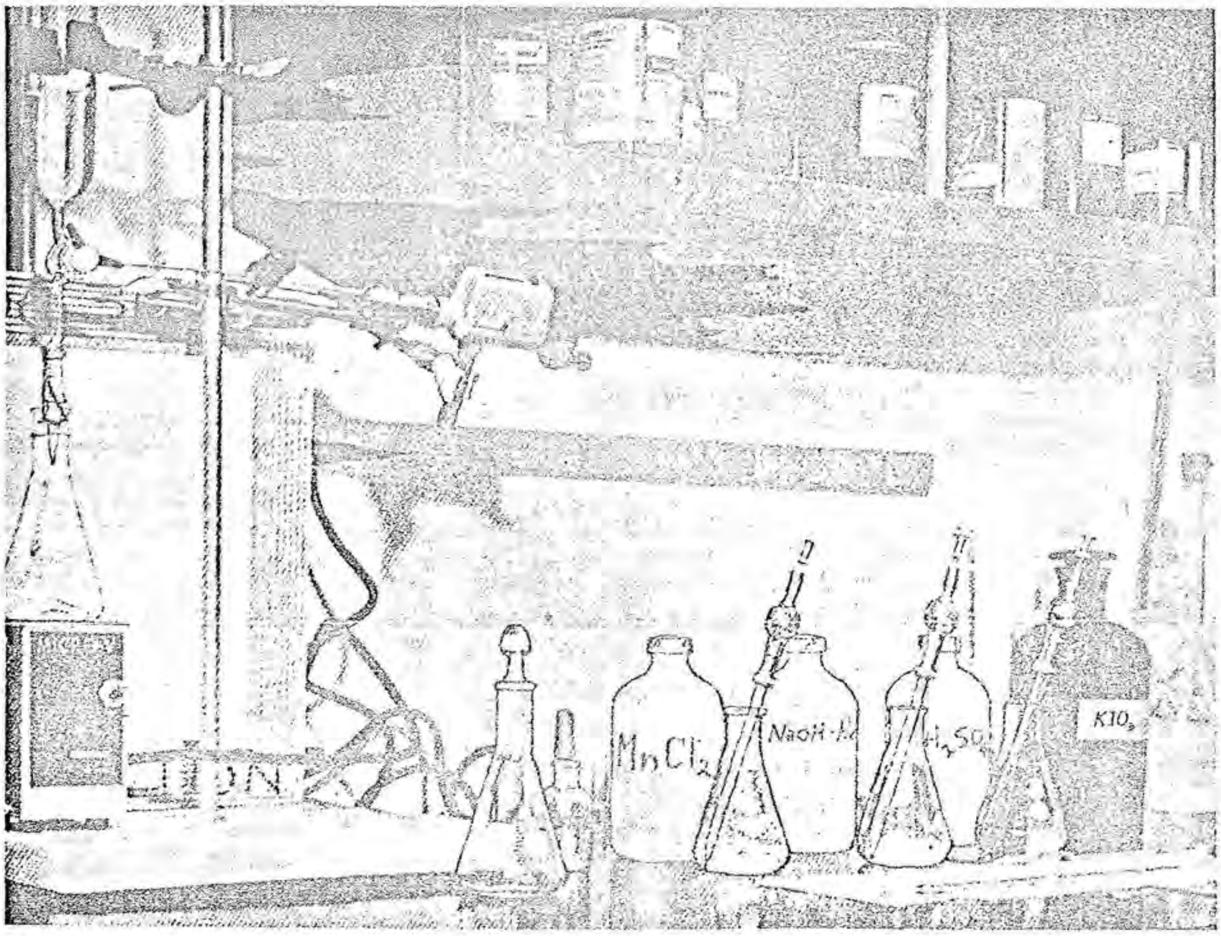

Figure J-4. (Micro) Winkler apparatus.

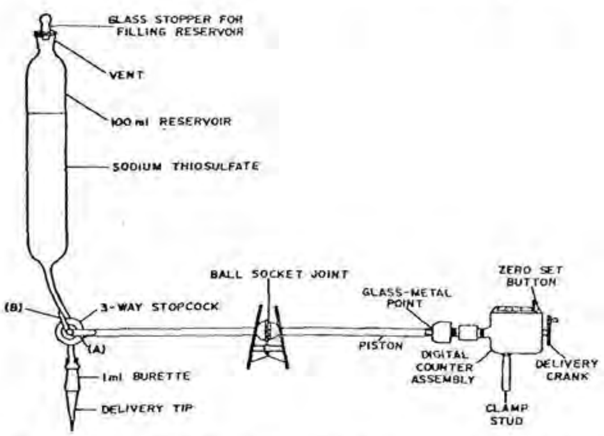

Figure J-5. **Details of the microburette and the digital counter.**

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

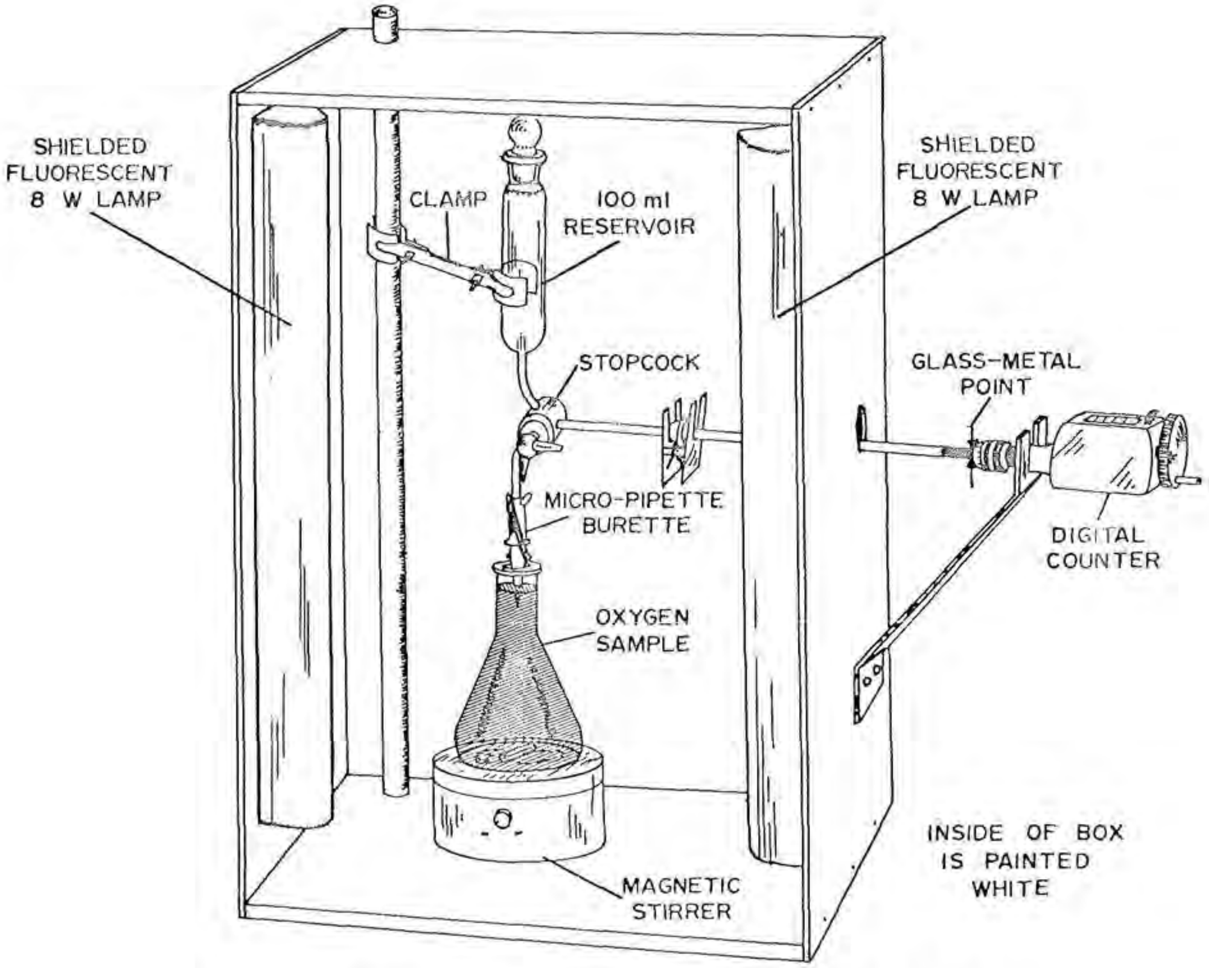

Figure J–6. Titration box (Micro) Winkler method (after J. H. Carpenter).

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

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OCEANOGRAPHIC LOG SHEET – CCC
NAVOCEANO-EXP-3167/66 (2-67)

(MICRO) WINKLER DISSOLVED OXYGEN DETERMINATION
For use with Pub. No. 607

VESSEL	CRUISE	CONSEC. STATION NO.	CHEMIST	DATE ANALYZED	CHECKED BY
BURTON ISLAND	ARCTIC 66	1	M. T. B.	20 Aug. 66	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

$$O_2 = \frac{(V - V_b)\, V_s \cdot N \cdot E}{(V_2 - V_b)\,(V_s - 2)} - OX$$

V_s = 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

$$K = \frac{V_s \cdot N \cdot E}{(V_s - 2)}$$

$$O_2 = \frac{(V - V_b)\, 559.8}{(V_2 \cdot V_b)\,(V_s - 2)} - 0.018$$

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.

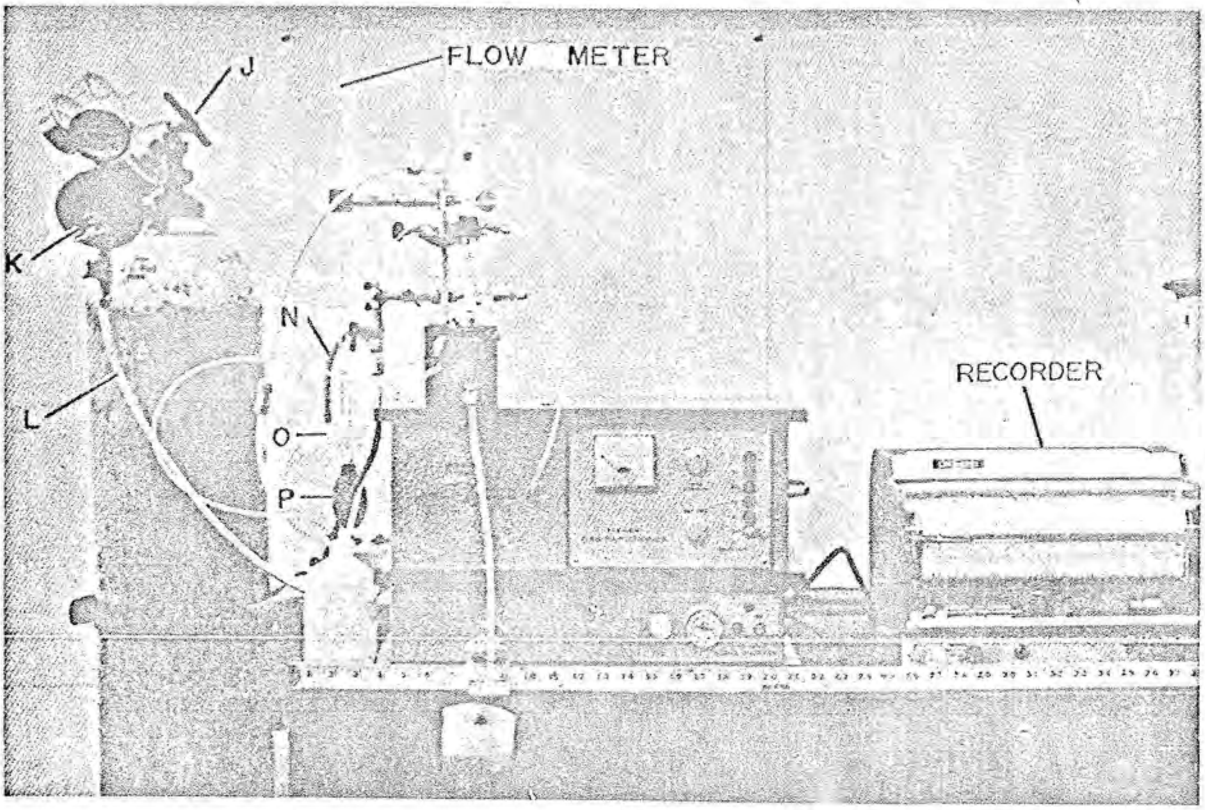

Figure J–8. Fisher Gas Partitioner modified, helium tank and recorder.

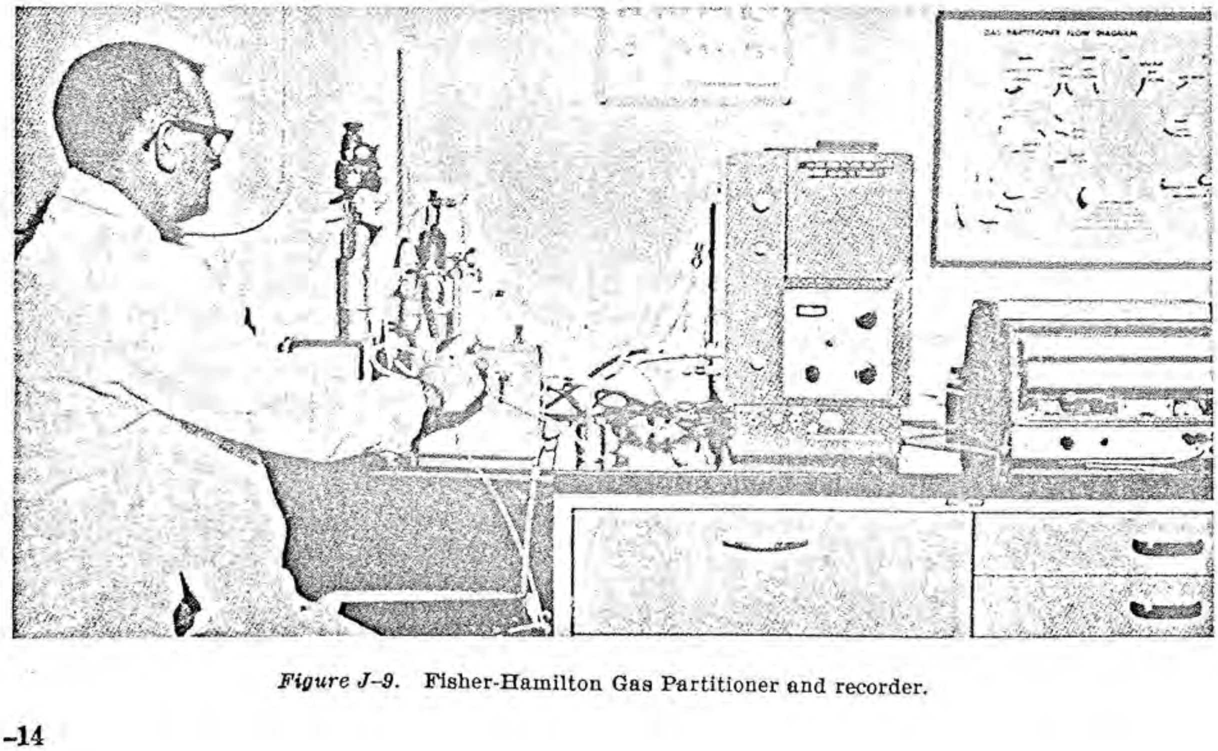

Figure J–9. Fisher-Hamilton Gas Partitioner and recorder.

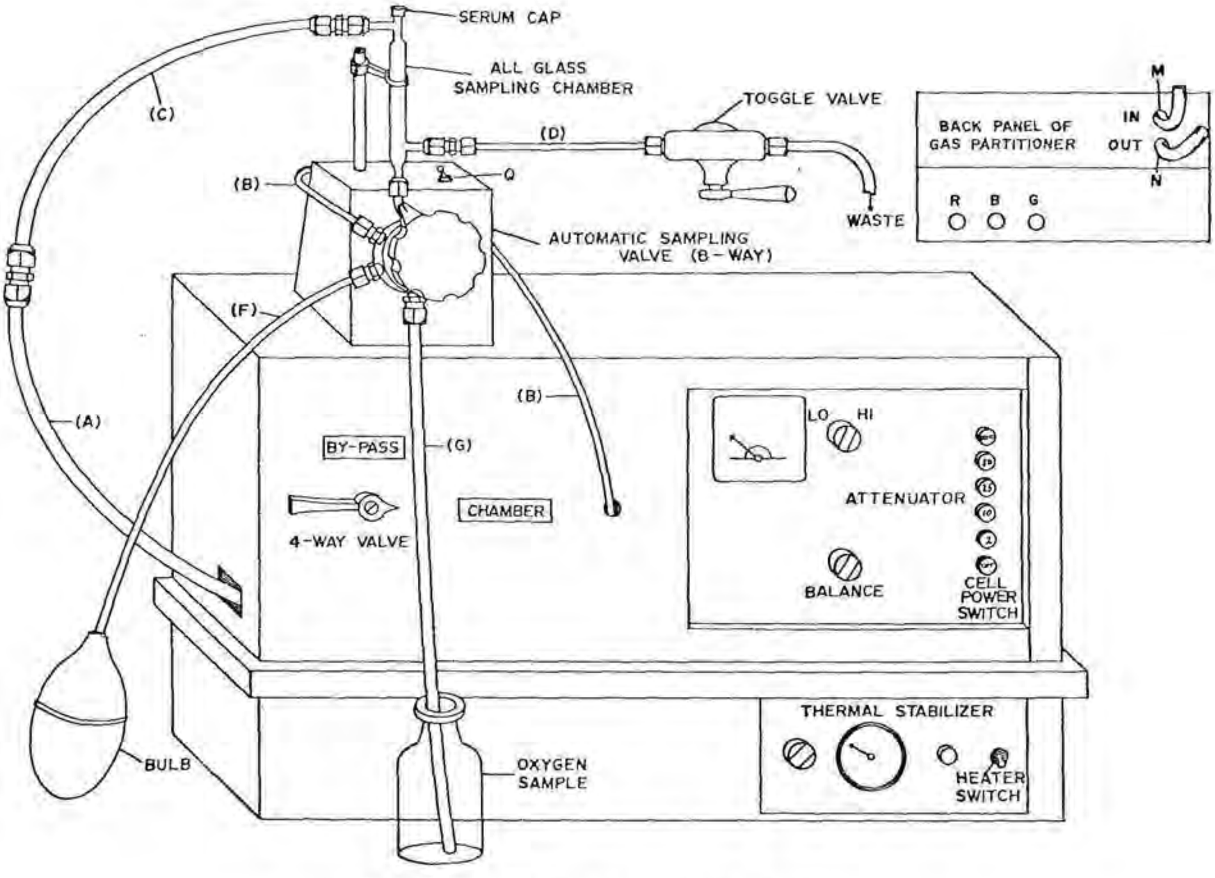

Figure J-10. Fisher Gas Partitioner, modified.

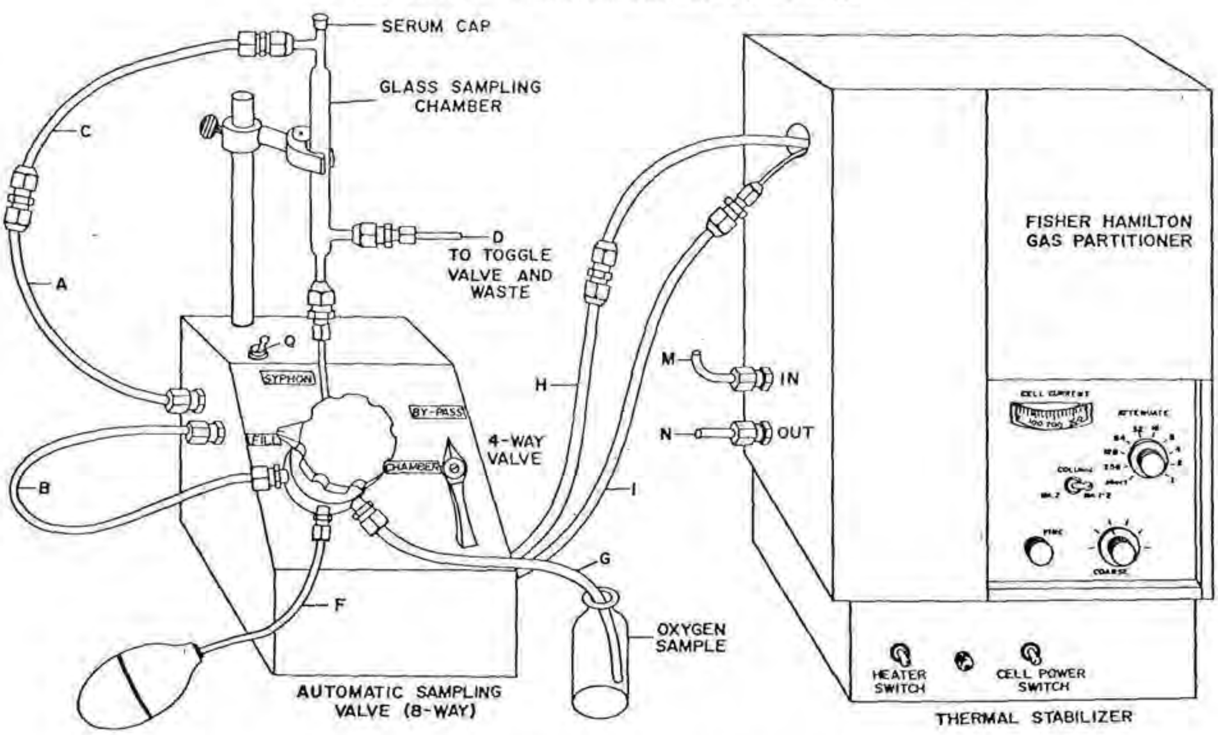

Figure J-11. Fisher-Hamilton Gas Partitioner, the glass sample chamber, and the valve cabinet.

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.

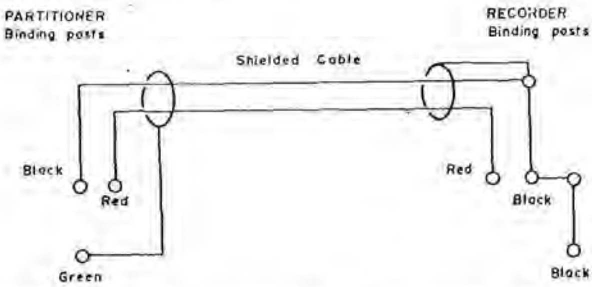

Figure J–12. Two-conductor cable connections between gas partitioner and recorder.

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

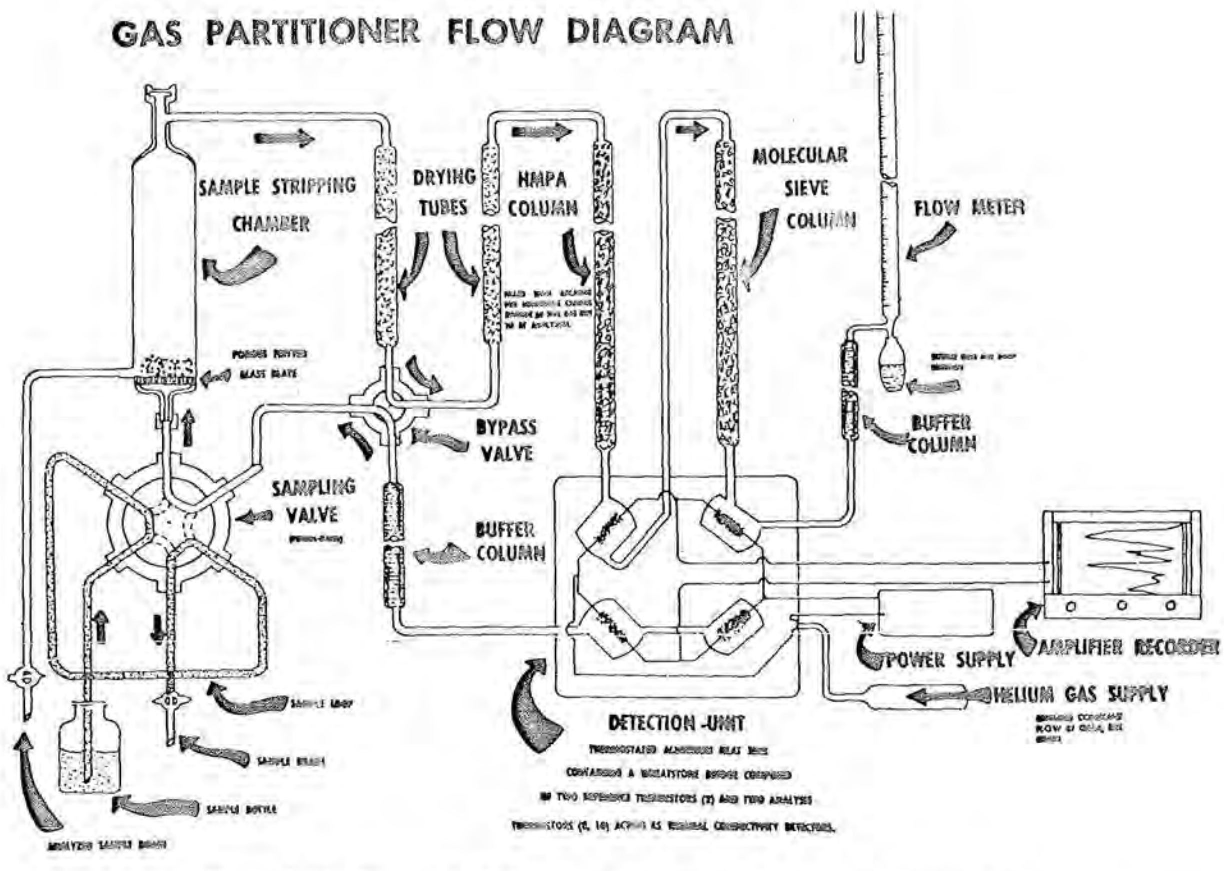

Figure J–13. Flow path of the carrier gas through the gas partitioner system.

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)

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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}	6086	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		5646	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.

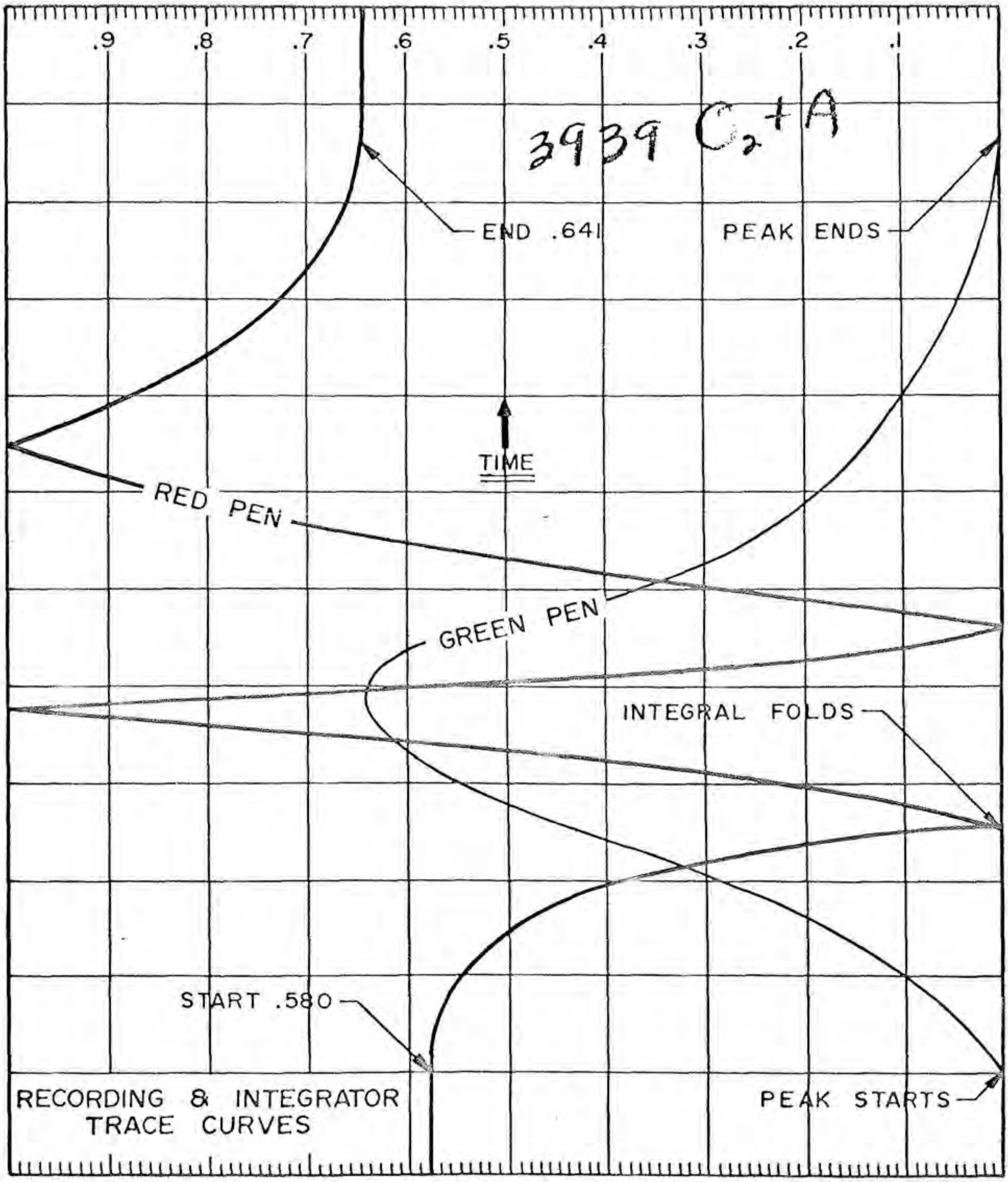


Figure J-15. Chromatogram showing red and green pen traces.

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 JAS 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=3.954×10^{-4}.

Step 3. Convert $A+O_2$ Counts Read to 100 percent by dividing by sensitivity, e.g., 6085 ÷.25=24340. Convert N_2 Counts Read to 100 percent, e.g., 11428÷.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= (8.0×10^{-5}) (T) + (3.07×10^{-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.

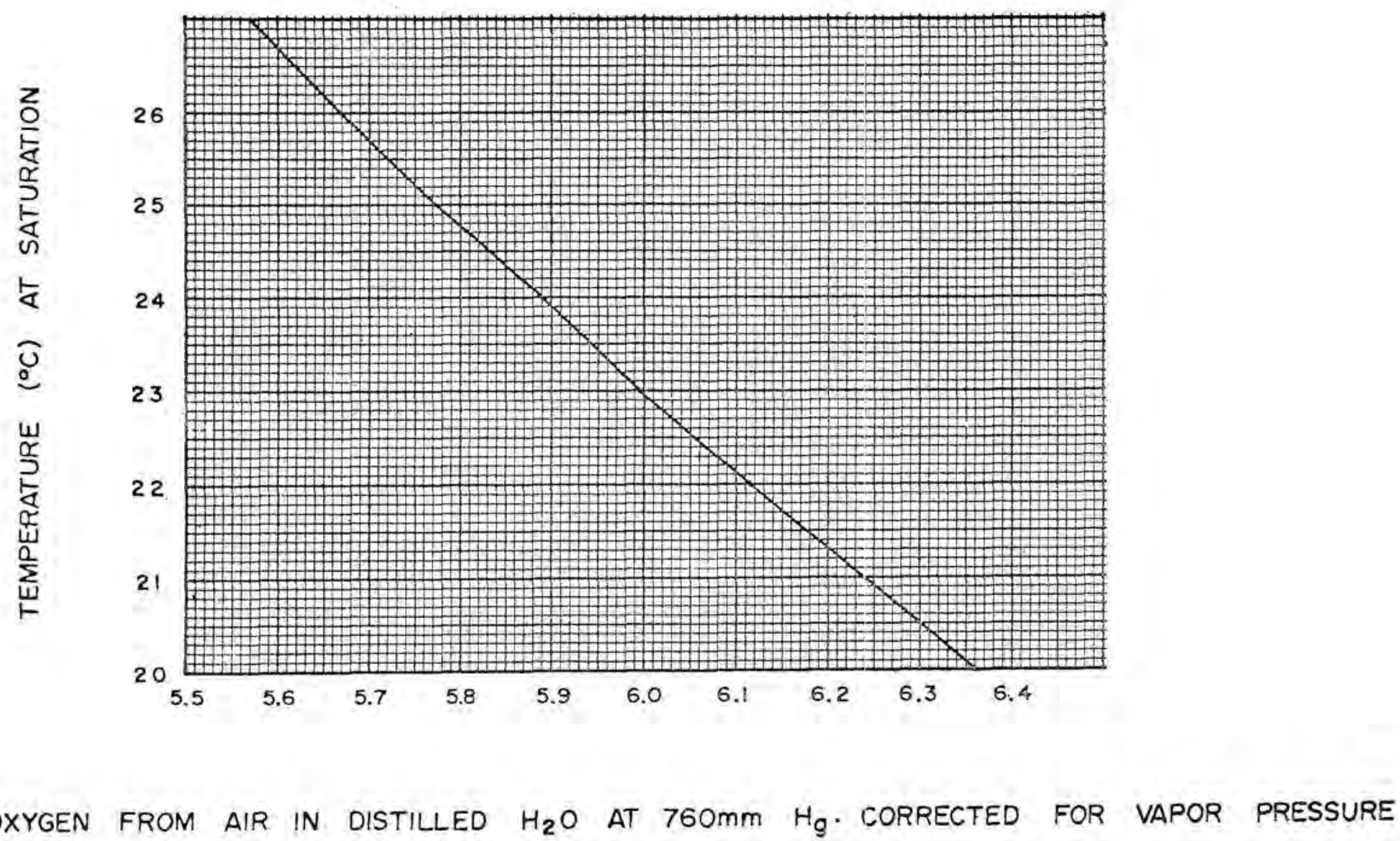


Figure J–17. Oxygen saturation graph (do not extrapolate beyond 20° or 26° C.). From Klots and Benson, Journal of Physical Chemistry, Volume 68, No. 1, January 1964, page 169–174.

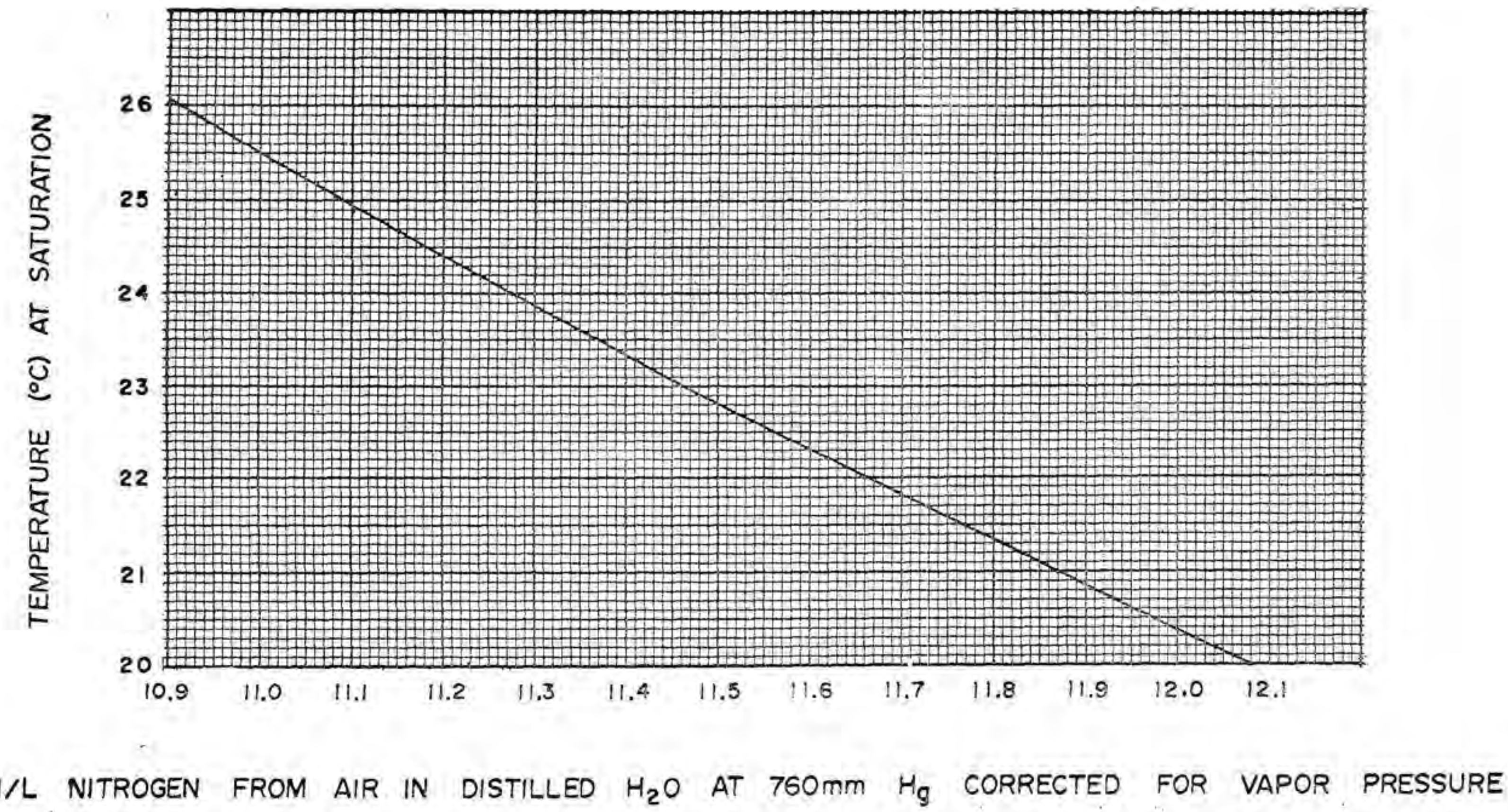


Figure J-18. Nitrogen saturation graph (do not extrapolate beyond 20° or 26° C). From Klots and Benson, Journal of Physical Chemistry, Volume 68, No. 1, January 1964, pages 169–174.

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 5/32– or 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.

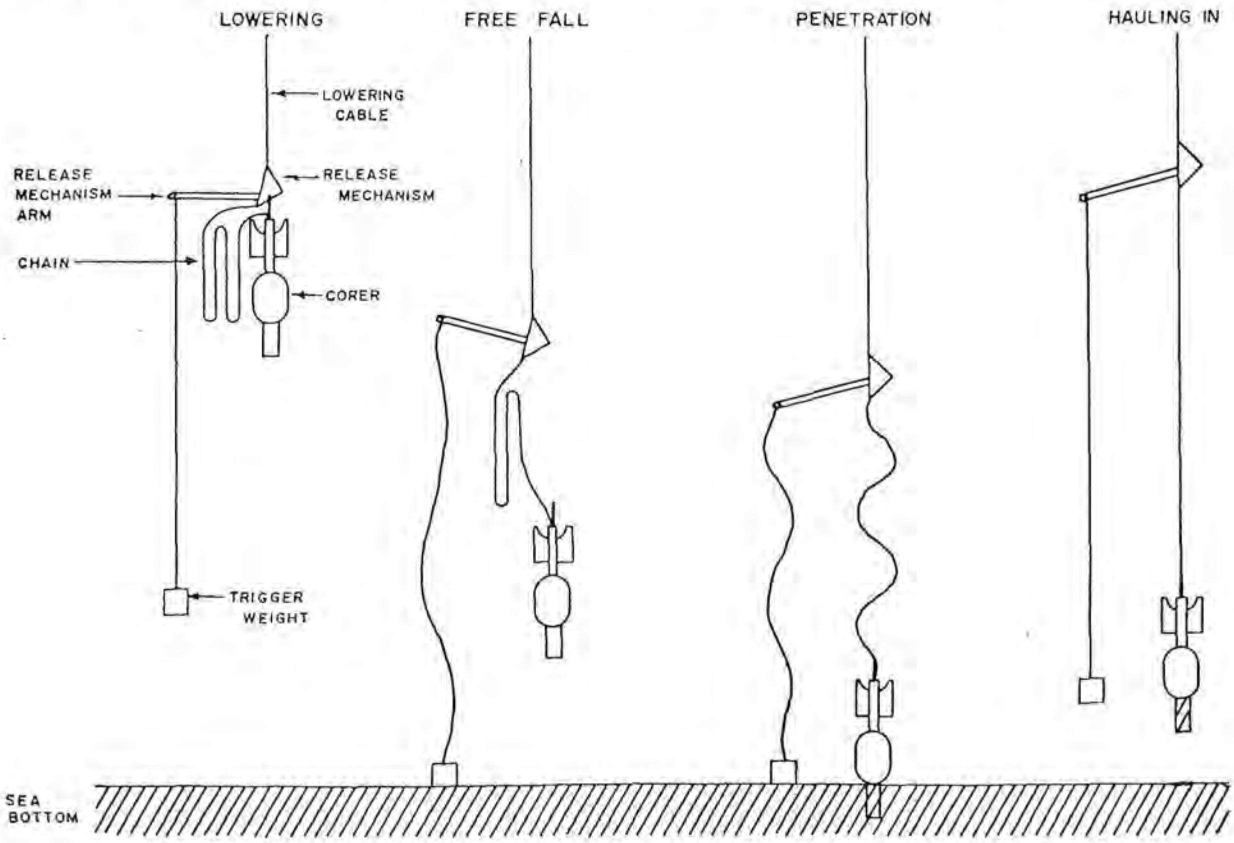


Figure L–1. Principle of operation of gravity-type corers.

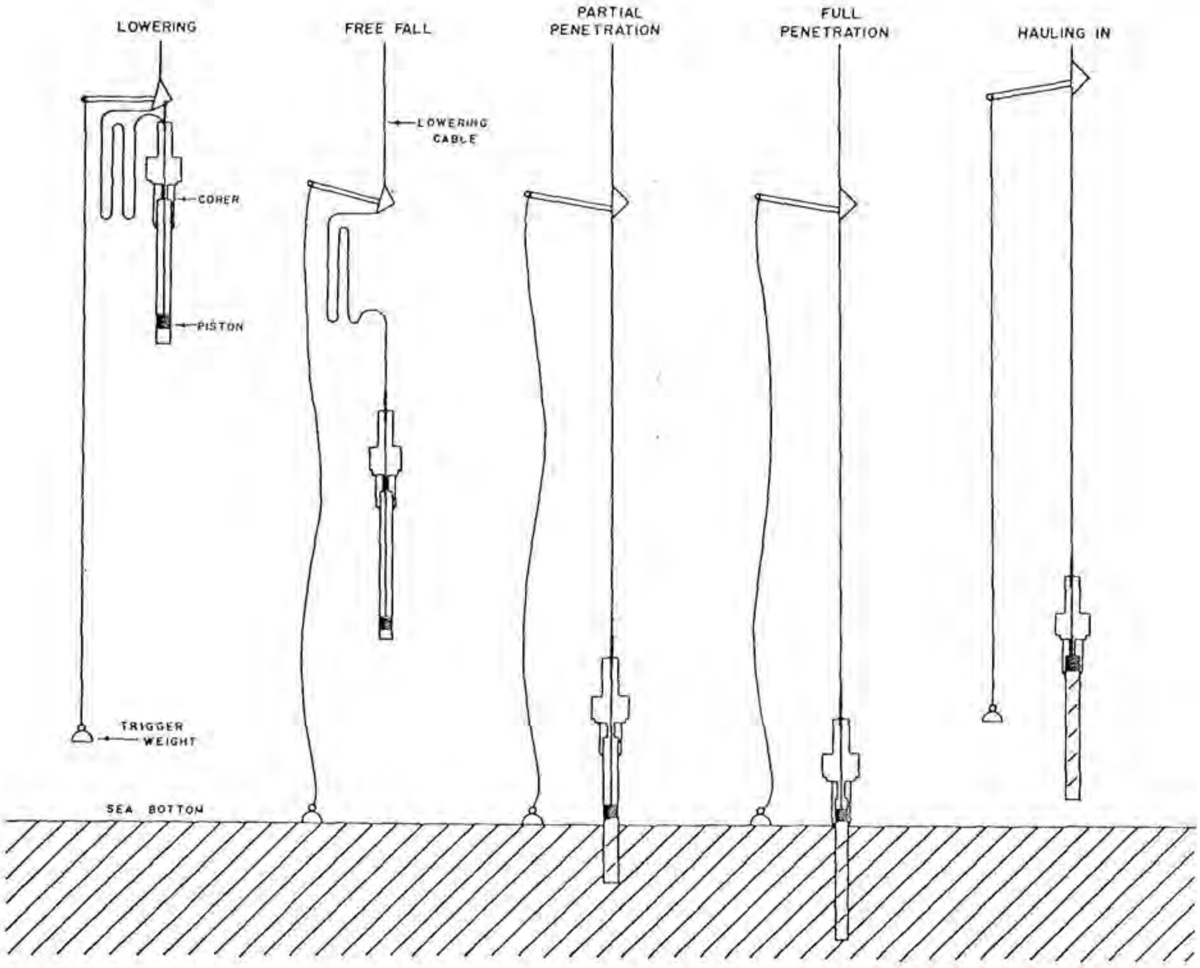


Figure L–2. Principle of operation of piston-type corers.

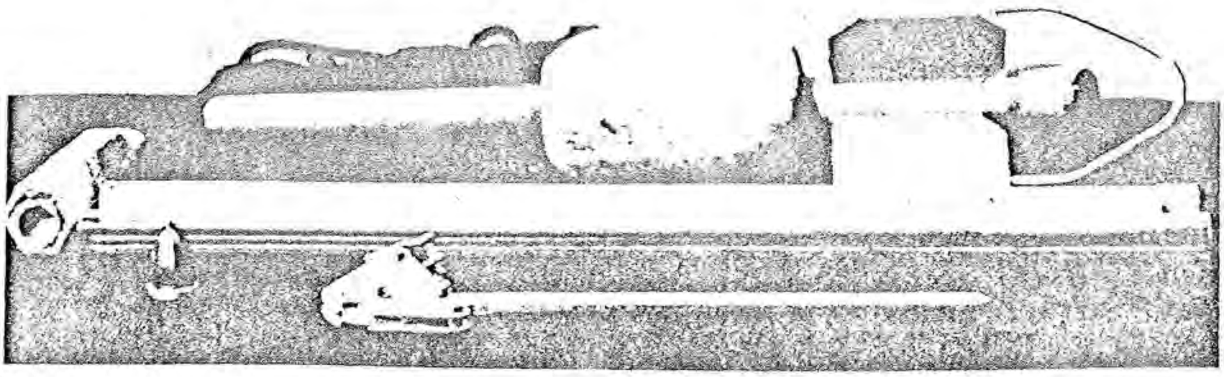


Figure L–3. Phleger corer assembly.

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;

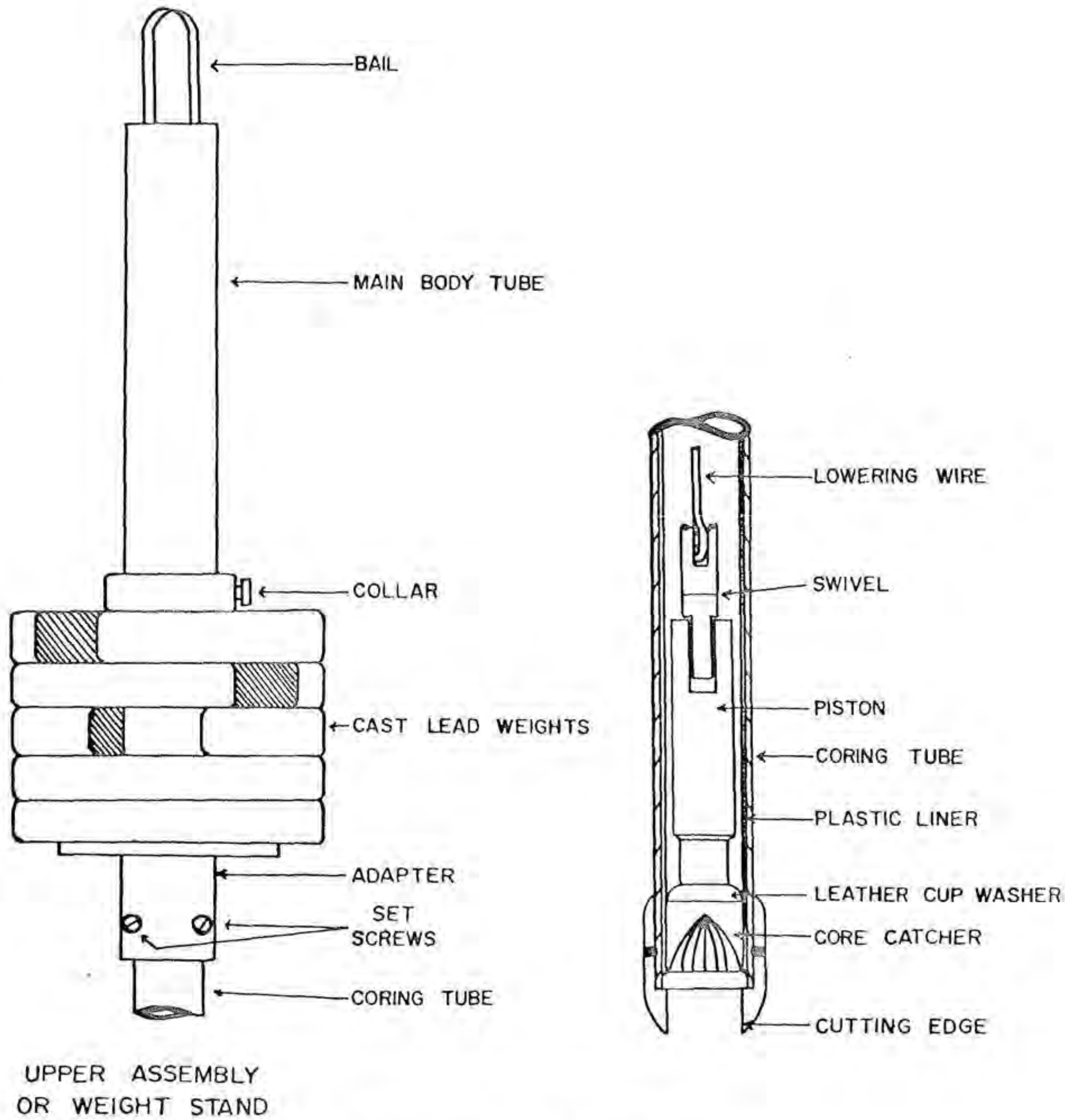


Figure L–4. Kullenberg piston corer assembly.

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;

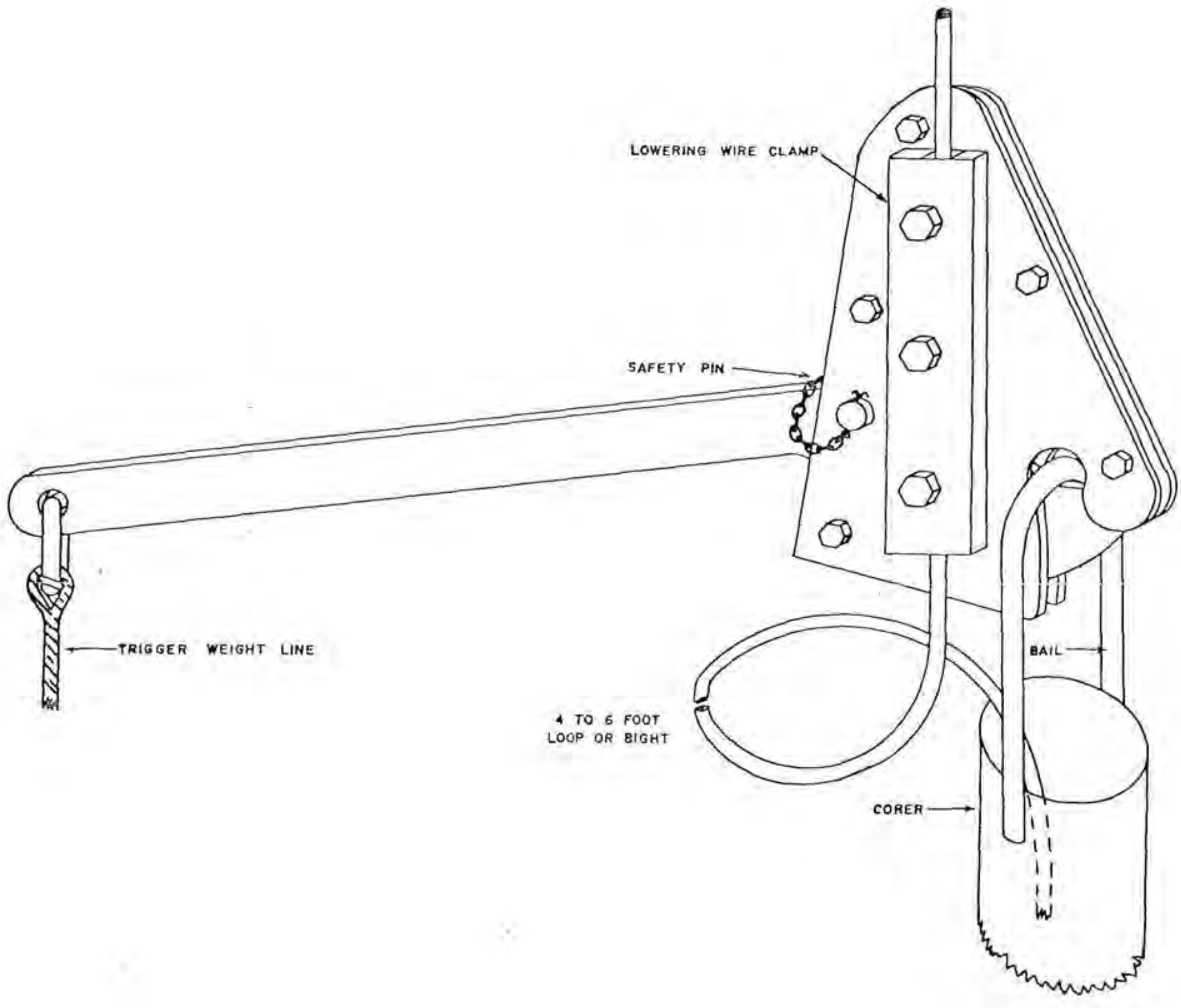


Figure L–5. Kullenberg piston corer release mechanism.

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.

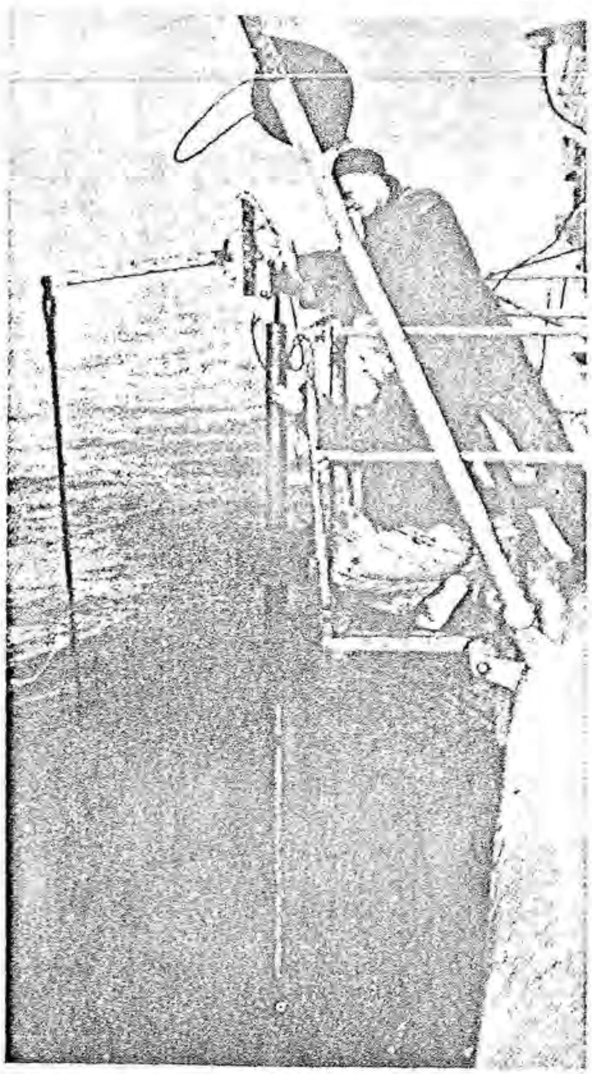


Figure L–6. **Taping bight of lowering wire to Kullenberg corer.**

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;

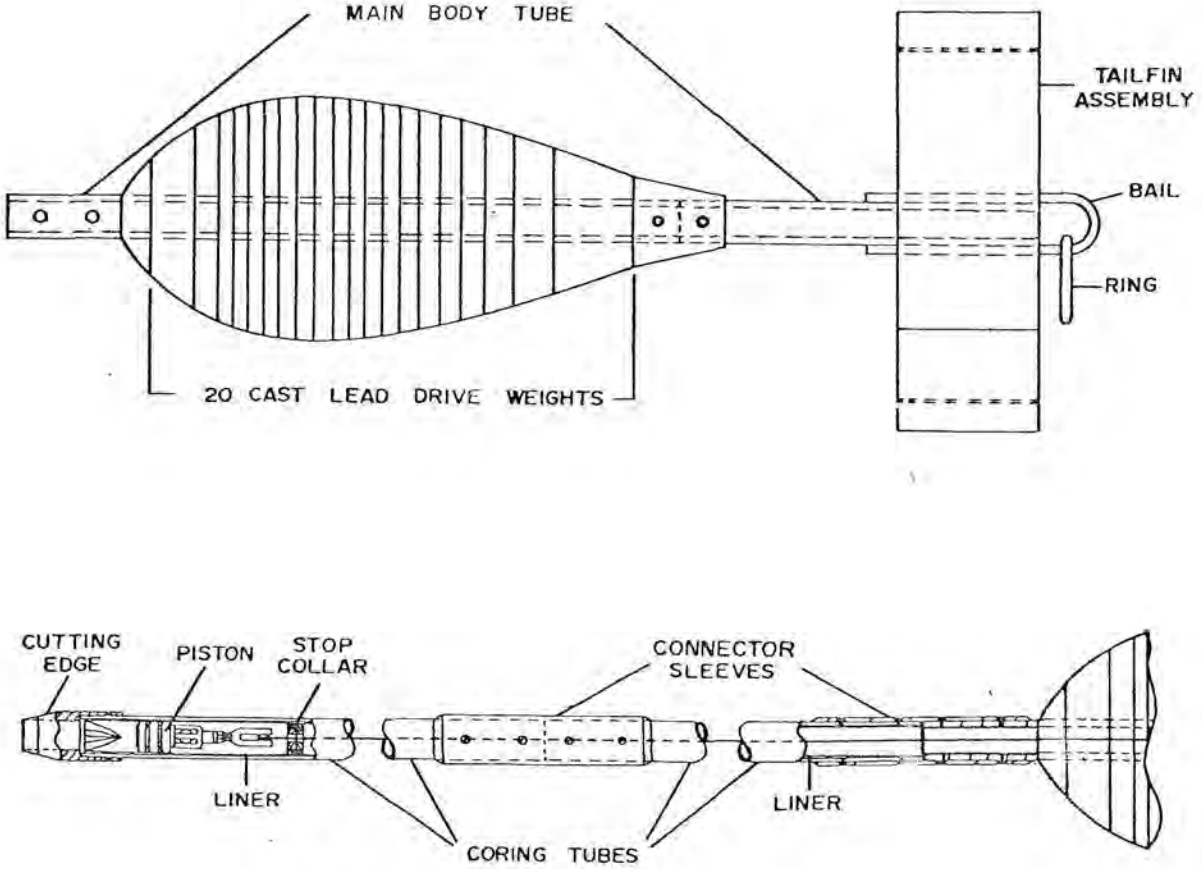


Figure L–7. The Ewing corer (2,000 pound) assembly.

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.

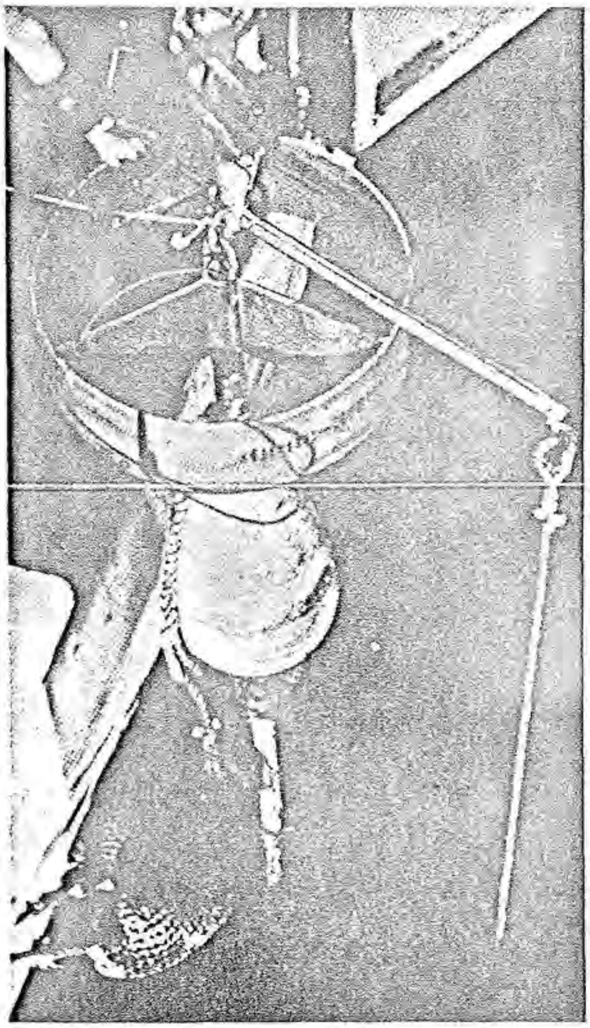


Figure L–8. The Ewing corer.

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;

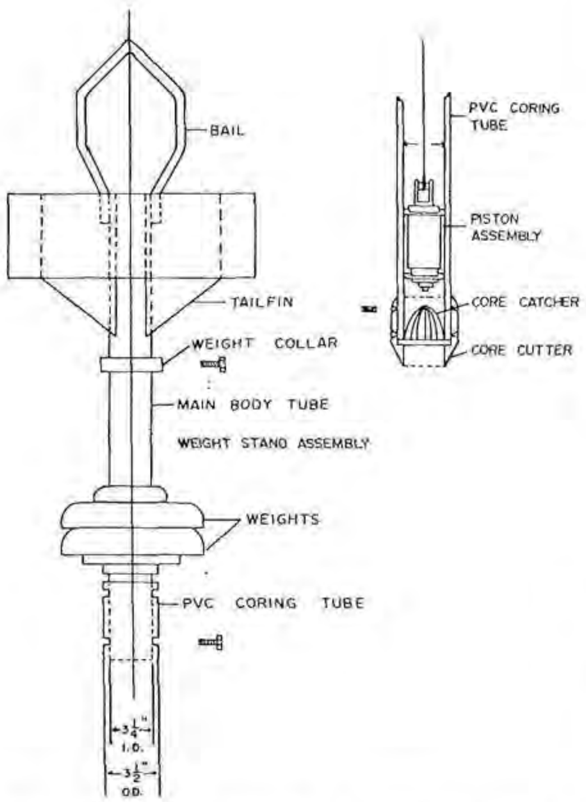


Figure L–9. The Hydro-Plastic (PVC) piston corer assembly.

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.

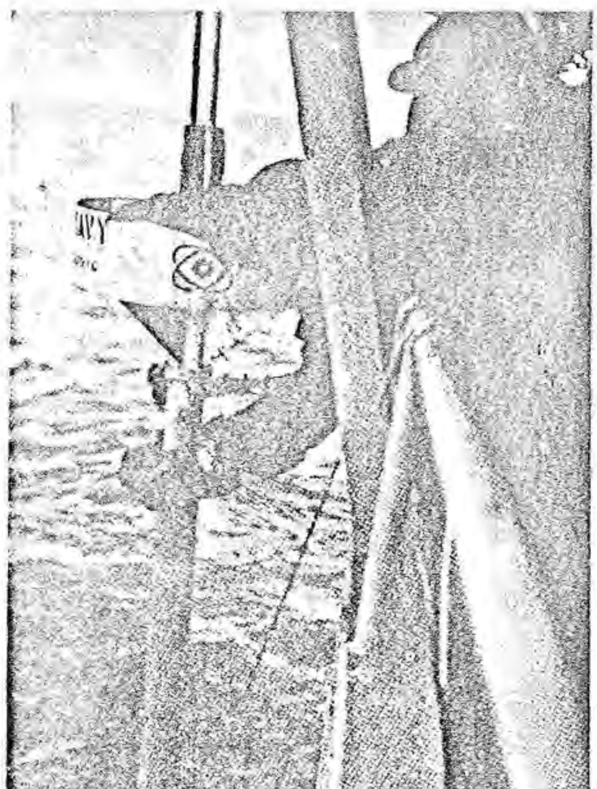


Figure L–10. Attaching weights to PVC corer.

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).

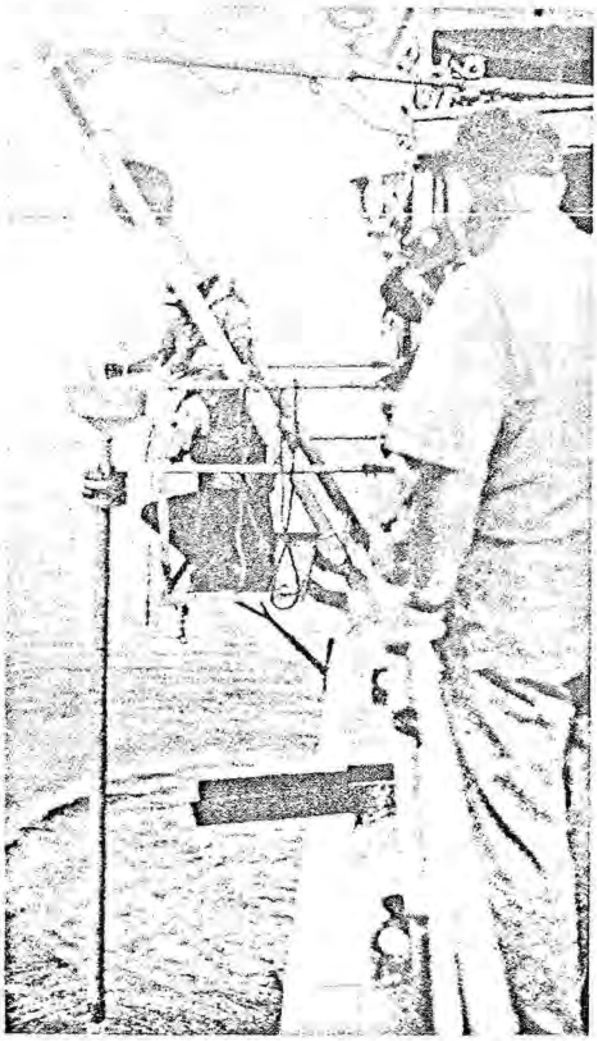


Figure L–11. The Hydro-Plastic (PVC) corer at deck working level.

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.

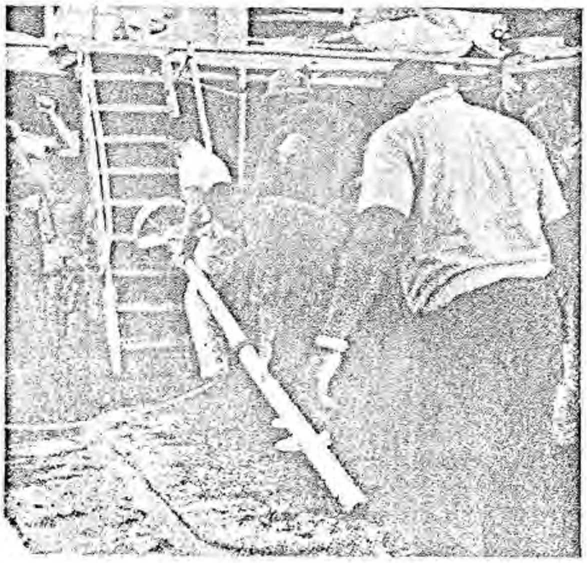


Figure L–12. Bringing the Hydro-Plastic (PVC) piston corer aboard.

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).

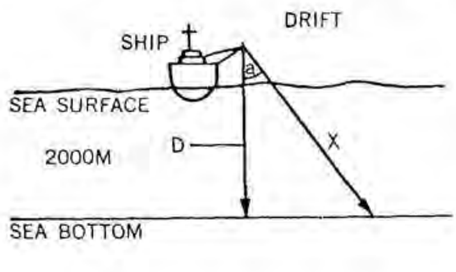
Step 7. Pack, store, and ship cores in accordance with instructions given in paragraph L–41, Packing, Storing, and Shipping Bottom Sediment Samples.

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.

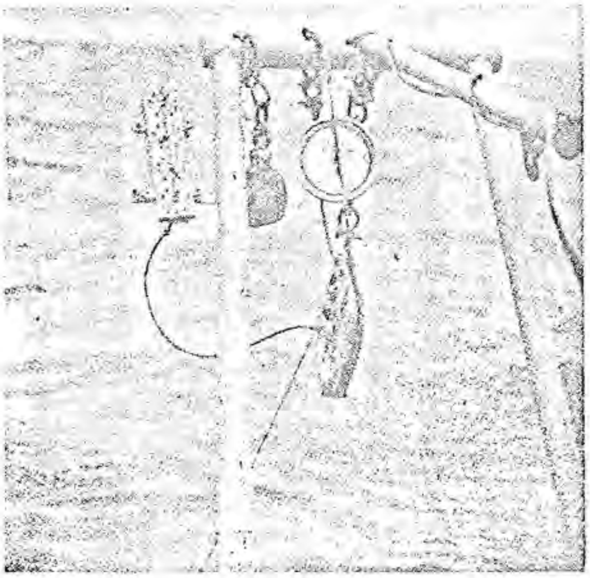


Figure L–15. Dynamometer attached to retractable A-Frame.

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.

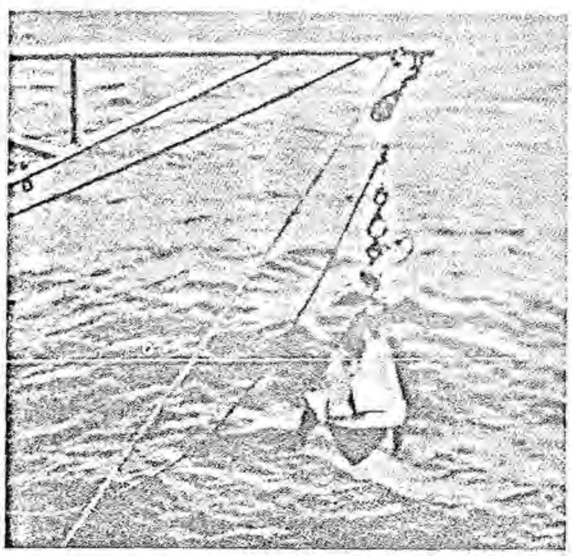


Figure L–17. Orange Peel bucket sampler rigged for lowering.

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

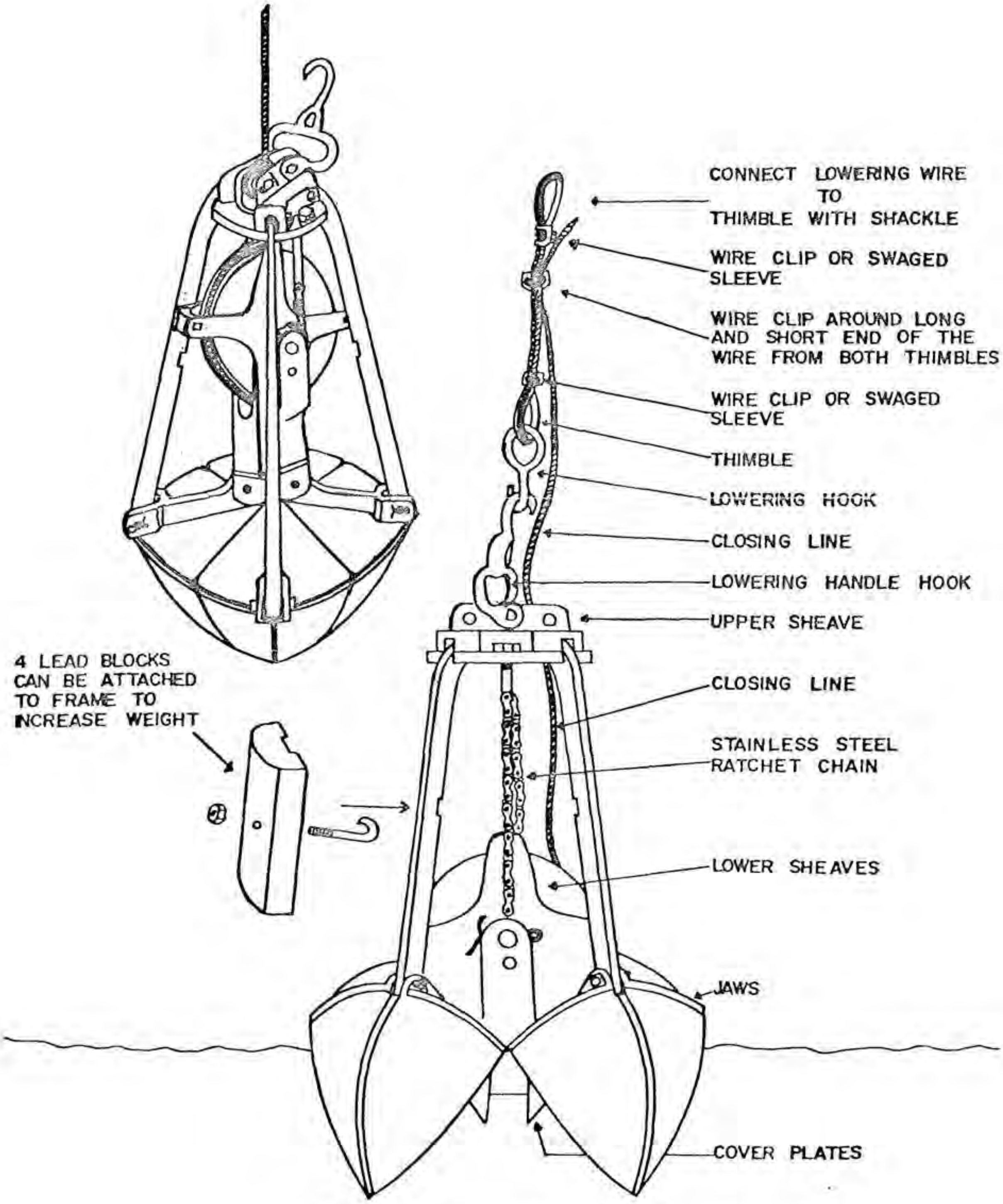


Figure L–18. Orange Peel bucket sampler.

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.

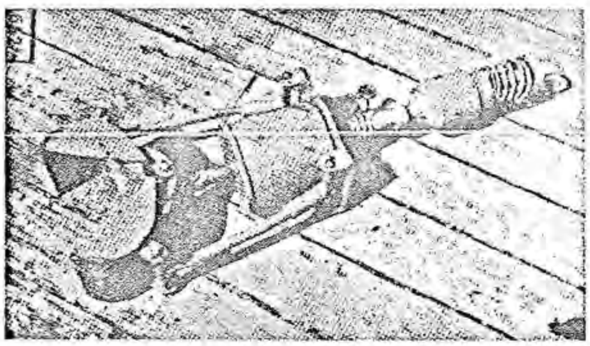


Figure L–19. Clamshell snapper.

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.

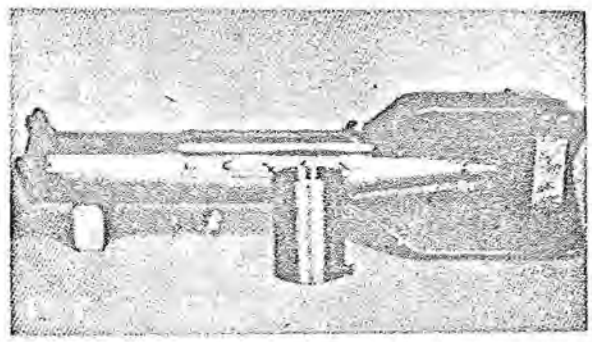


Figure L–20. Scoopfish underway sampler.

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 ¼-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.

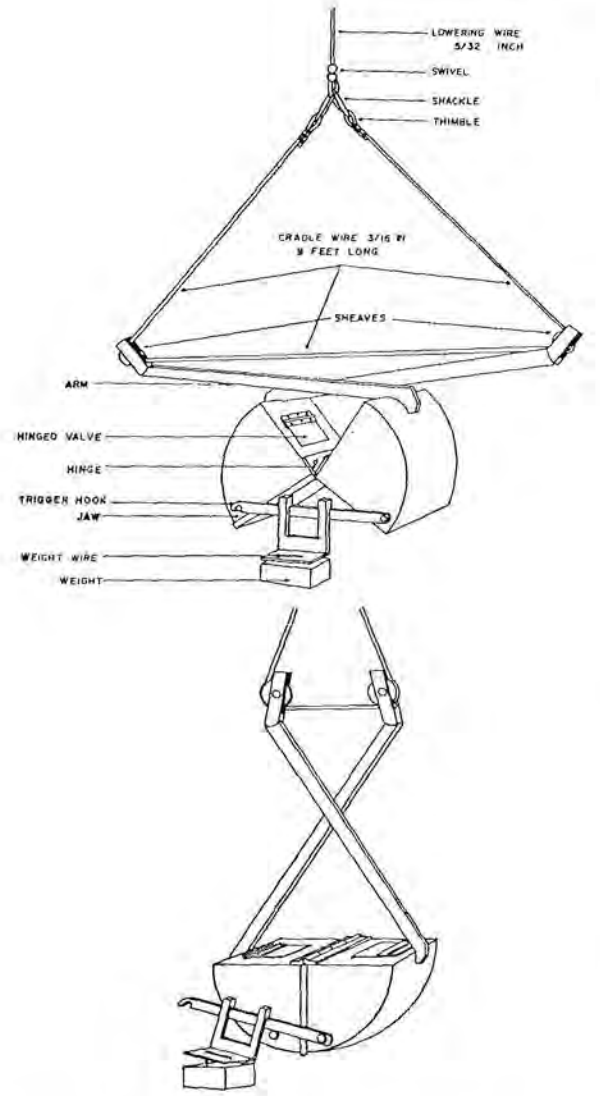


Figure L–21. The Van Veen sampler with modified trigger.

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.

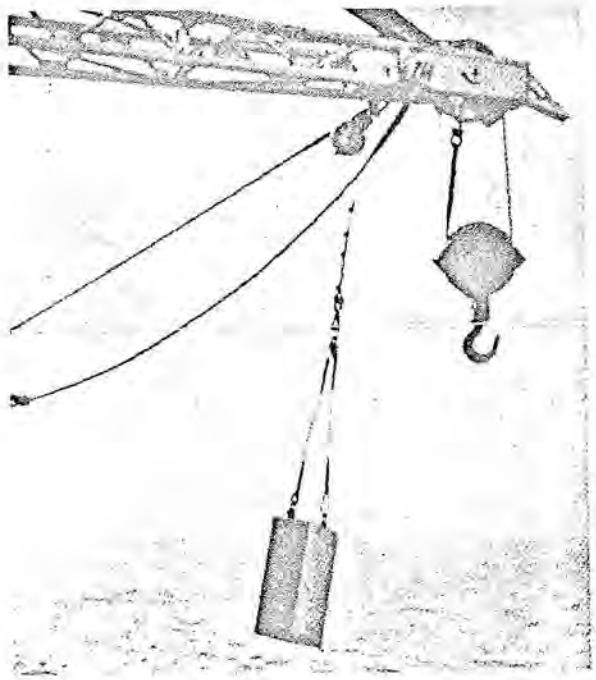


Figure L–22. Box shaped dredge.

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.

OCEONOGRAPHIC LOG SHEET-M
BOTTOM SEDIMENT DATA

Return To:
U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

VESSEL: USS ATKA (AGB-3) | CRUISE: 0-191 | CHECKED BY: R. Stewart | DATE CHECKED: 29 August 1962

BOTTOM SEDIMENT NO.	DATE (1962)	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 TOP	ROCK COLOR CHART CORE BOTTOM	FIELD DESCRIPTION OF CORE AND REMARKS	OBS. INIT.
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	JX
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.	JX
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.	JX
2	11 Aug.	72°57'	011°00'	1,105	GREENLAND SEA OFF EAST COAST OF GREENLAND	HYDROPLASTIC (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.)	JX
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.	JX
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.	JX
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)	JX
6	19 Aug.	76°54'	000°13'	936	CENTRAL GREENLAND SEA	ORANGE PEEL GRAB	90 lbs.					MAINLY SAND AND SILT; SOME PEBBLES.	JX
7	21 Aug.	78°58'	002°55'	686	NORTH GREENLAND SEA	ORANGE PEEL GRAB	90 lbs.					SOME SILT, SAND, GRANULES, PEBBLES, AND COBBLES.	JX
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.	JX
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.	JX
9A	24 Aug.	79°00'	008°30'	213	WEST OF SVALBARD	CUTTER & CATCHER						CLAY	JX
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.)	JX

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.

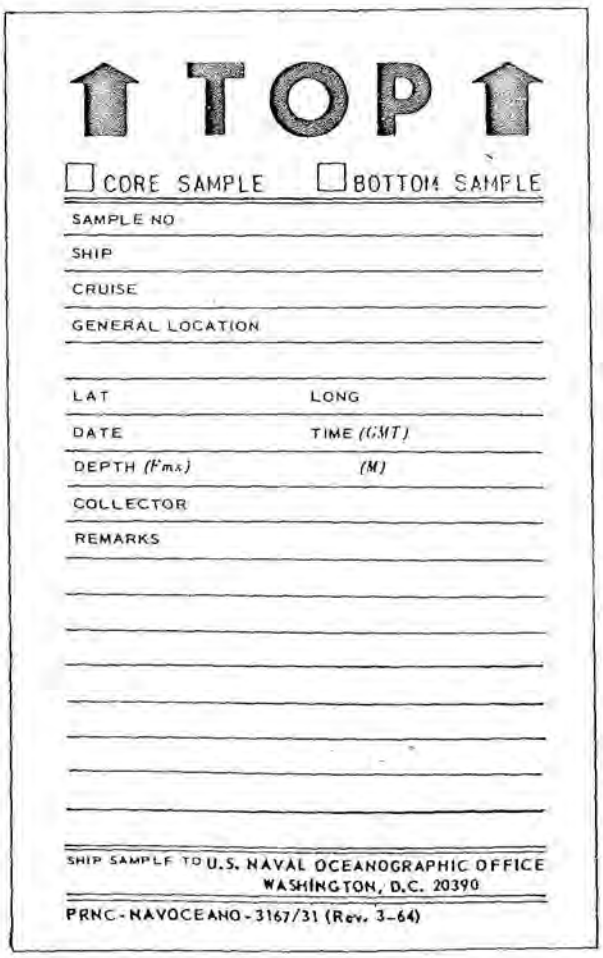
Field Description.—A complete description of a bottom sample consists of: One or more adjectives descriptive as to size, composition, or consistency; one or more adjectives designating color; and one or more nouns naming the class of bottom material. The descriptions should be based on the nouns and 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

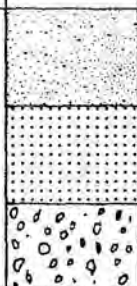
REMARKS

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 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) / Coral (Co)	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.			
	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.

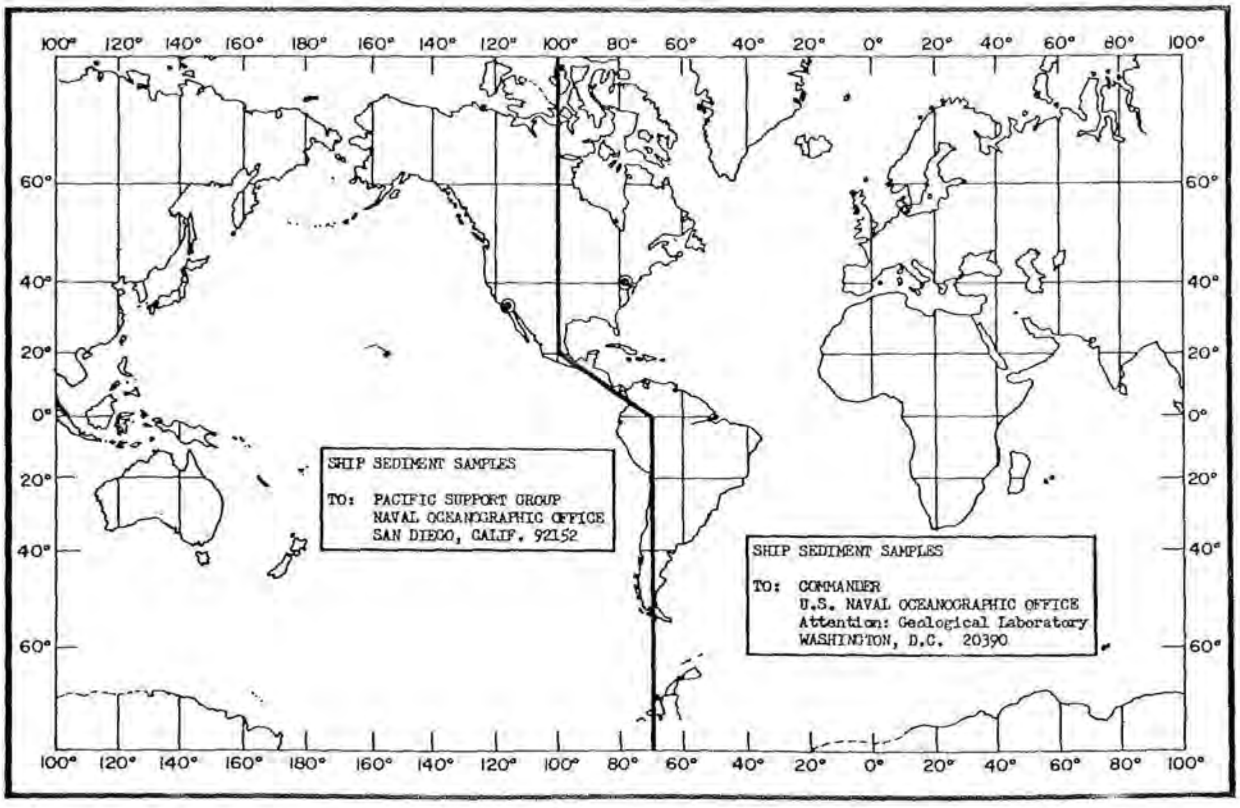


Figure L–25. World chart showing where to ship sediment samples.

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

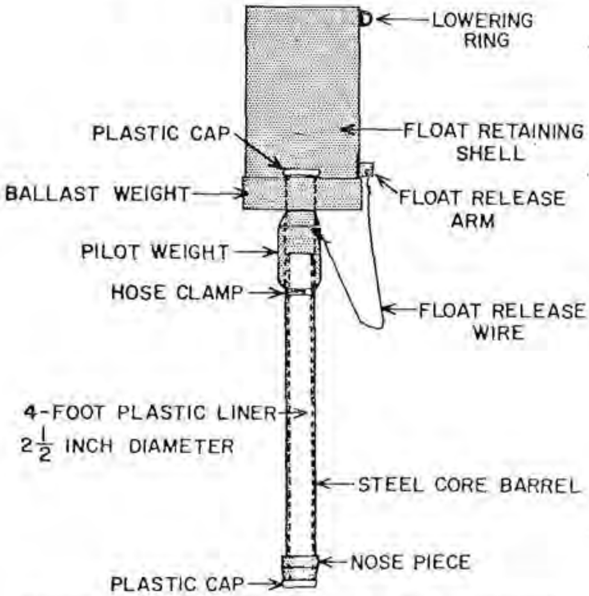


Figure L–26. Boomerang corer ballast component.

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

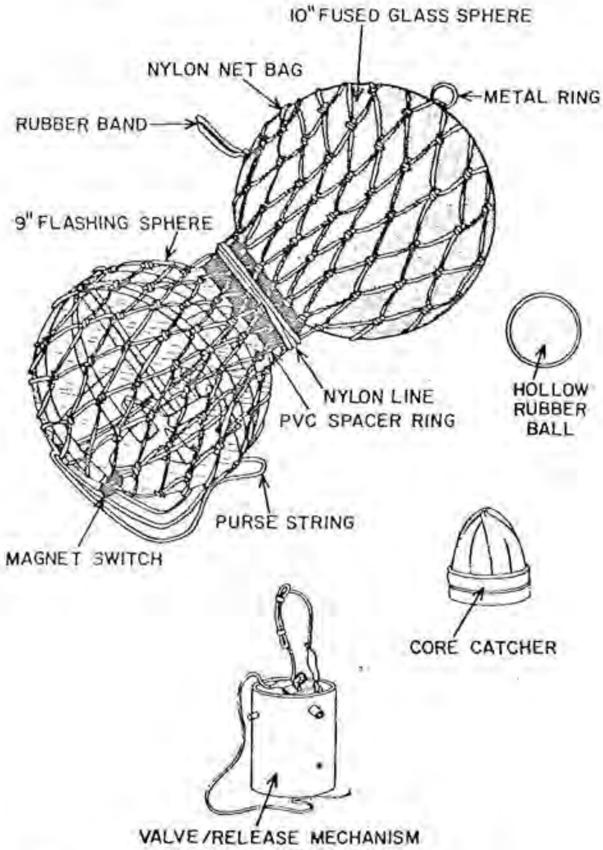


Figure L–27. Boomerang corer float component.

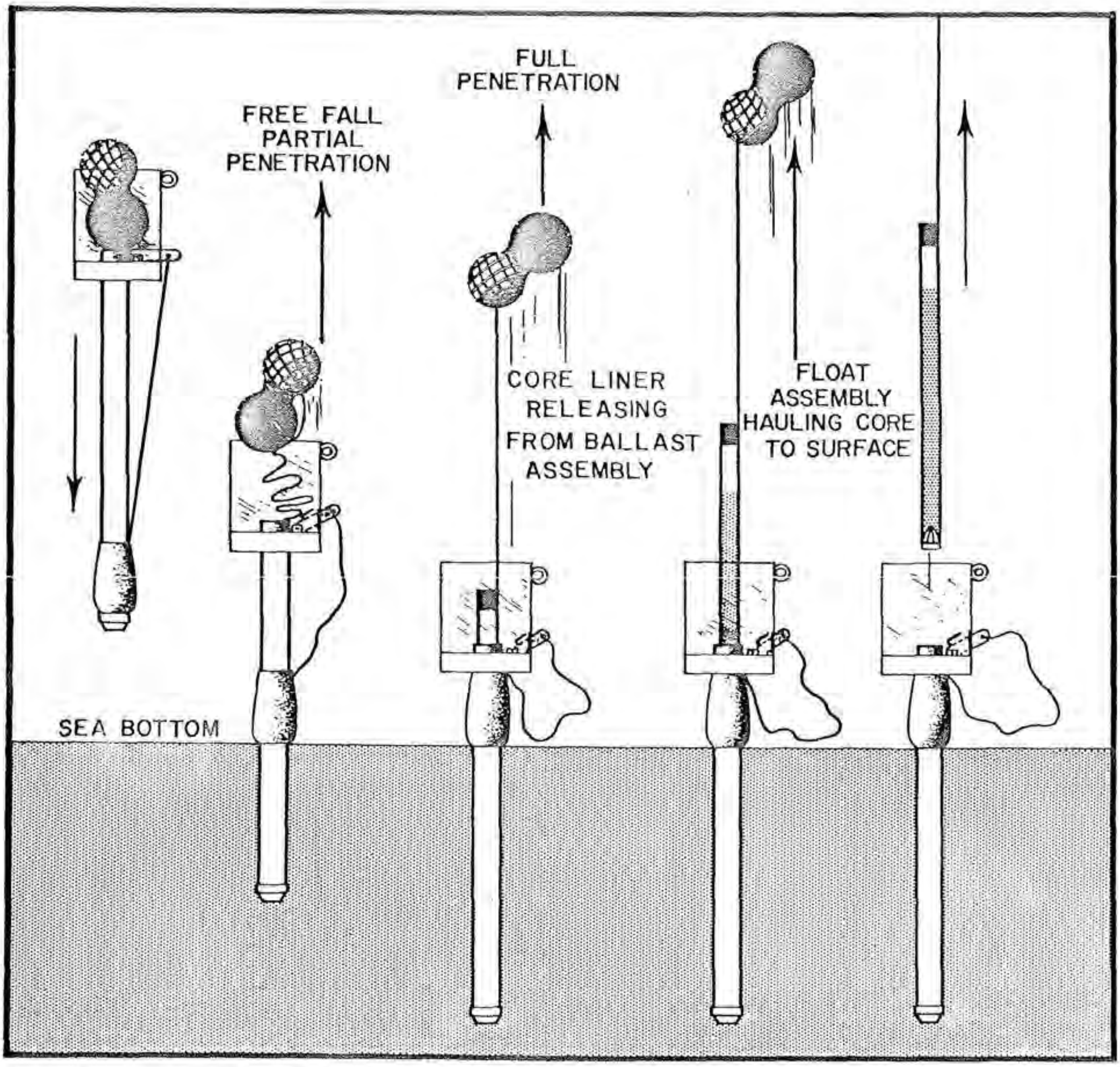


Figure L–28. **Principle of operation of Boomerang gravity-type corer.**

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.

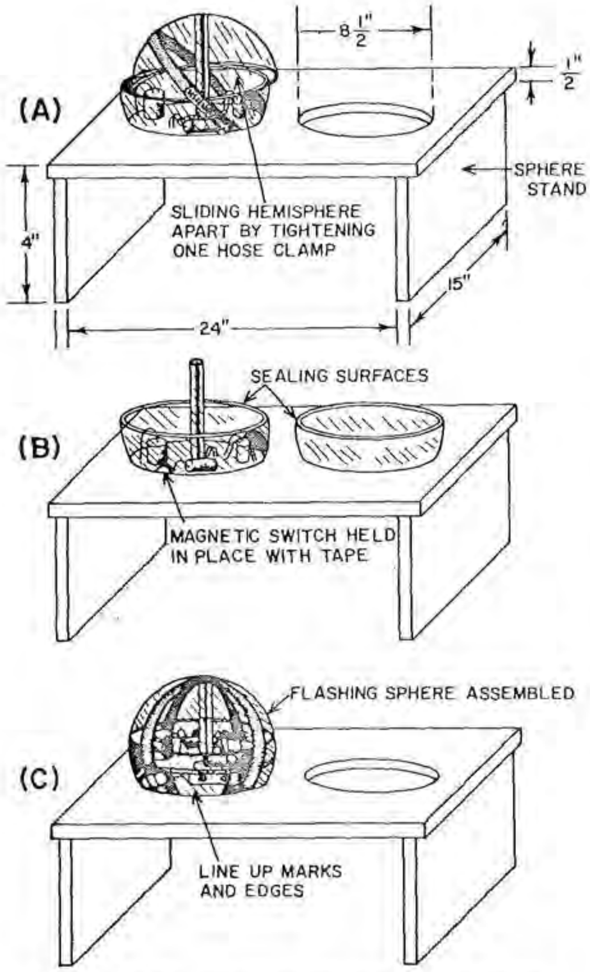


Figure L–29. Flashing sphere in sphere stand.

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

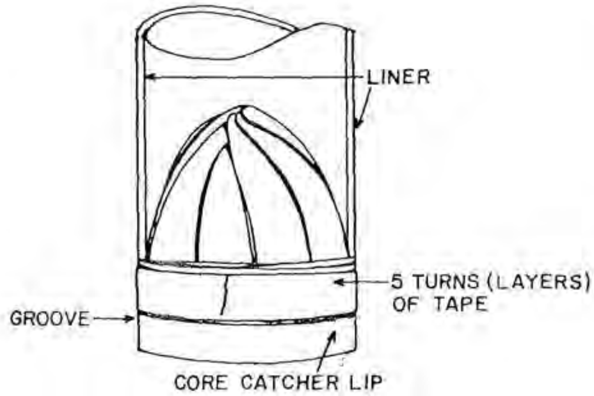


Figure L–30. Core catcher installed in liner.

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.

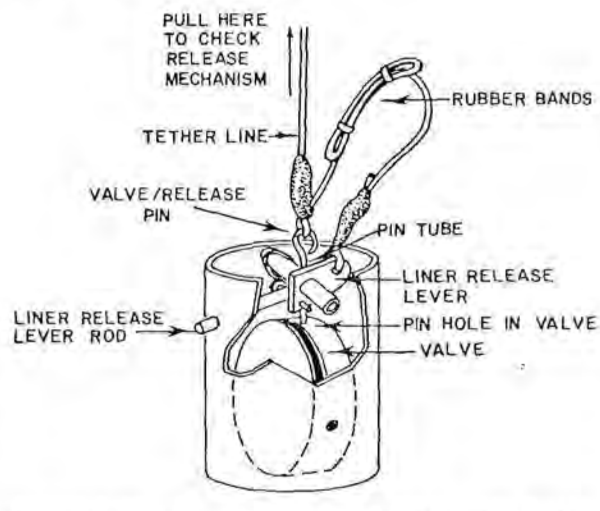


Figure L–31. Boomerang corer valve/release mechanism tube (cutaway view).

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

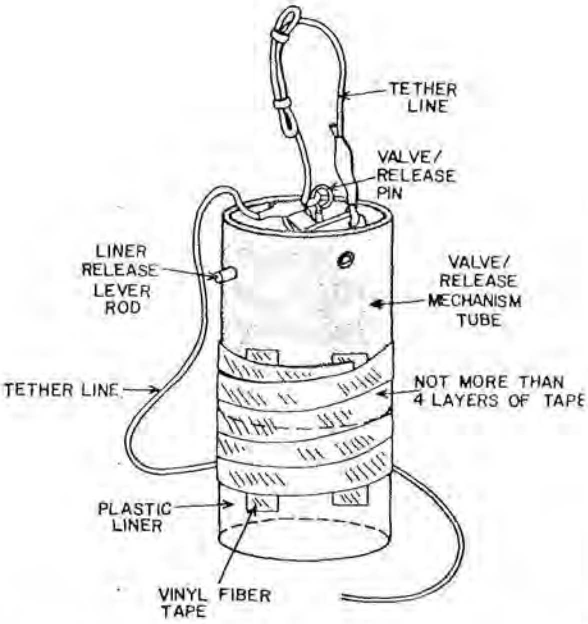


Figure L–32. Valve/release mechanism tube installed on liner.

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).

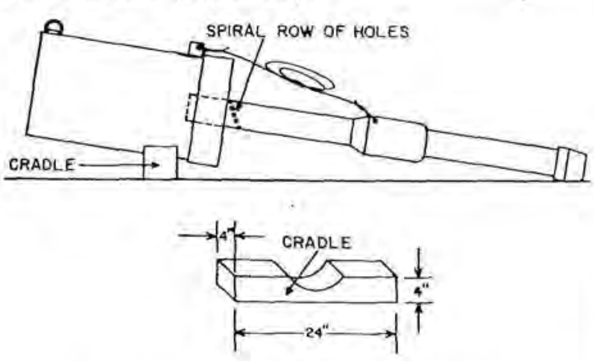


Figure L–33. Ballast component in cradle.

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

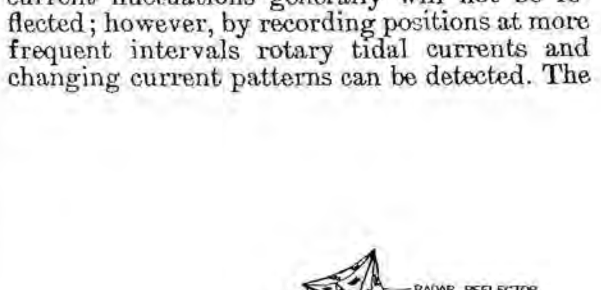


Figure M-1. Parachute drogue array.

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

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°06′	59°29′

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

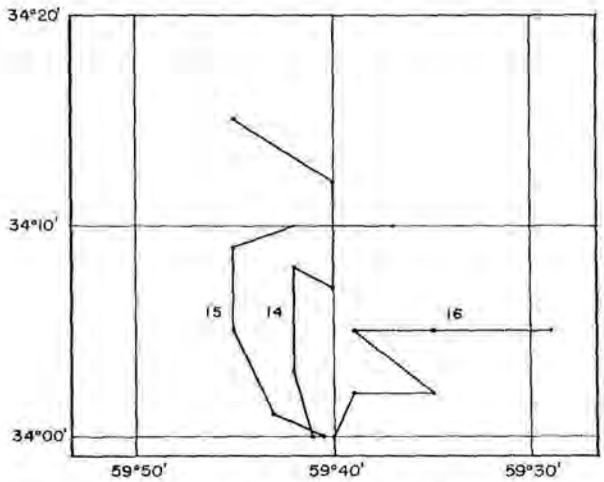


Figure M–3. Drogue plots.

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 3/32-, 5/32-, or 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

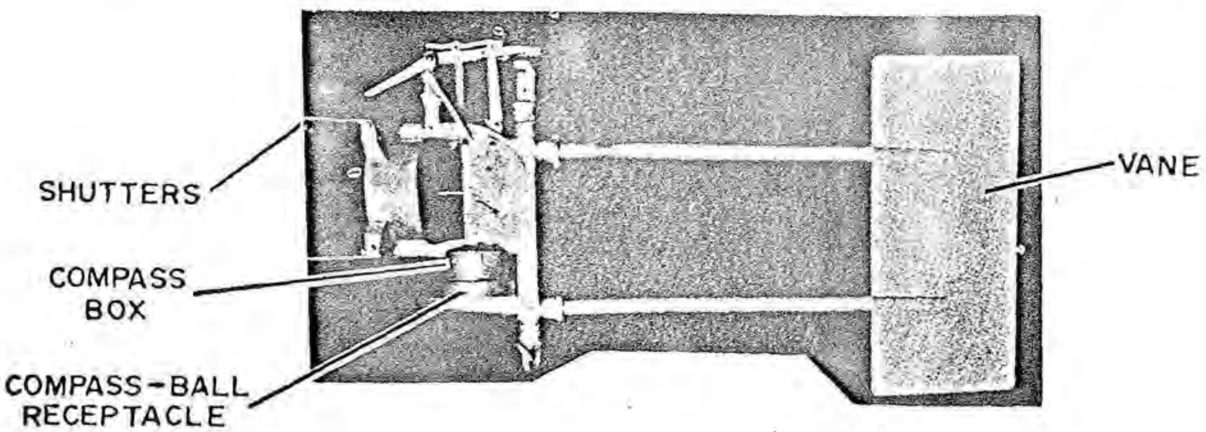


Figure M–4. Ekman current meter.

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.

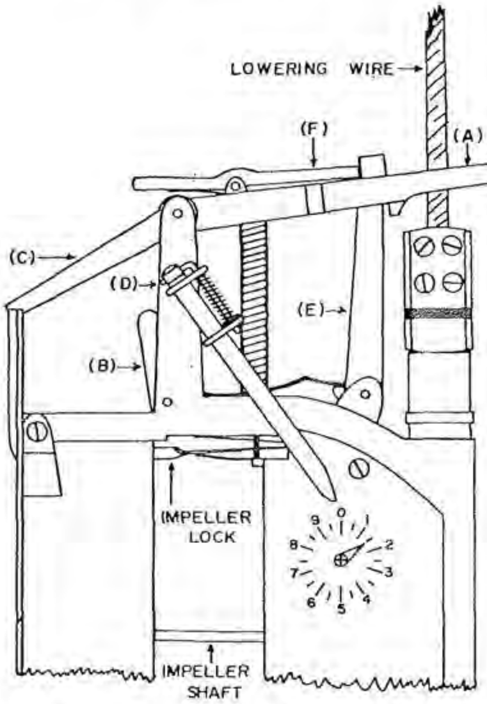


Figure M–5. Trigger mechanism Ekman current meter.

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 | Date: 11 July 1965 | Position angles at station occupied: (Radar)

General locality: PANAMA CANAL (PAC) | Water Depth: 20 meters | True bearings of reference objects:

Location of station: | Mag. Variation: 4° E | Time meridian:

Latitude: 08°50.75′ Longitude: 79°31.65′ | 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.	DIR	MAG. DIR.	TRUE DIR.	VELOCITY Knots	Tenths	WIND Dir. °True	Vel. Knots	TIDE	REMARKS	OBSERVER
1	1730	13	10min	3015	2410	605	19	3	310°	328°	324°		7	090°	5			T.McK
								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

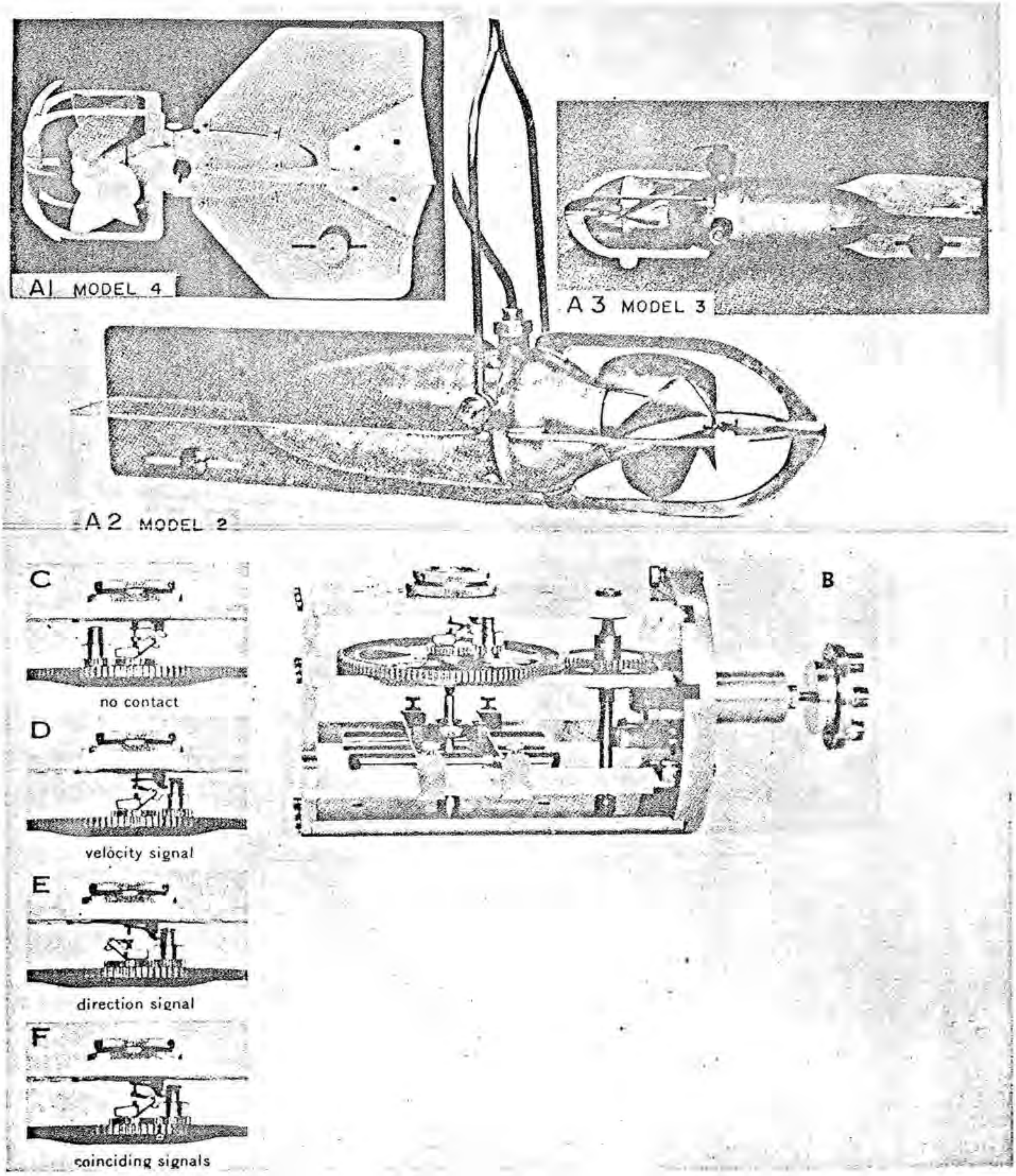


Figure M-7. Roberts radio current meters.

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

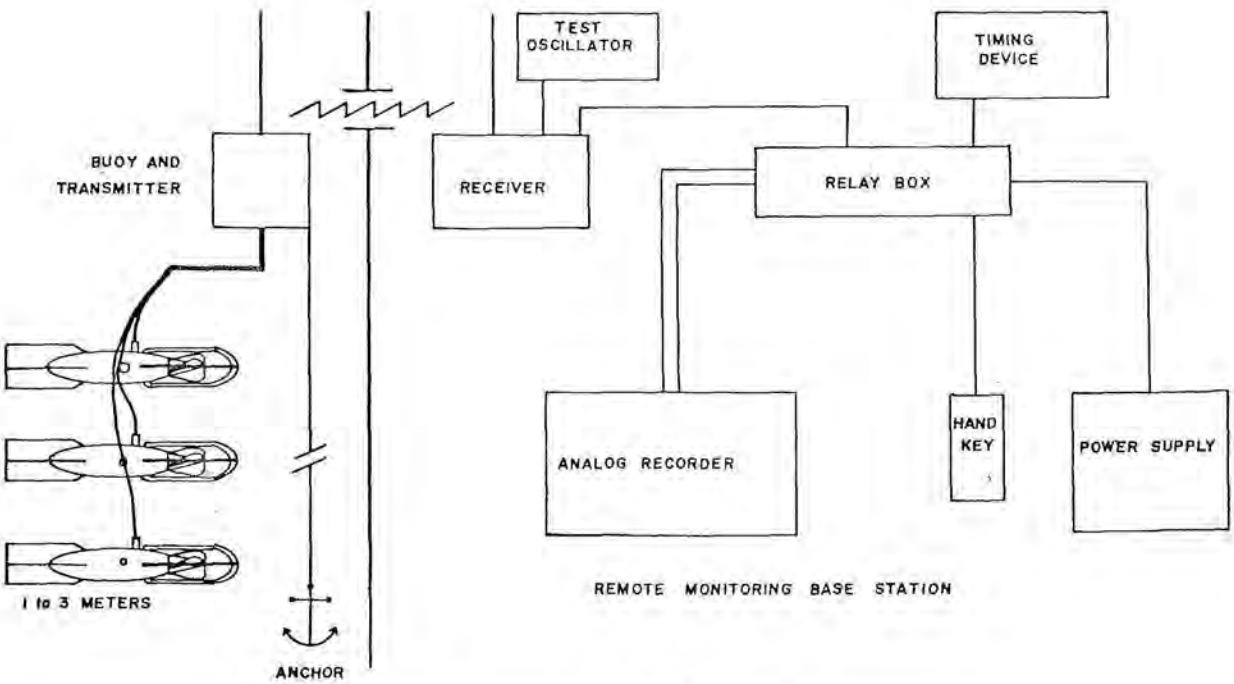


Figure M–8. Telemetering system for Roberts radio current meters.

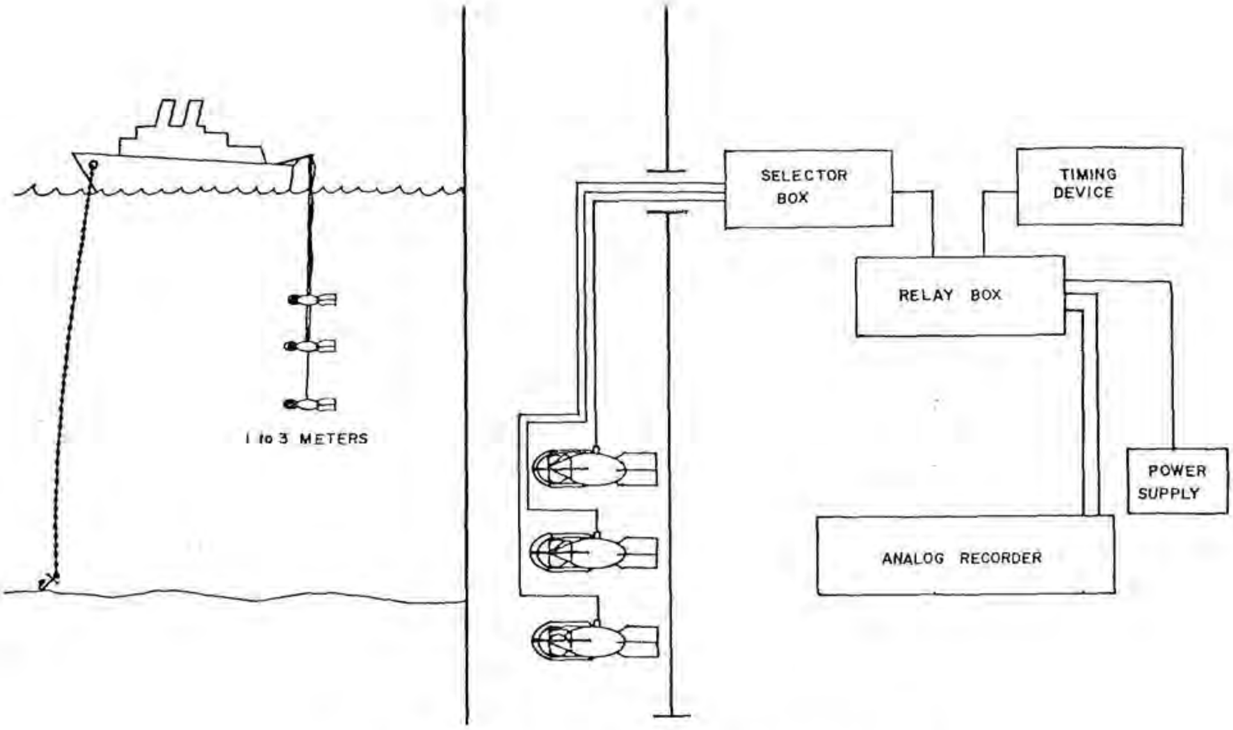


Figure M–9. Roberts current meters suspended from ship.

Current station No.: 62-55
General locality: PUERTO RICO
Location of station: Roos. Rds.
Latitude: 18°11'39" N

Date: 17 Nov. 1967
Depth:
Longitude: 65°36'42" W

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

TIME Z	Depth of Meter	Number of Revs.	Time in Seconds	Time Interval	DIR. by Meter	Number of Dir.	COMPASS VAR.	DIR. OF CURRENT	VELOCITY by Meter		WIND Dir.	WIND Vel.	Tide	REMARKS	OBSERVERS
h. m.	ft.					Signals		True	Knots	Tenths	True	Knots			
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.

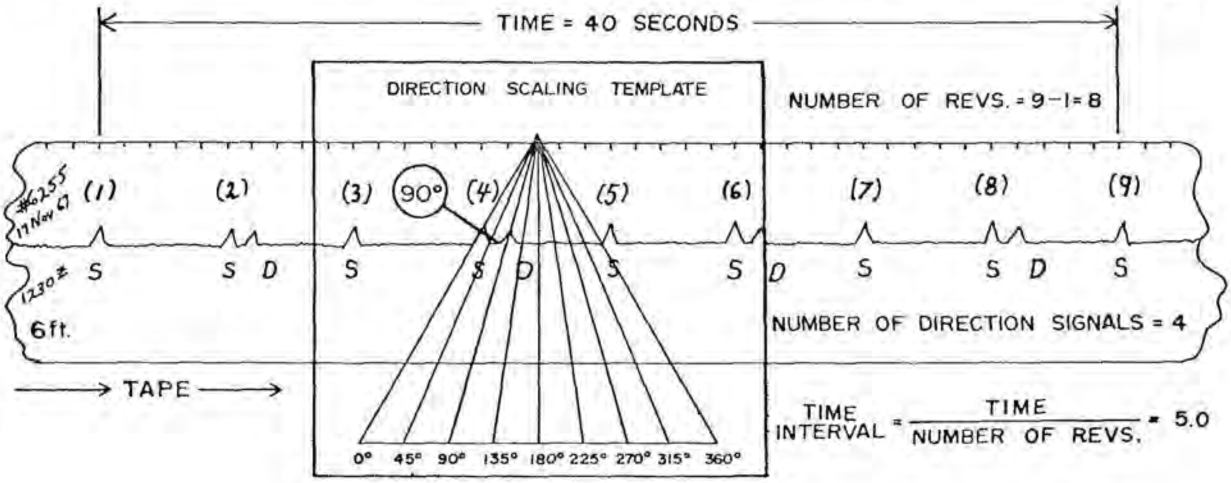
Step 5. Speed in knots is determined from the "Calibration Data for Meters" tables using the time interval. Enter in *Velocity by Meter* column.

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-

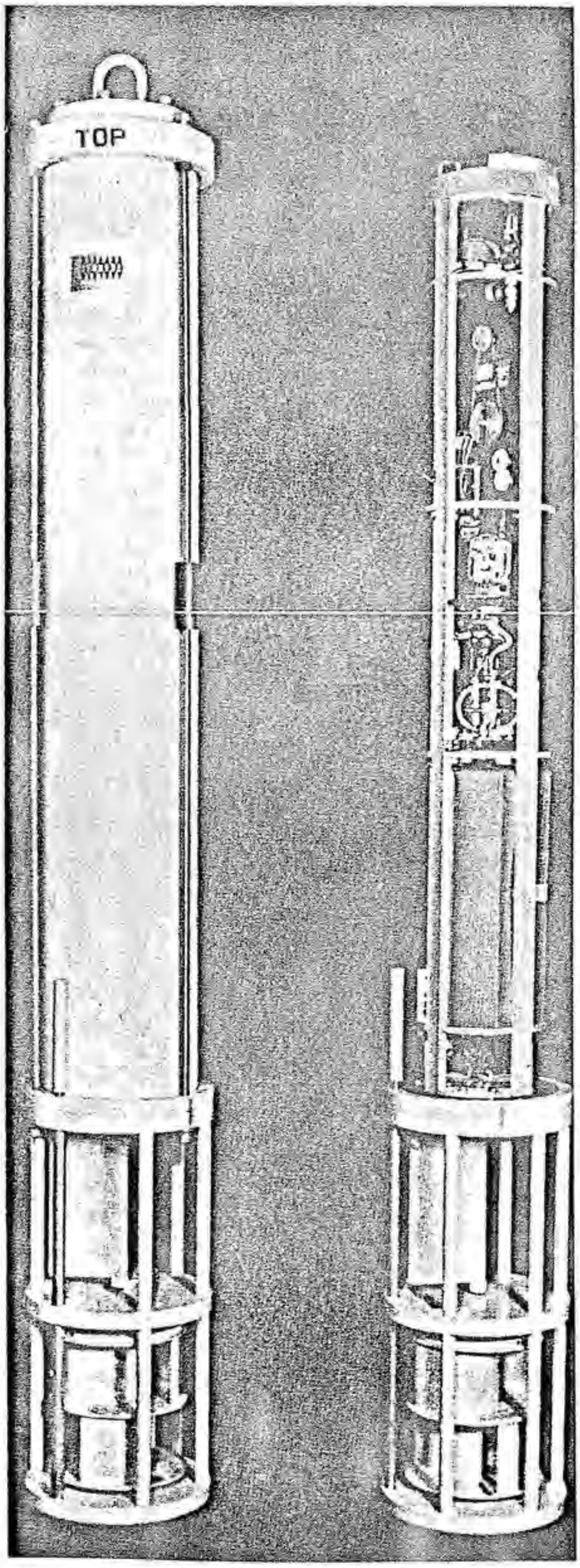


Figure M–12. Geodyne model A–101 current meter.

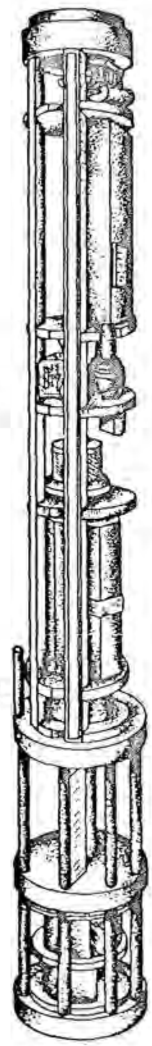


Figure M-13. Main components of the Geodyne current meter.

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

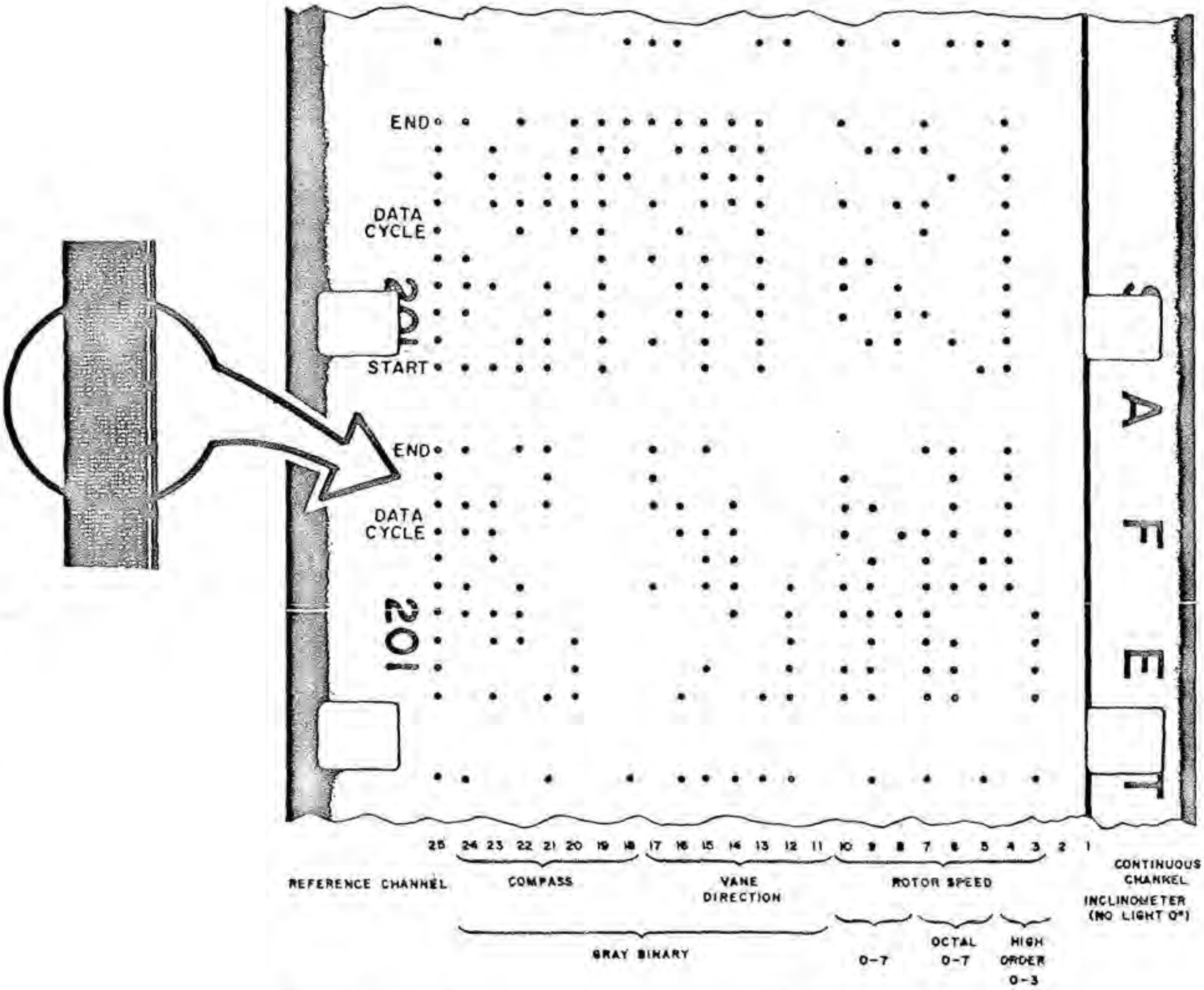


Figure M–15. Geodyne current meter model A–101 film record.

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),

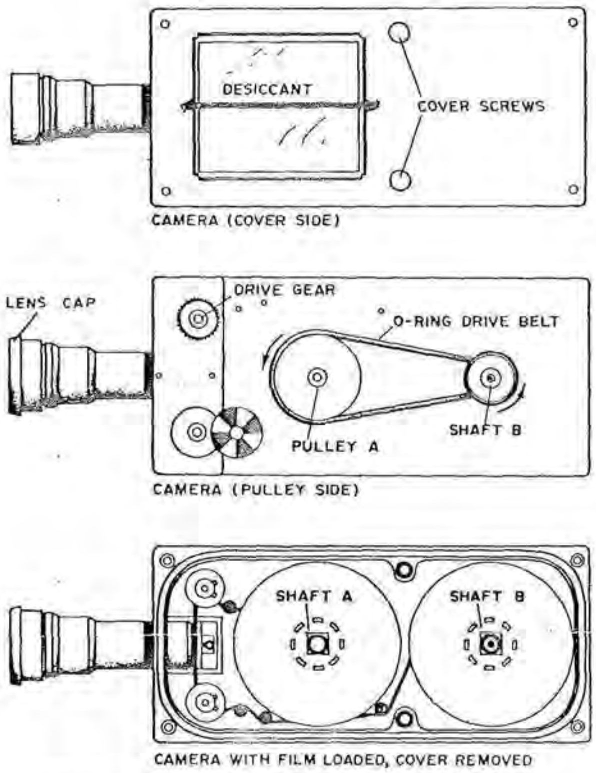


Figure M-16. Geodyne current meter camera model A-101.

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 ($\frac{9}{16}$-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

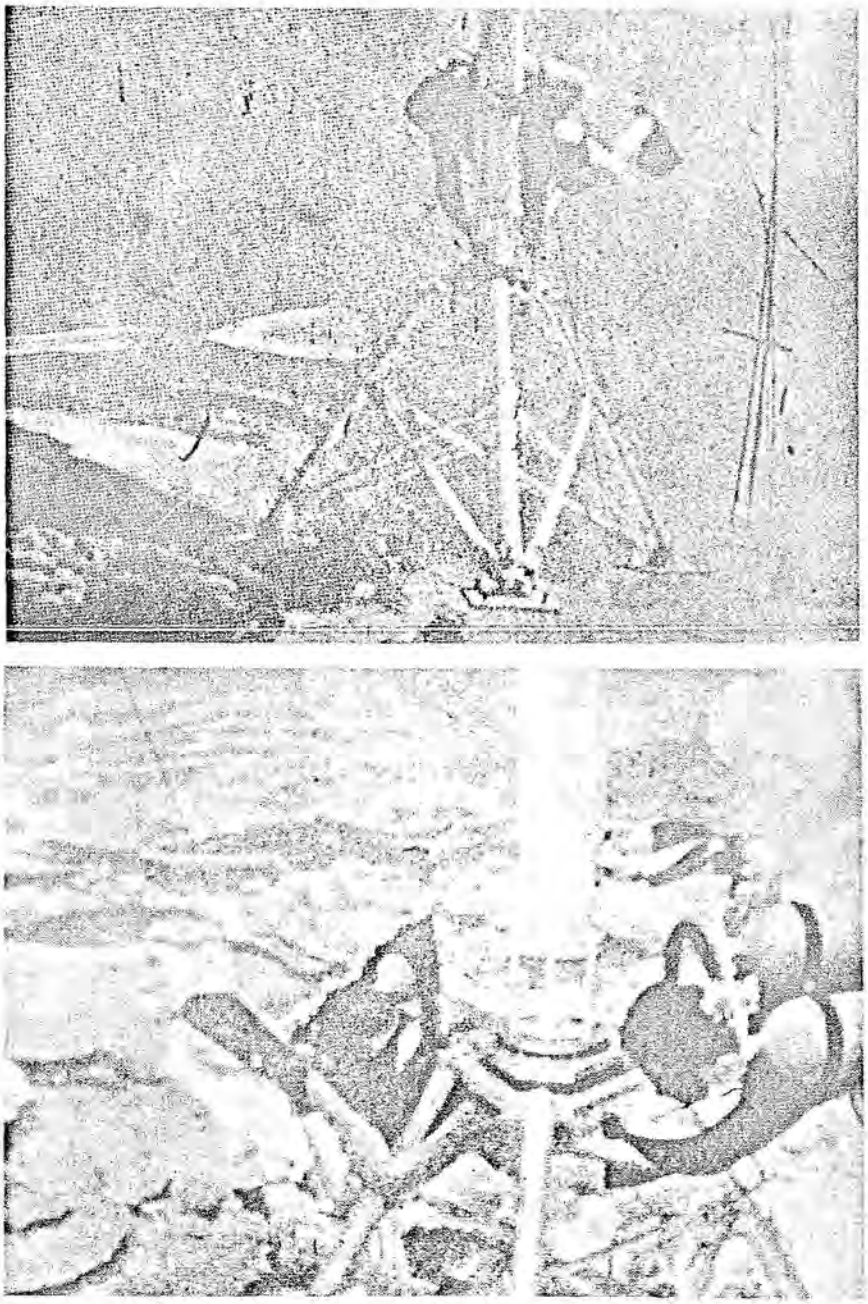


Figure M–17. Divers planting Geodyne current meter on tripod.

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

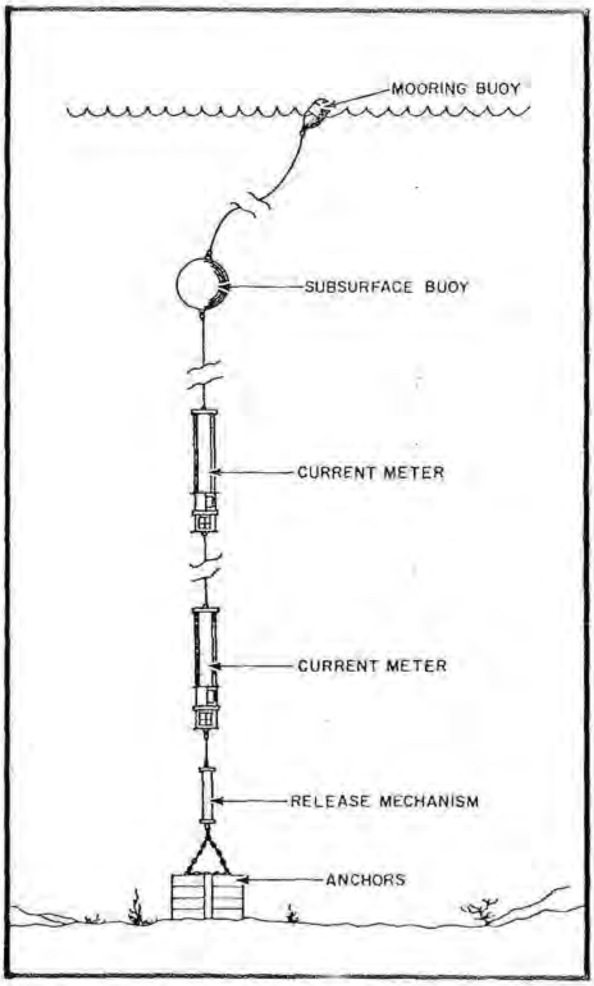


Figure M–18. Geodyne current meter array.

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.

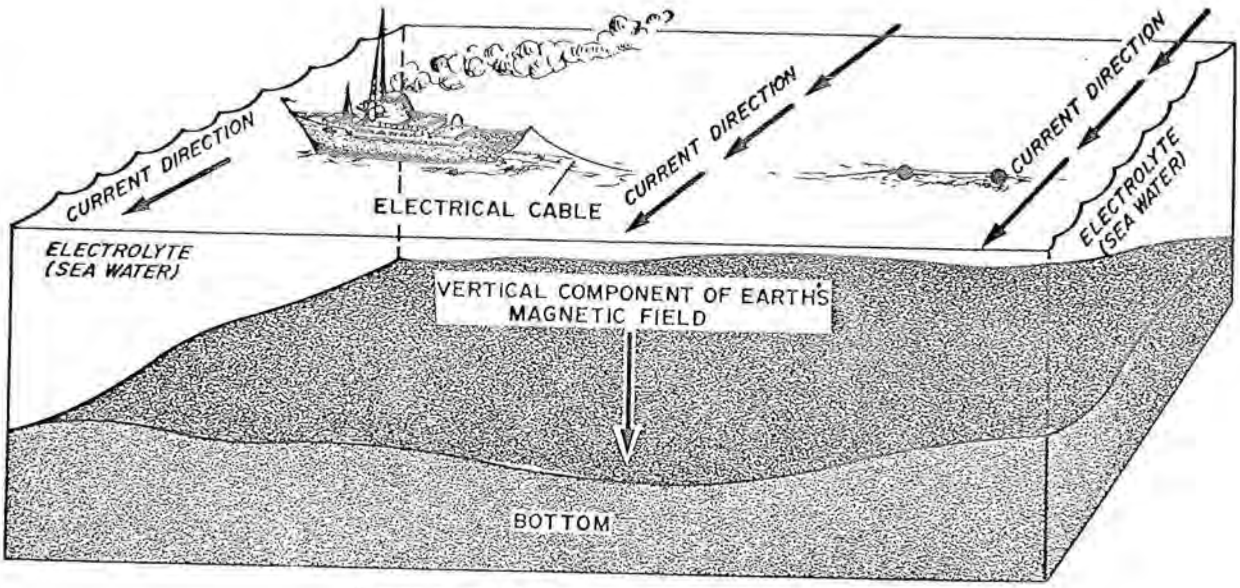


Figure M-20. Measuring currents with the GEK.

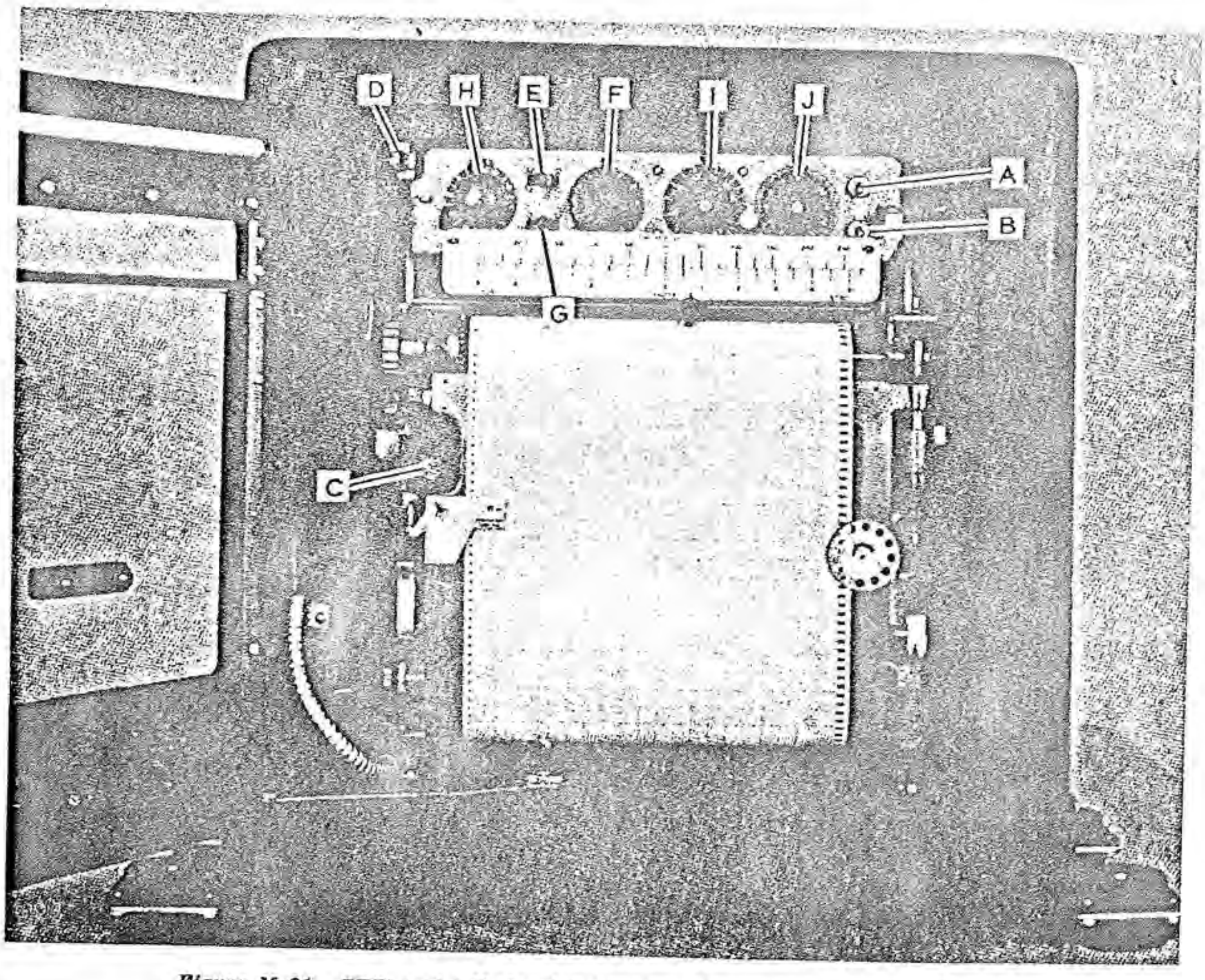


Figure M-21. GEK model V showing location of operating switches and dials.

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.

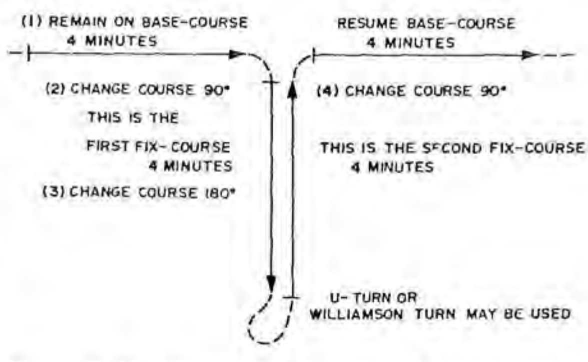


Figure M–22. Directions for executing a GEK current fix.

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
PRC-HO 3167/7 (Rev. 5-58)

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 ELECTROKINETOGRAPH 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)	LONGITUDE (E or W)	SHIP'S AVERAGE SPEED (Knots, ft./sec.)	DEPTH OF WATER (f.(m.))	VERTICAL MAGNETIC INTENSITY (Milliversteds): STAND. I	LOCAL II	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
1	13 Aug. 65	0354	39°06'N	71°15'W	13.5	1480	0.5	0.520	138	-5	228	-75	048	-30
2	13 Aug. 65	1647	37°22'N	70°27'W	13.5	2550	0.5	0.510	030	30	120	-122	300	60
3	14 Aug. 65	0245	36°59'N	70°15'W	13.5	2590	0.5	0.510	050	-15	140	-153	320	145
4	14 Aug. 65	1246	35°33'N	70°11'W	13.5	2500	0.5	0.510	180	45	270	53	090	41
5	15 Aug. 65	0046	36°11'N	70°06'W	13.5	2350	0.5	0.510	015	75	105	-63	285	85
6	26 Aug. 65	1044	44°27'N	30°16'W	13.5	2450	0.5	0.510	090	-20	180	-85	000	122
7	26 Aug. 65	1345	44°27'N	30°25'W	13.5	2550	0.5	0.490	010	25	100	38	280	-70
8	27 Aug. 65	1420	43°58'N	29°42'W	12.0	1350	0.5	0.480	034	-147	124	-157	304	-749

GEK SERIAL NO.	RESUMED BASE-COURSE: DIR. (°T) IX	SIG. (cm./sec.) X	ZERO POINT (cm./sec.) XI	AVERAGE BASE-COURSE SIGNAL: MAG. (cm./sec.) XII	DIR. (°T) XIII	AVERAGE FIX-COURSE SIGNAL: MAG. (cm./sec.) XIV	DIR. (°T) XV	RESULTANT SIGNAL VECTOR: MAG. (cm./sec.) XVI	DIR. (°T) XVII	CORRECTION TO STANDARD ISODYNAMIC LINE (Multiplier) XVIII	CURRENT VELOCITY: SPEED (cm./sec.) XIX	SPEED (Knots) XX	DIR. (°T) XXI
1	138	-1	-62.5	+59.5	138	12	048	60	126	1.00	60	1.17	216
2	030	32	-31.0	62.0	030	91	300	111	334	1.02	113	2.20	064
3	050	-15	-7.0	11.0	230	149	320	149	316	1.02	152	2.95	046
4	180	51	47.0	01.0	000	4	270	4	282	1.02	4	0.08	012
5	015	40	10.0	47.0	015	75	285	90	318	1.02	92	1.79	048
6	090	-25	18.5	41.0	270	104	000	112	339	1.02	114	2.21	069
7	010	17	14.0	07.0	010	24	100	25	031	1.06	26	0.51	171
8	034	-149	-153.0	05.0	034	4	304	6	355	1.08	6	0.12	085

EQUATIONS

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

GEK MEASURES SURFACE CURRENT MINUS AVERAGE CURRENT TO BOTTOM

REMARKS

Figure M-23. Oceanographic log sheet—GEK.

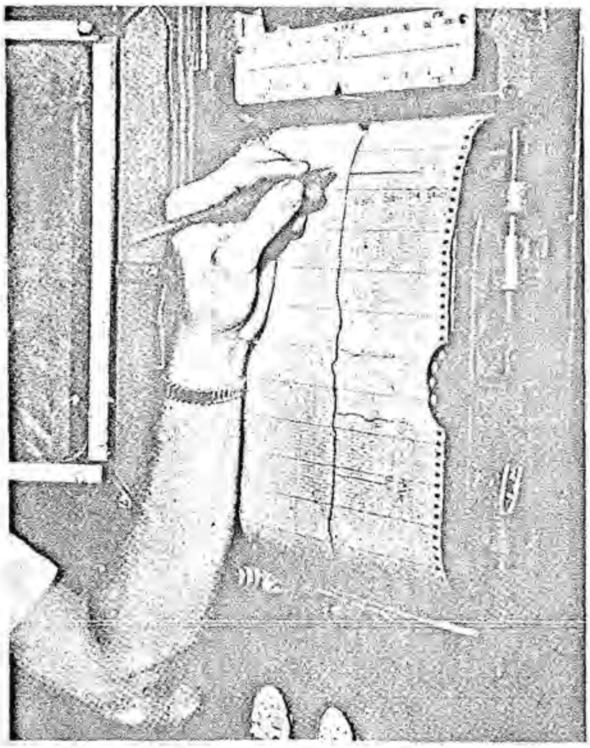


Figure M–24. Annotating the GEK record.

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° \text{ T}}{228° \text{ T}}$0358Z (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 ⅛ 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.

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.

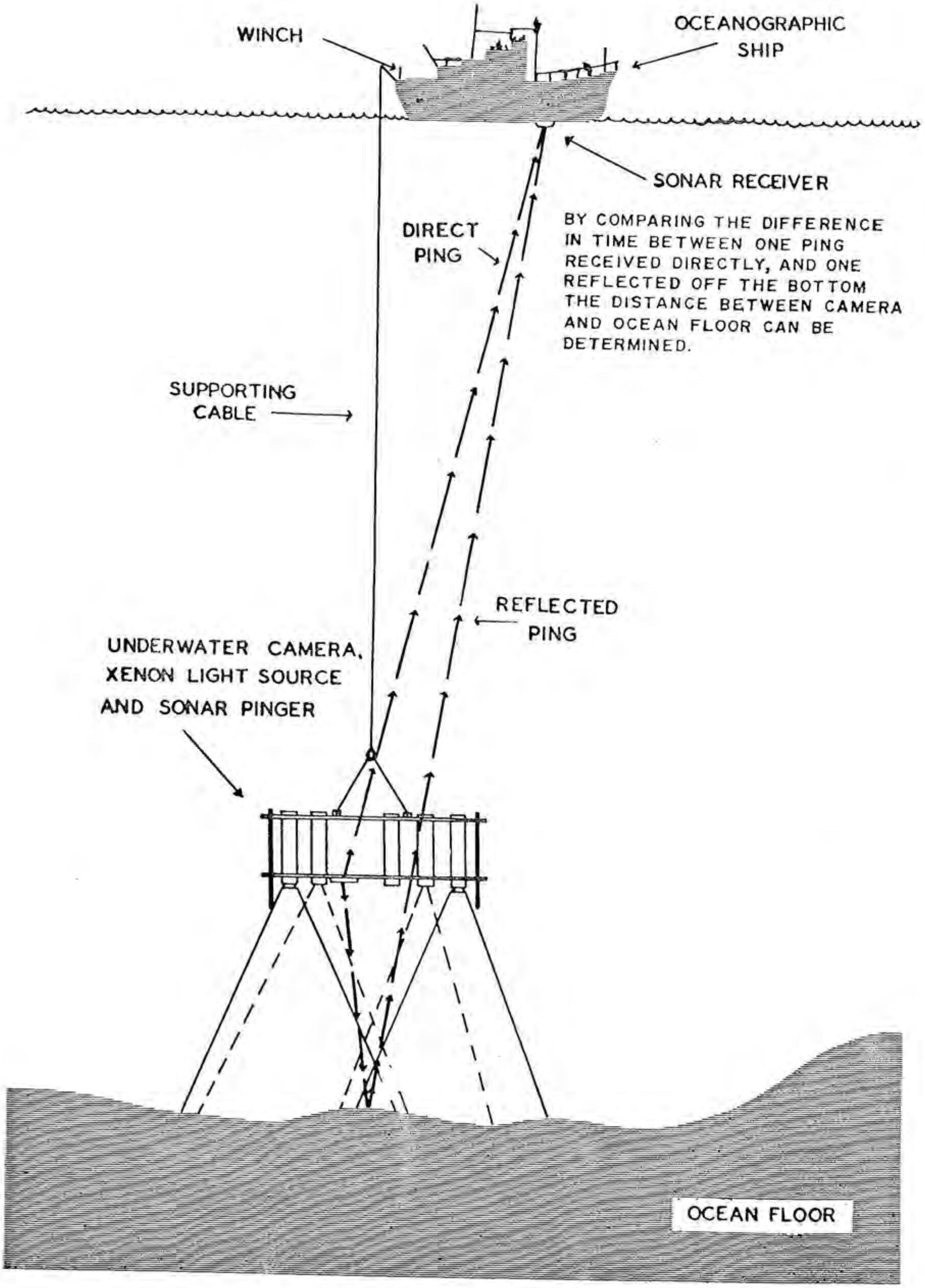


Figure N–1. Deep sea underwater camera system.

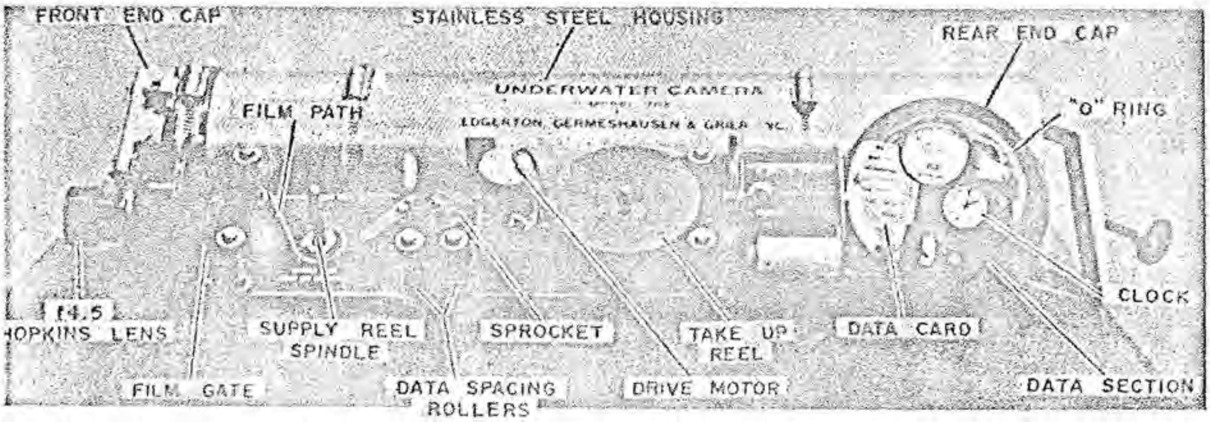


Figure N–2. Underwater camera (EG & G Model 204).

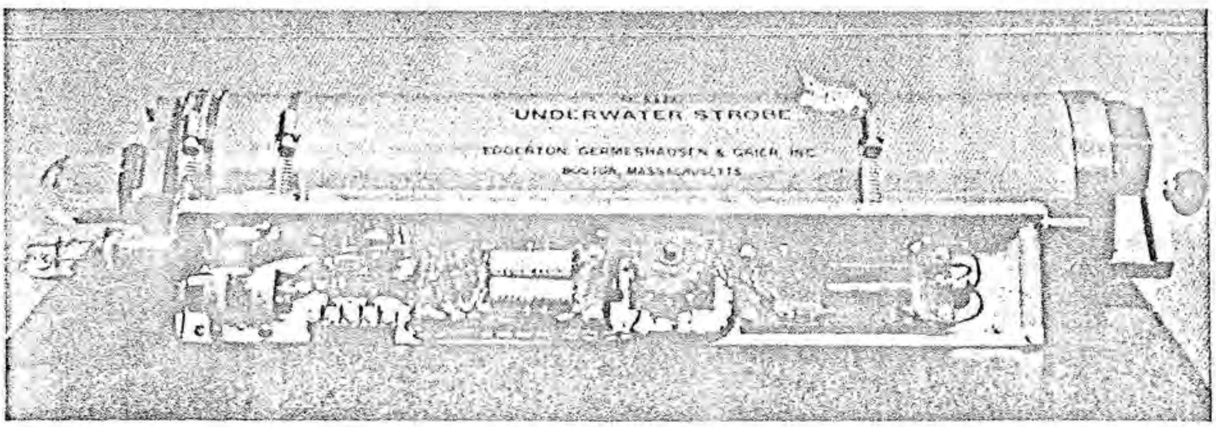


Figure N–3. Underwater light source (EG & G Model 214).

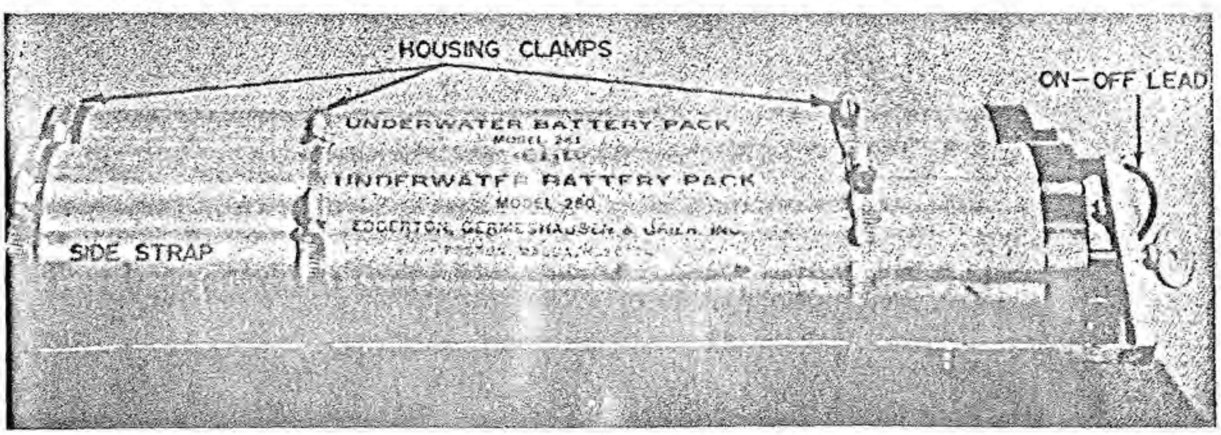


Figure N–4. Underwater battery packs (Model 280 contains time delay unit and Model 281 contains 15-second cycling device).

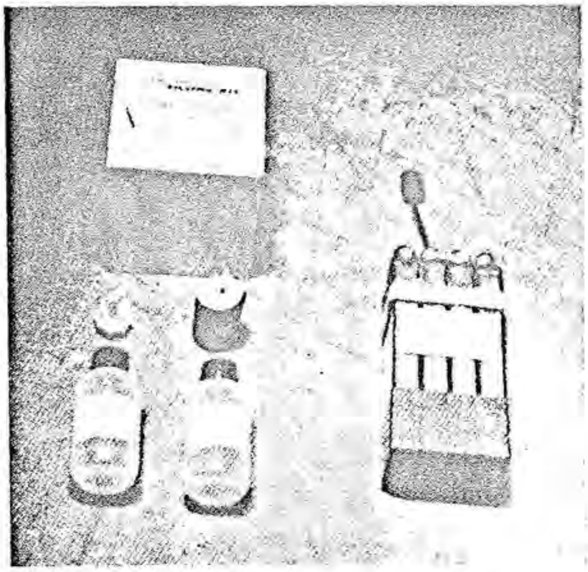


Figure N–5. Silver zinc wet cell battery and filling kit.

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.

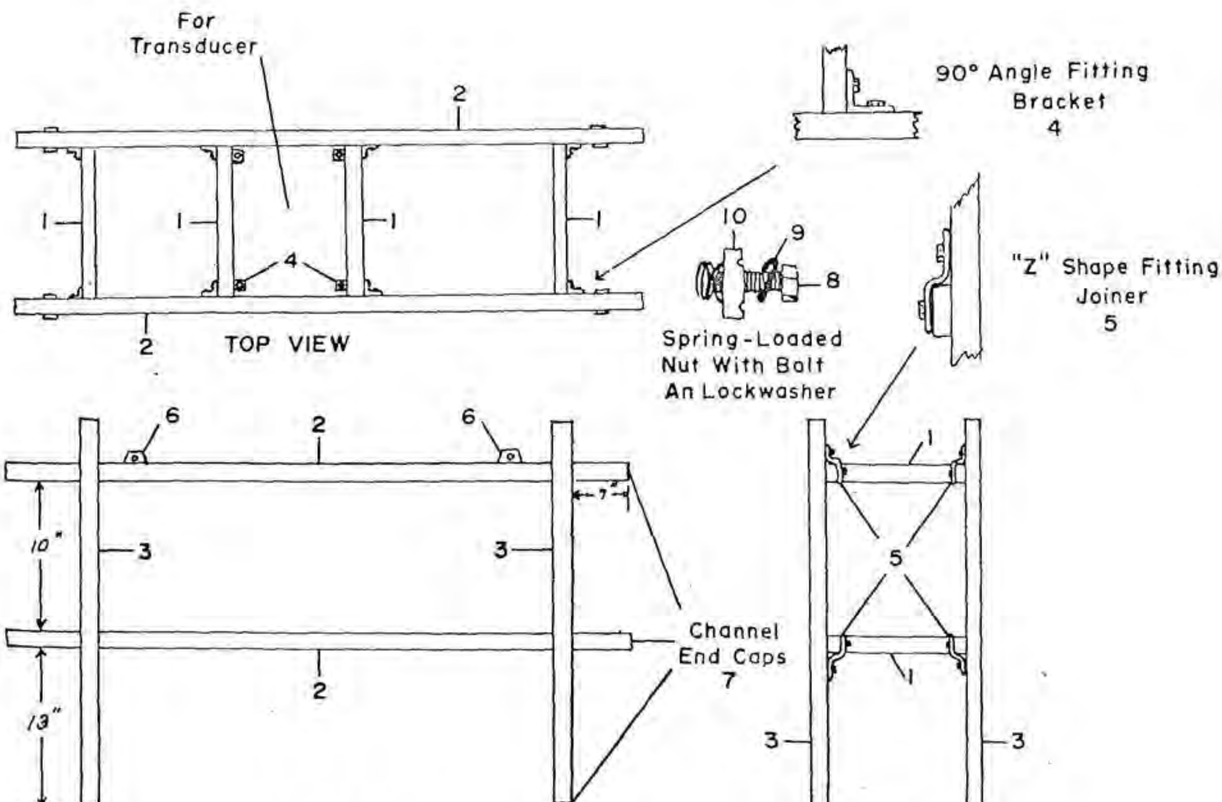


Figure N–6. Top, side, and end view of mounting rack.

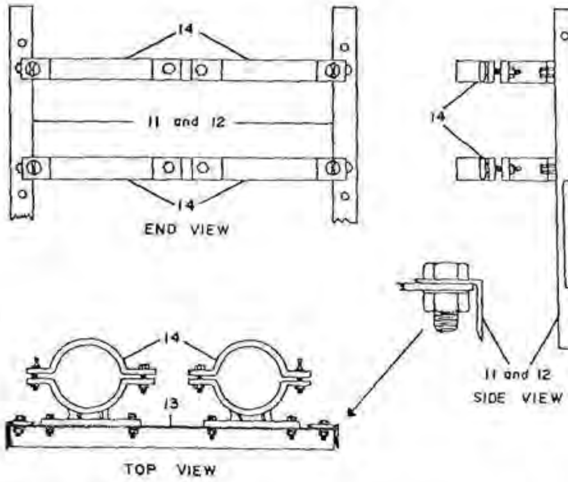


Figure N–7. Top, side, and end view of instrument holder assembly.

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.

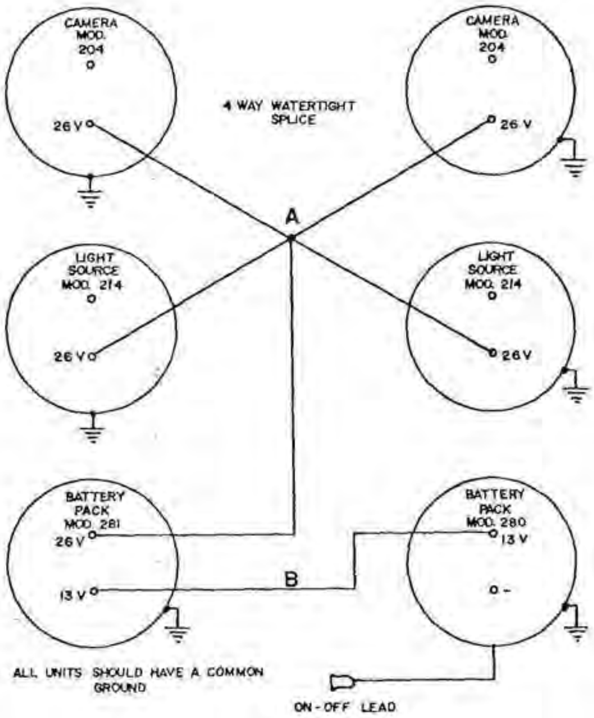


Figure N–8. Wiring diagram for cameras, light sources, and battery packs.

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

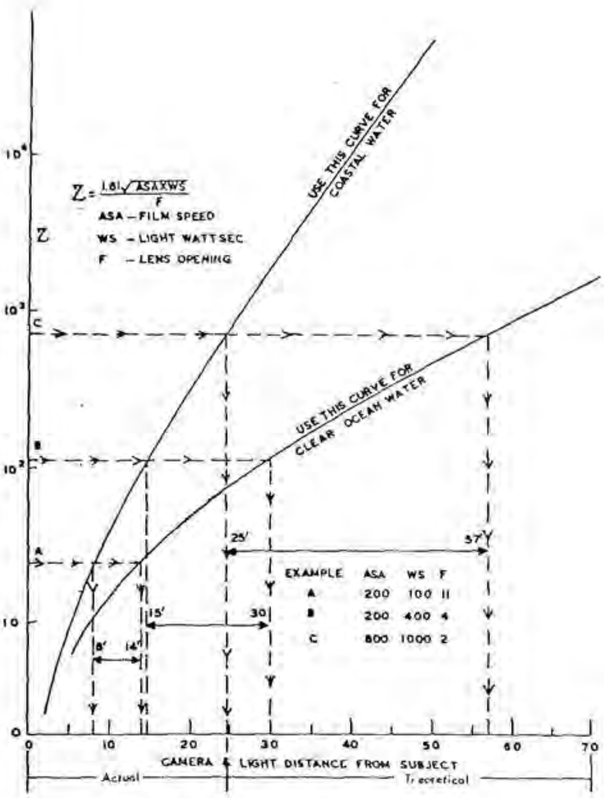


Figure N-9. Film selection graph.

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.

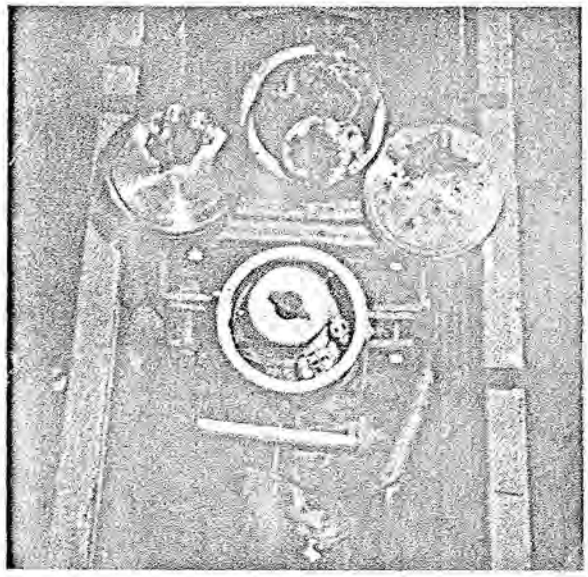


Figure N-10. The unit at the top of the photograph was imploded at depth because of a faulty seal. Note the total destruction of internal components.

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.

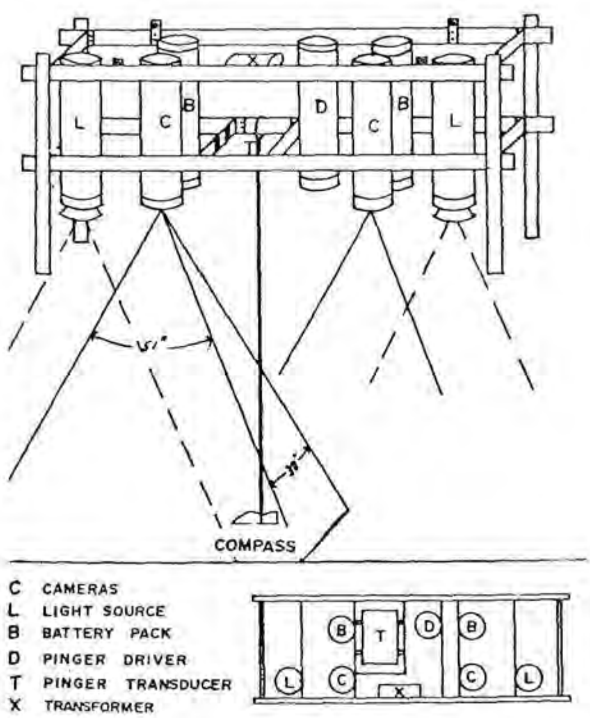


Figure N-11. Relationship of components for a standard stereo mounting arrangement.

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).

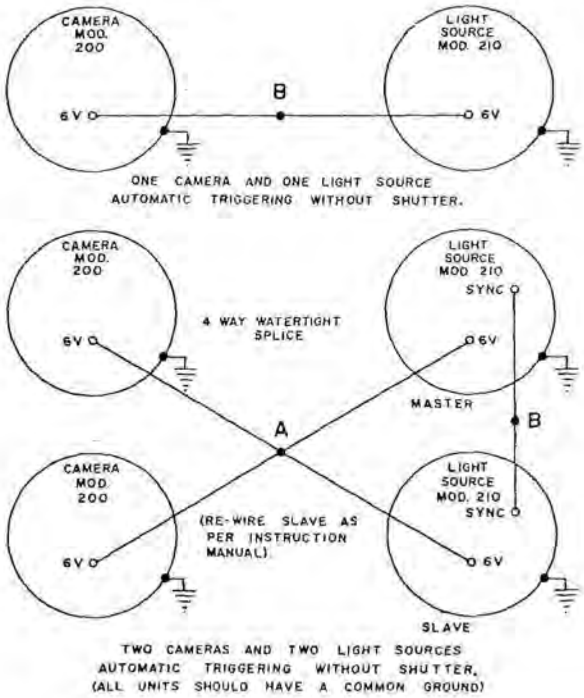


Figure N–12. External wiring diagrams for Model 200 camera and Model 210 light source.

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.

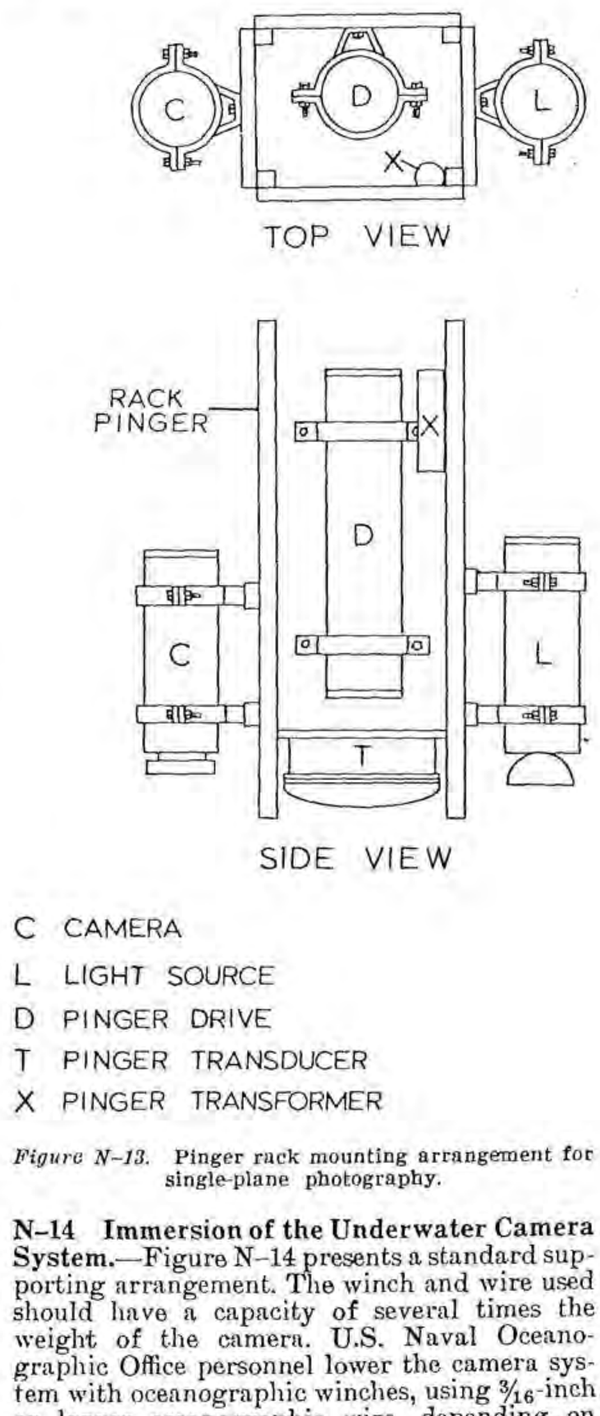


Figure N–13. Pinger rack mounting arrangement for single-plane photography.

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

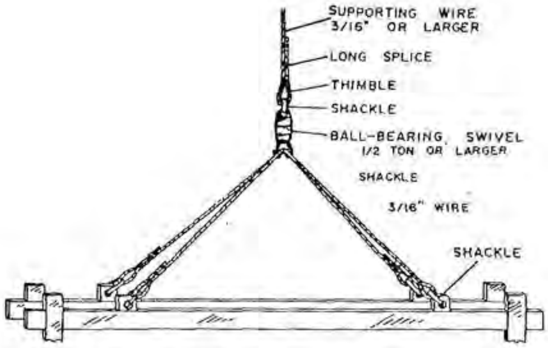


Figure N-14. Standard supporting arrangement.

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 camera reaches bottom — TIME IN WATER 0935; 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.

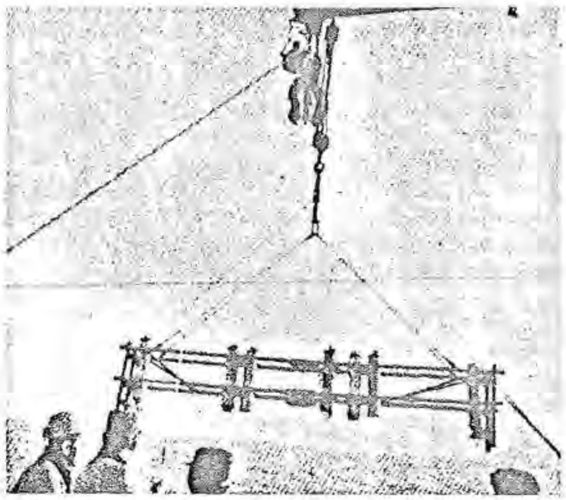


Figure N-16. Hoisting underwater camera system over the side.

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.

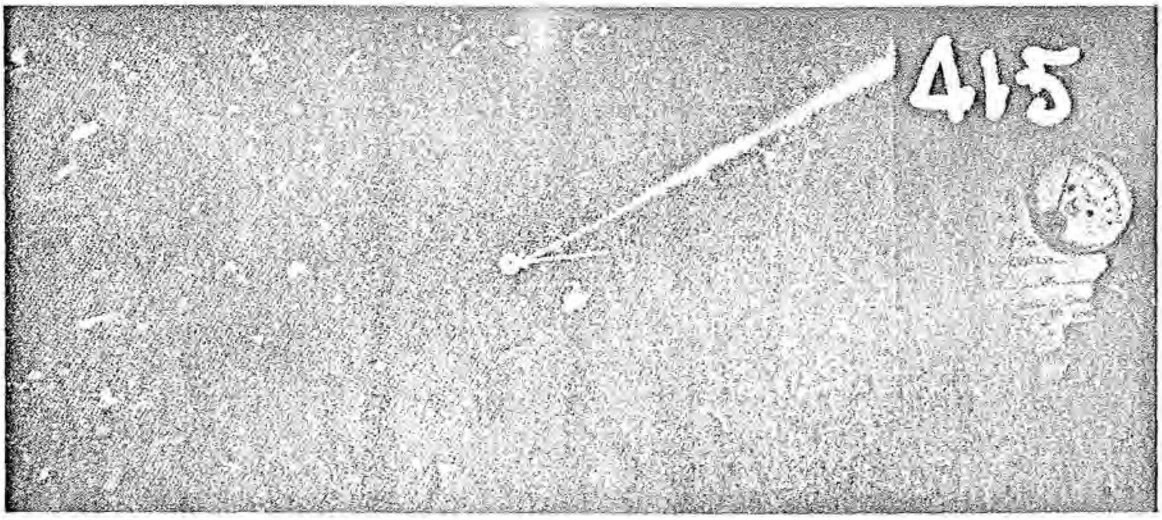


Figure N–17. Underwater photographs. Note compass.

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

TYPE OF PRESERVATIVE 4% FORMALIN

CONSEC. STA.NO.	ASSGN. STA. NO.	SAMPLE NO.	DATE 19 65	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.

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.

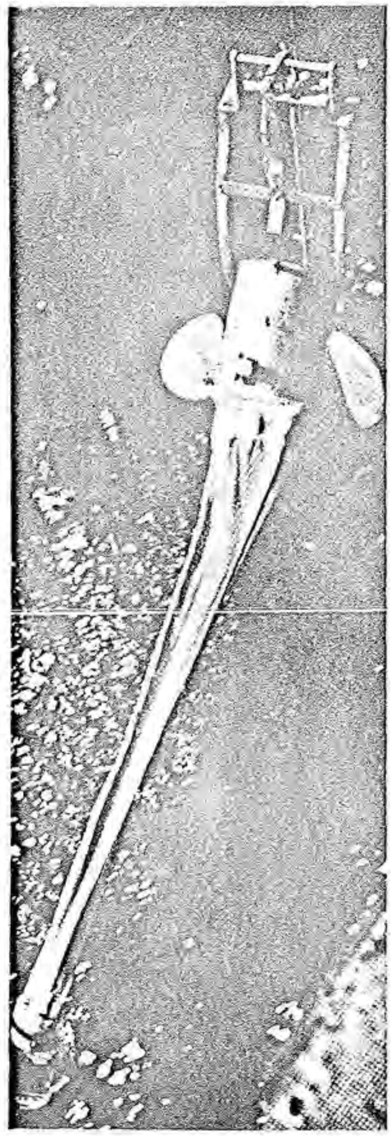


Figure O-3. Clarke-Bumpus quantitative plankton sampler.

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

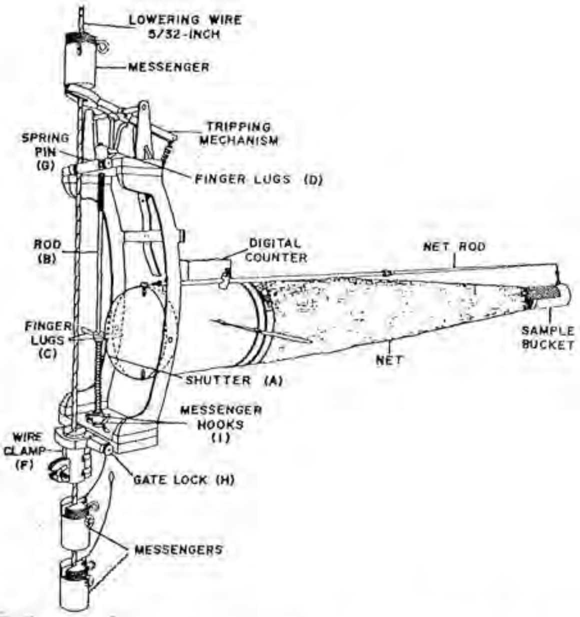


Figure O–4. Side view of Clarke-Bumpus plankton sampler.

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.

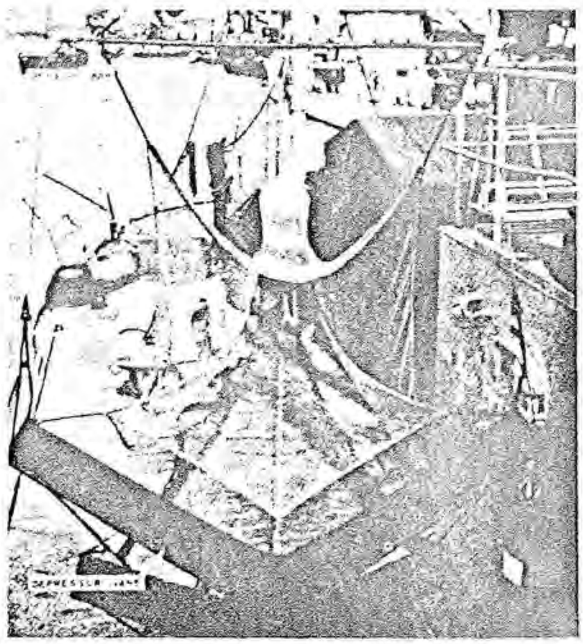


Figure O–5. The midwater trawl.

The midwater trawl is essentially an asymmetrical cone of $2\frac{1}{2}$-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 $\frac{1}{2}$-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

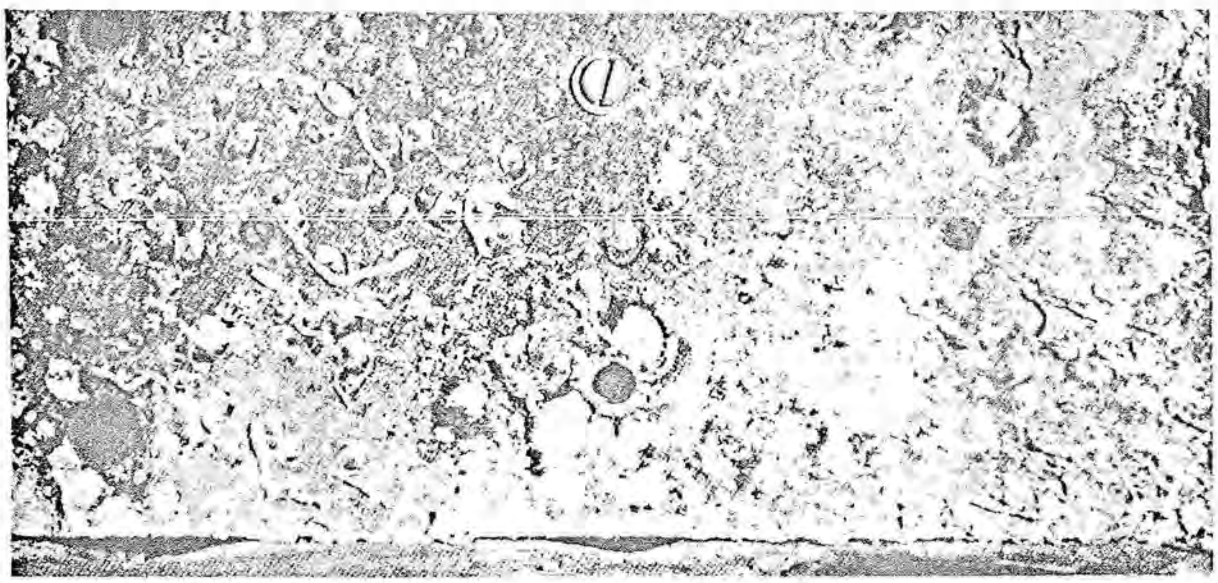
NAVOCEANO-3167/82 (8-66)

Figure O–7. Biological sample labels.

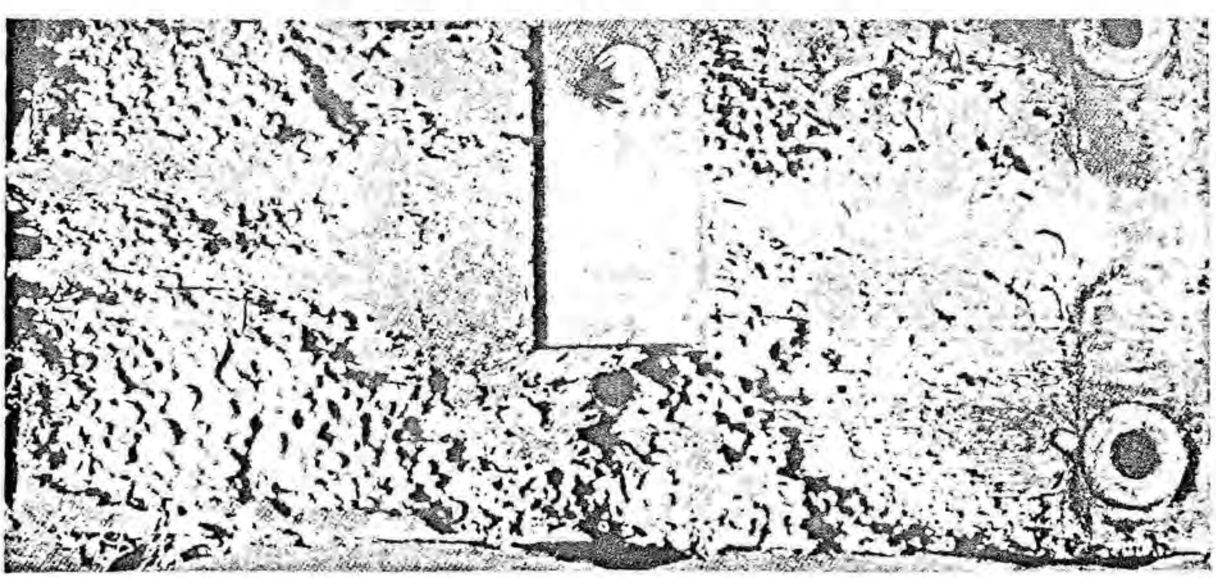
O–19 Marine Fouling Observations.—Marine Fouling observations are conducted by the U.S. Naval Oceanographic Office to determine the composition and intensity of marine biological fouling communities in the coastal waters of the world. These observations usually are taken over a 12-month period. Since 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.

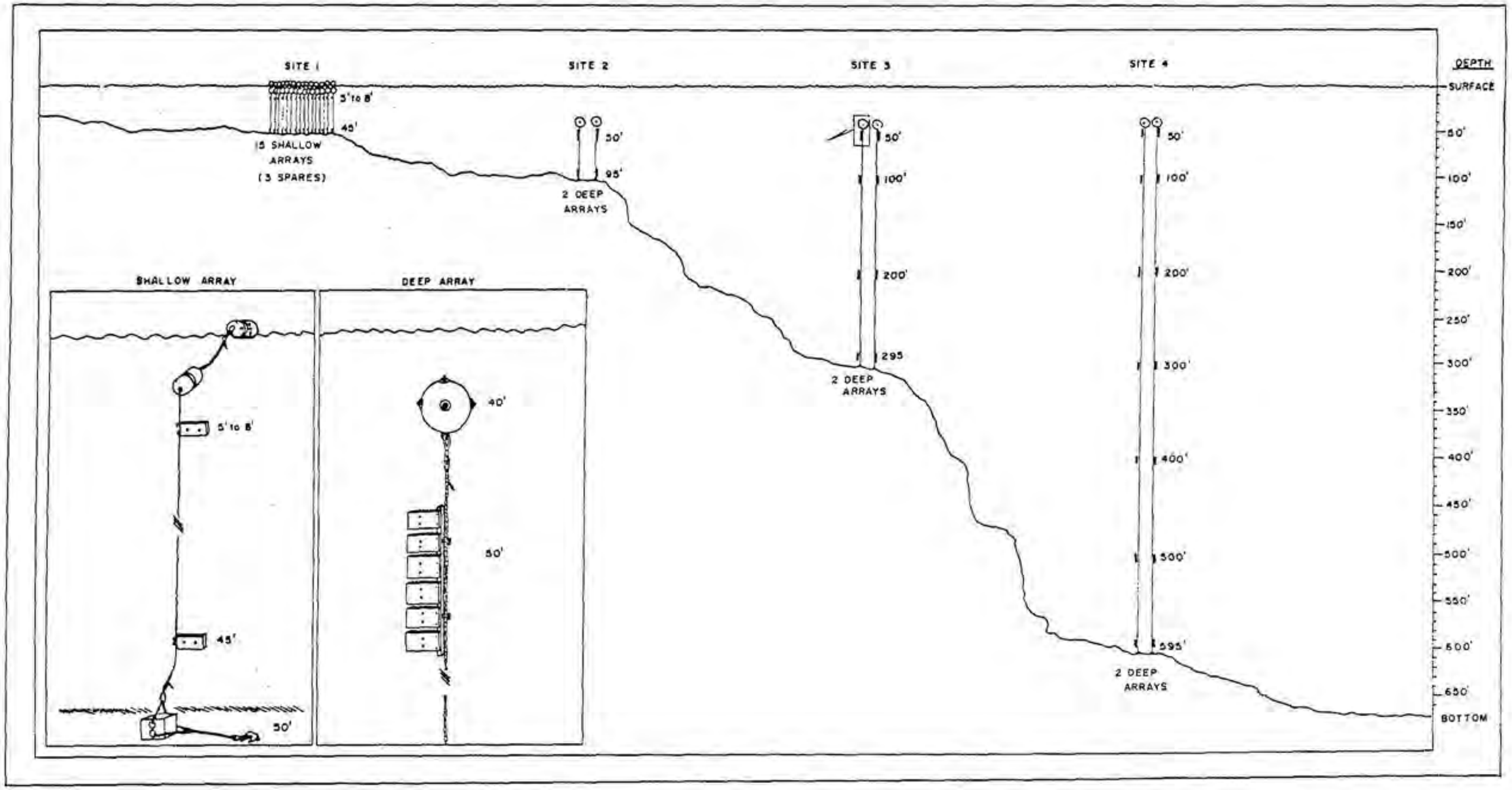


Figure 0-9. **Diagram showing site depths, standard intervals, and deep and shallow arrays at a geographic area.**

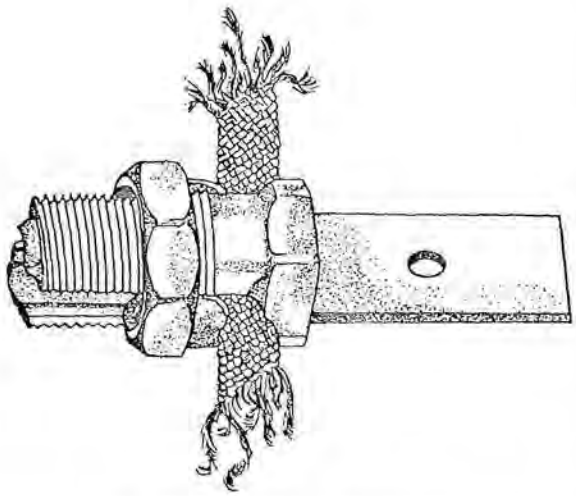


Figure O-10. Modified split bolt connectors (S-1/0) for attaching panels to line.

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.

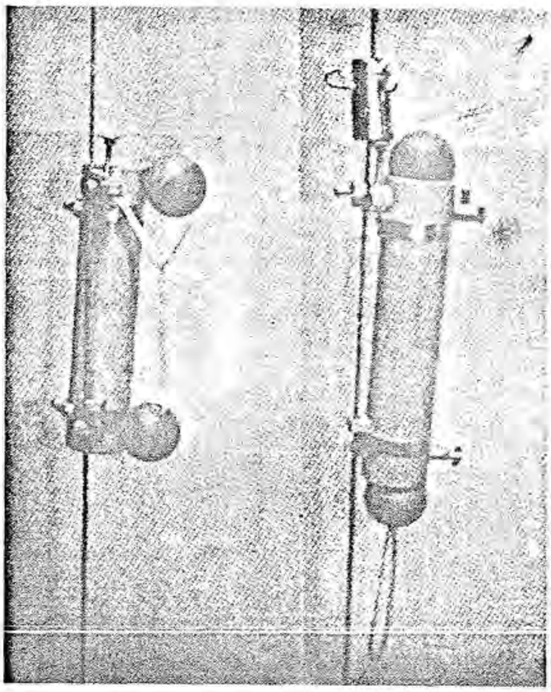


Figure O–12. Frautschy water sampling bottle before and after tripping.

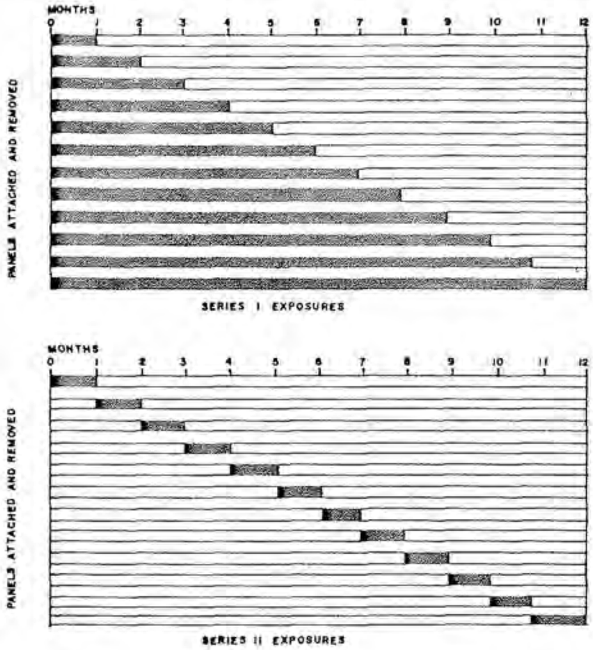


Figure O–13. Test panel exposure systems.

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 O–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.

VSS 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	

	Comparative Size	length	wing spread	
	warbler	5"	7"	
	bluebird	7"	11"	
X	pigeon	12"	2'	X
	crow	19"	3'	

Comparative Size	length	wing spread
large gull	26"	5'
eagle	33"	6.5'
albatross	45"	11'

Direction of flight

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).

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

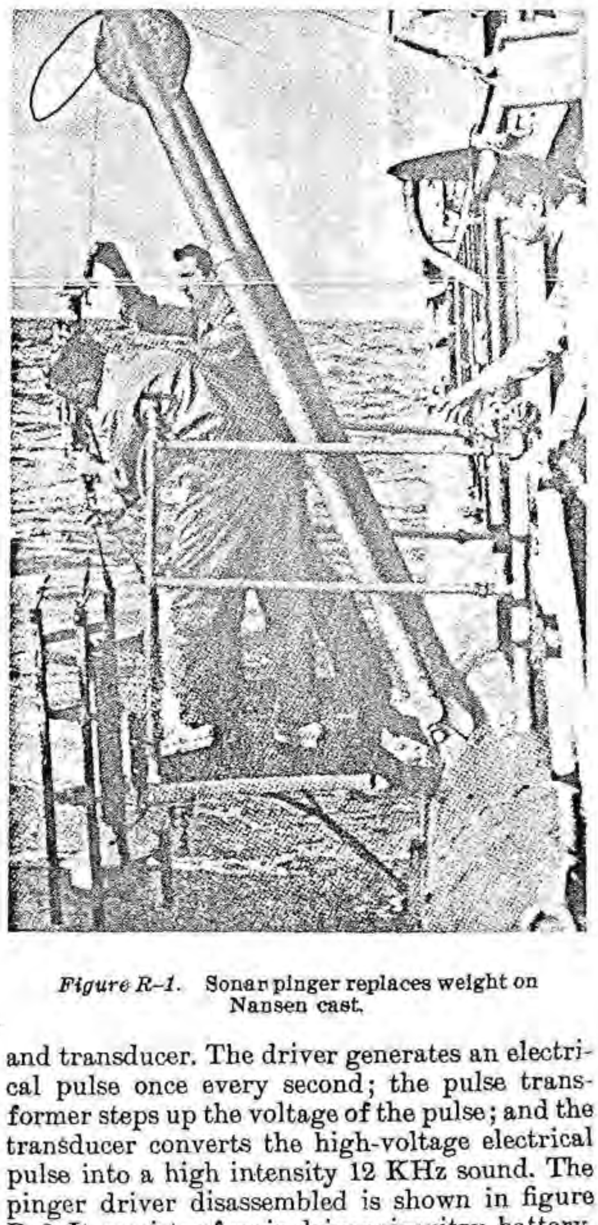


Figure R-1. Sonar pinger replaces weight on Nansen cast.

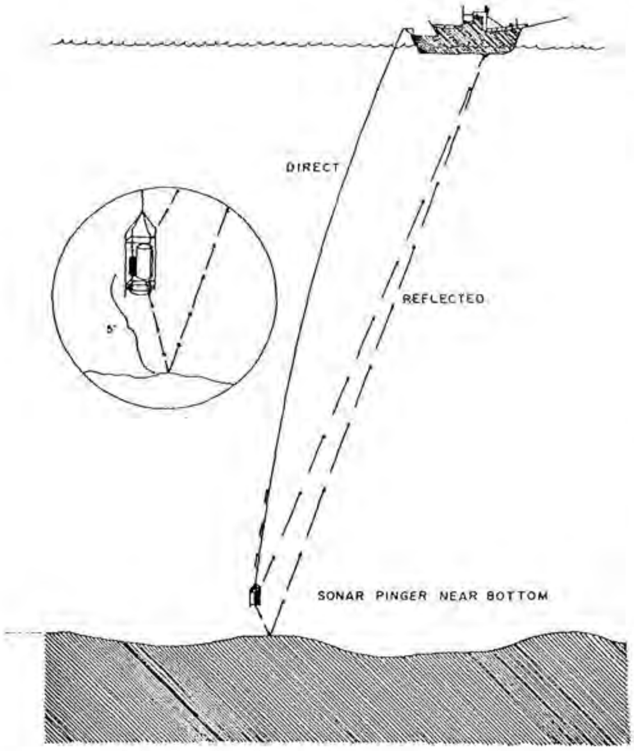


Figure R-2.—Sonar pinger bottom positioning technique for Nansen cast bottom temperature measurements.

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.

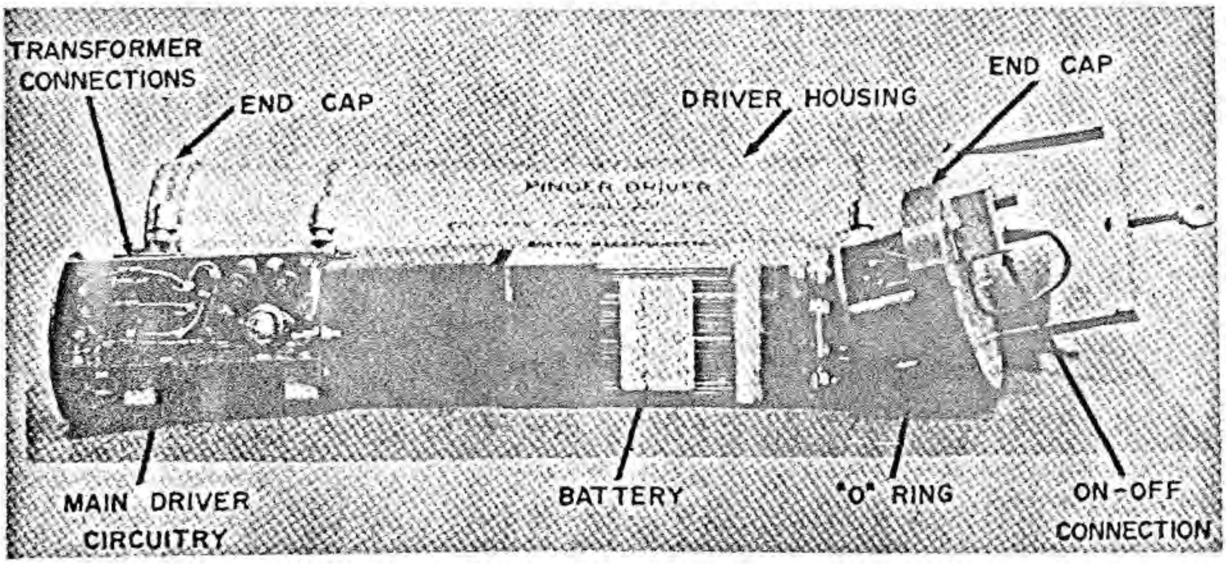


Figure R-3. The pinger driver disassembled.

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.

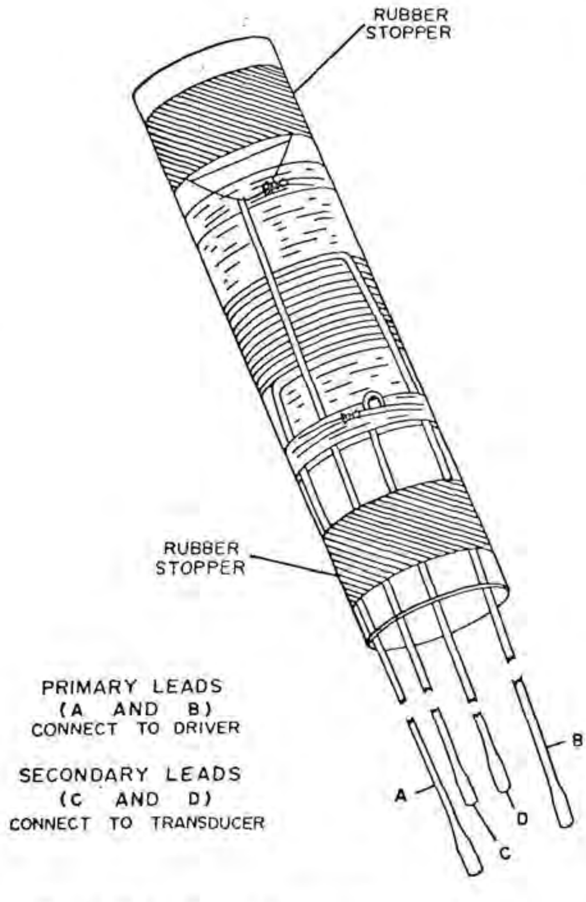


Figure R-4. Sonar pinger pulse transformer.

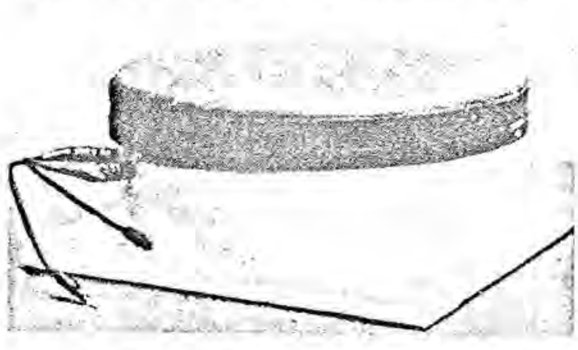


Figure R-5. Sonar pinger transducer.

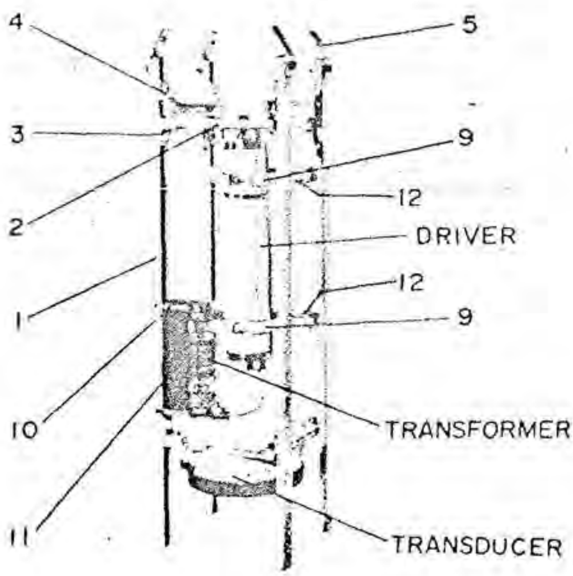


Figure R-6. Sonar pinger and mounting rack.

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 capicator 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.

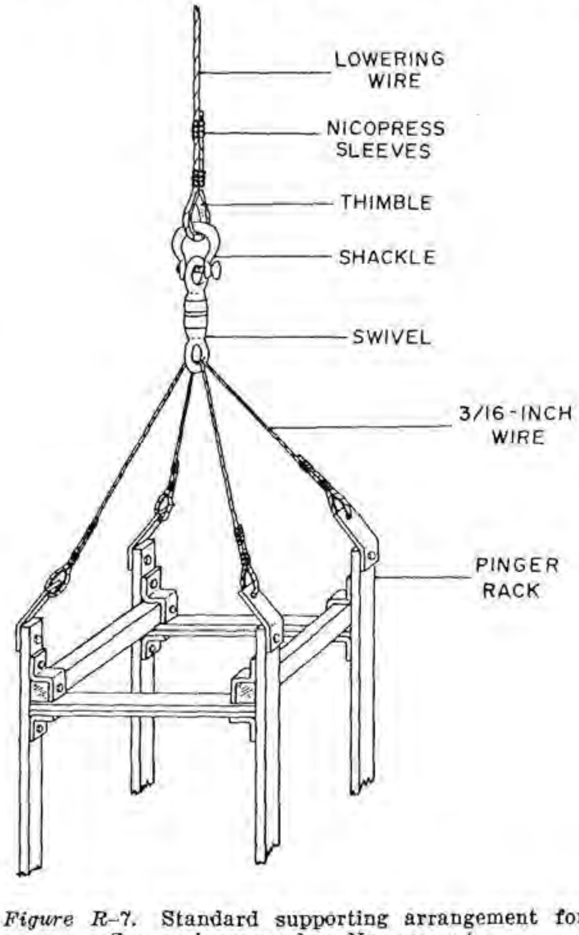


Figure R-7. Standard supporting arrangement for Sonar pinger used on Nansen cast.

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

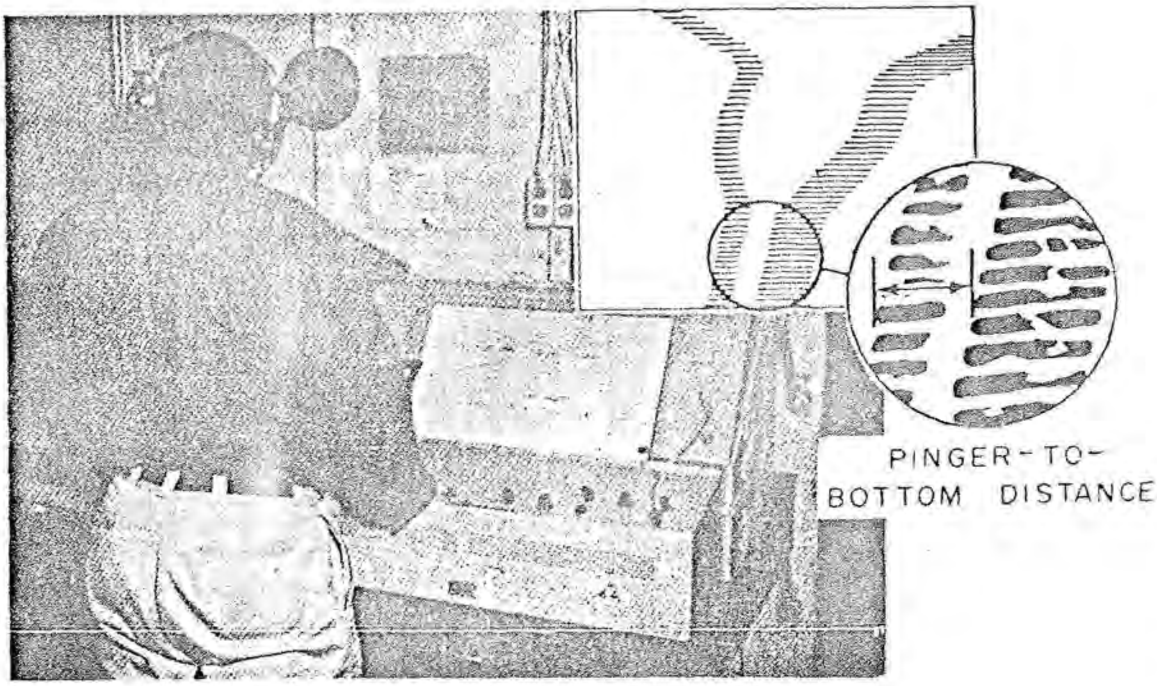


Figure R–8. NAVOCEANO scientist using the Mark 15A Precision Depth Recorder to determine pinger-to-bottom distance.

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.

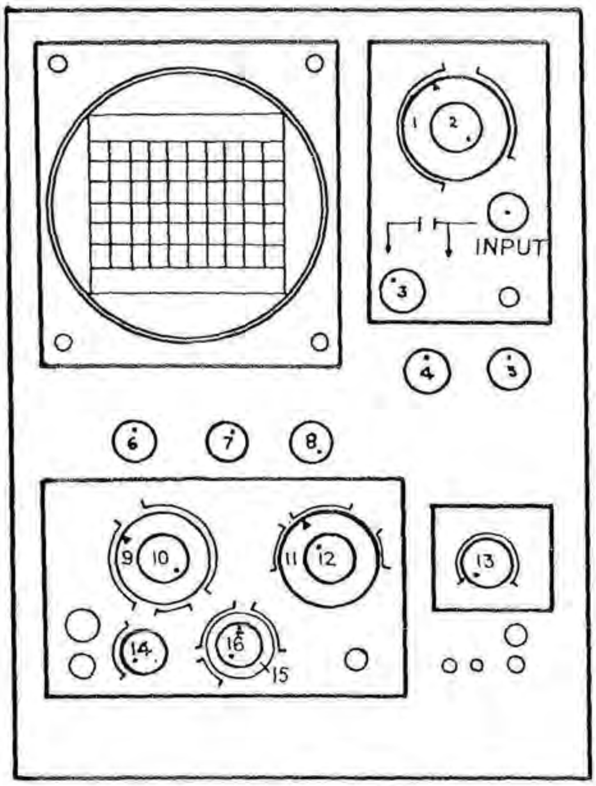
Step 2. If flooding has taken place, wash the parts with fresh water and dry.

Step 3. If malfunction of a component caused the trouble, refer to the instruction manual.

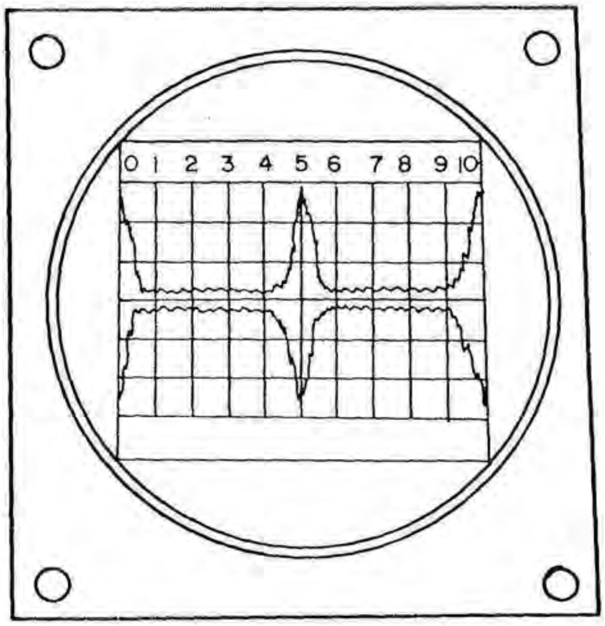
Step 4. If a lead was fouled and disconnected, cover the connection with electrical tape and lower again.

Step 5. Battery voltage should be checked after each lowering.

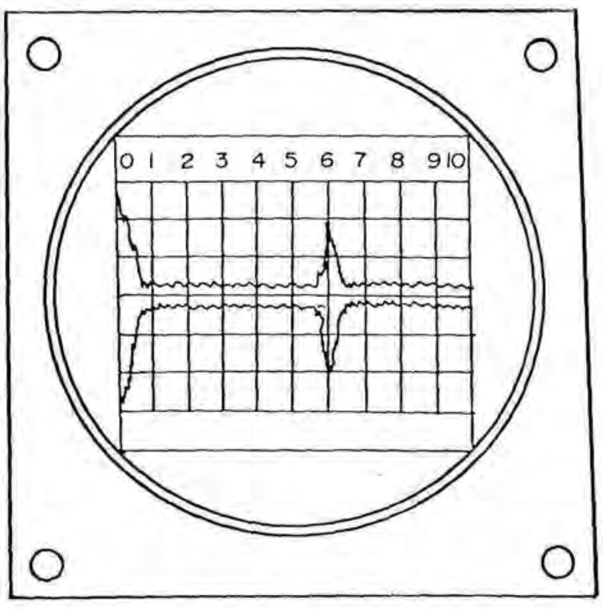
Step 6. To bench test the driver, connect the output leads across the transformer primary or across a 1-ohm 10-watt resistor.



(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.

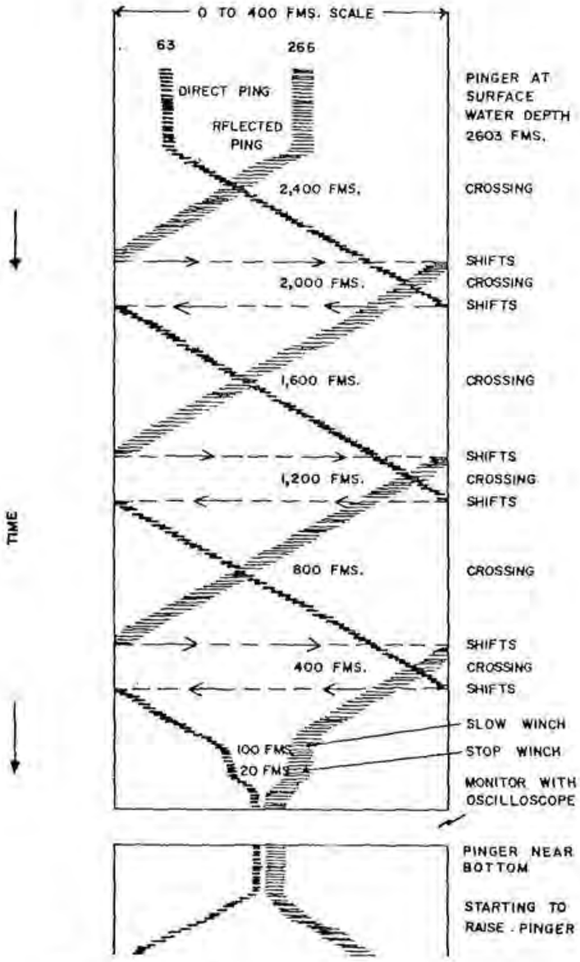


Figure R-10. PDR strip chart of Sonar pinger signals.

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	RC	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
			9 kts	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									
								2000									
								2500									
								3000									
								4000									
								5000									
								6000									

↑ Computed using SP-11 (σ_t)

↑ Interpolated values from Oceanographic Station Plotting Sheet.

↑ Computed using SP-58 (Sound velocity)

NAVY DPPO PRNC WASH D.C.

Figure S-1. Oceanographic Log Sheet-E.

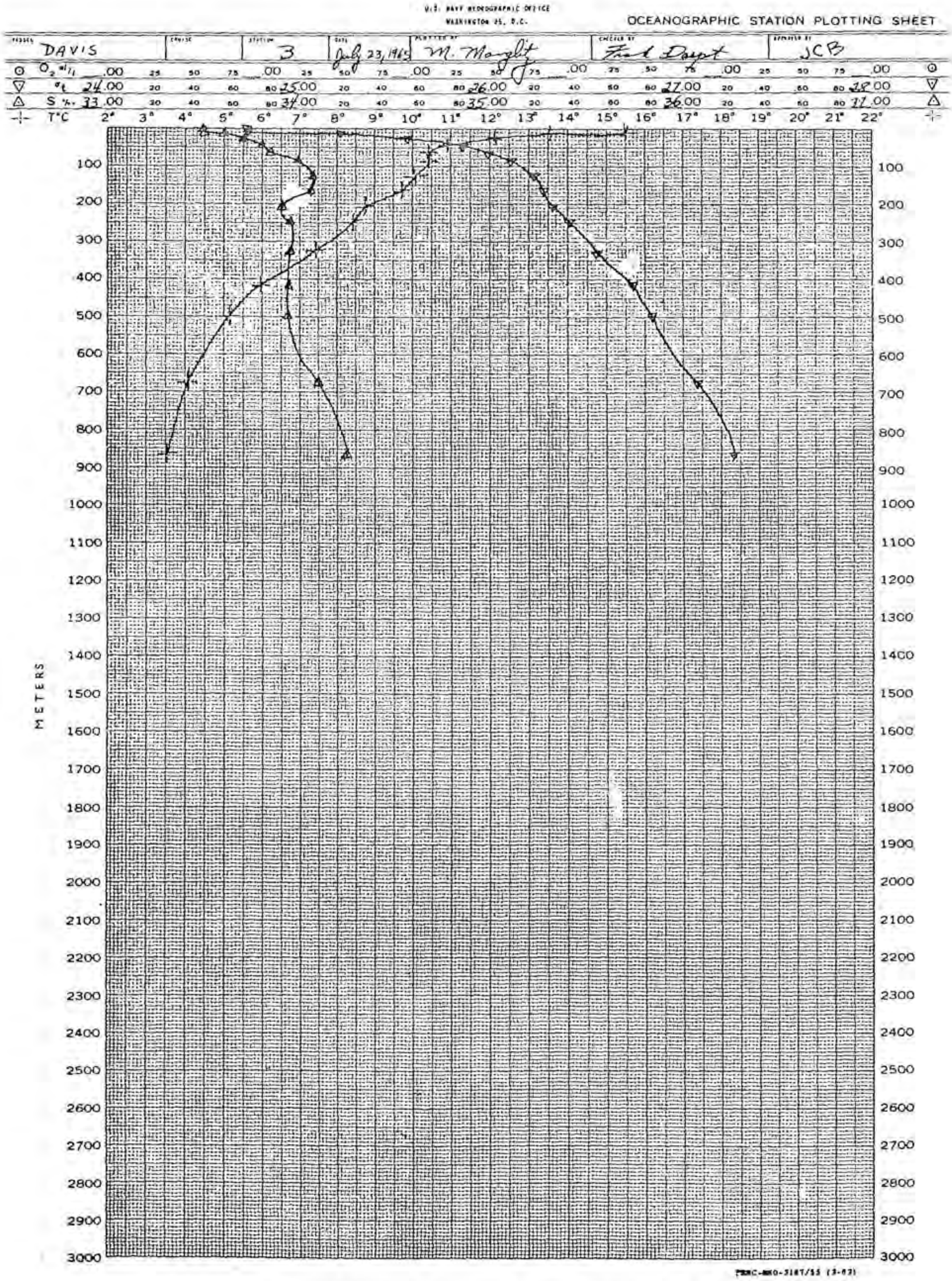


Figure S–2. Oceanographic Station Plotting Sheet.

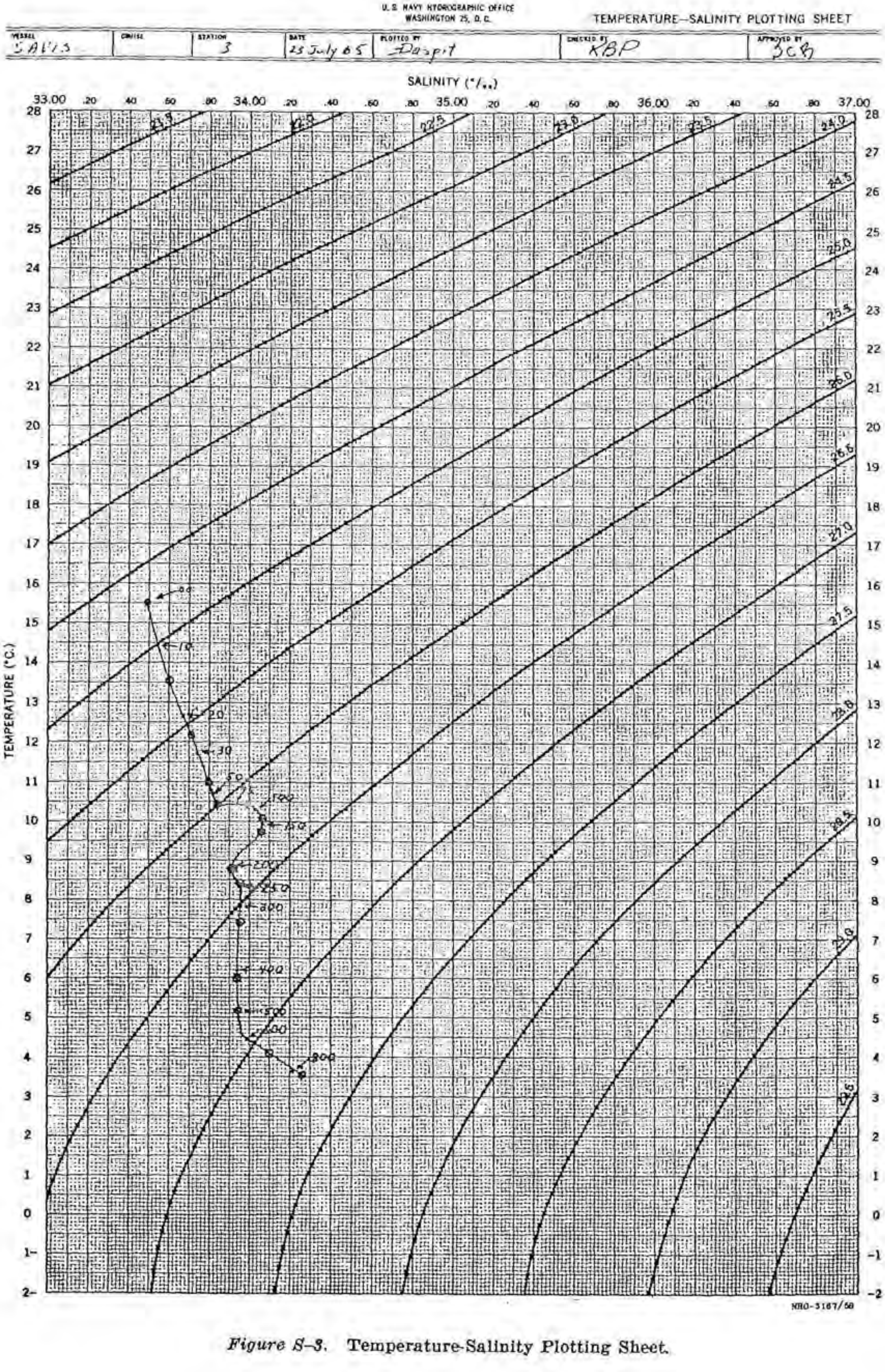


Figure S-3. Temperature-Salinity Plotting Sheet.

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

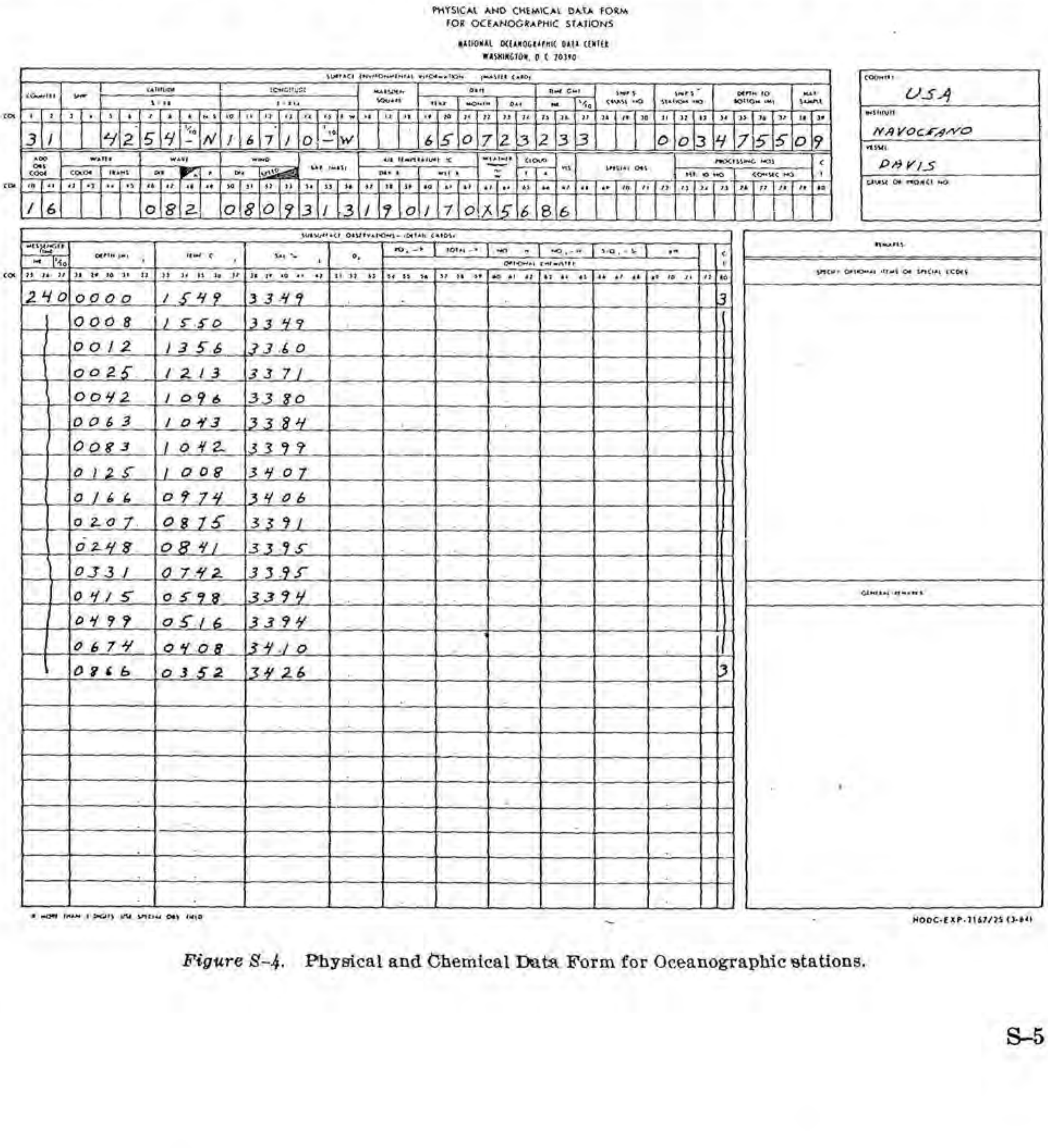


Figure S–4. **Physical and Chemical Data Form for Oceanographic stations.**

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 Volume Anomaly — X 10⁻⁵	ΣΔD Dyn. M. X 10³	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 punch-cards 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.

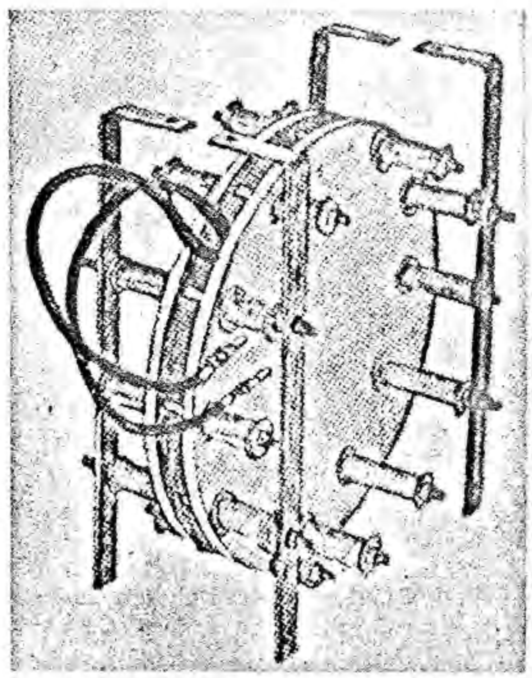


Figure T-1. Boomer sound source (EG&G Model 238).

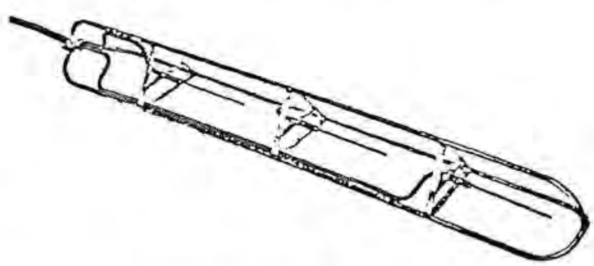


Figure T-2. Sparker acoustic pulse generator (EG&G Model 267 Sparkarray).

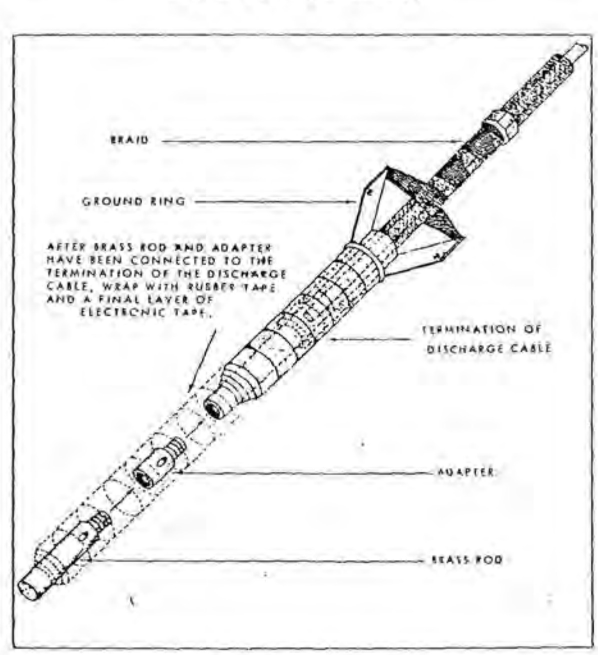


Figure T-3. The "bared cable" sparker acoustic pulse generator.

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,

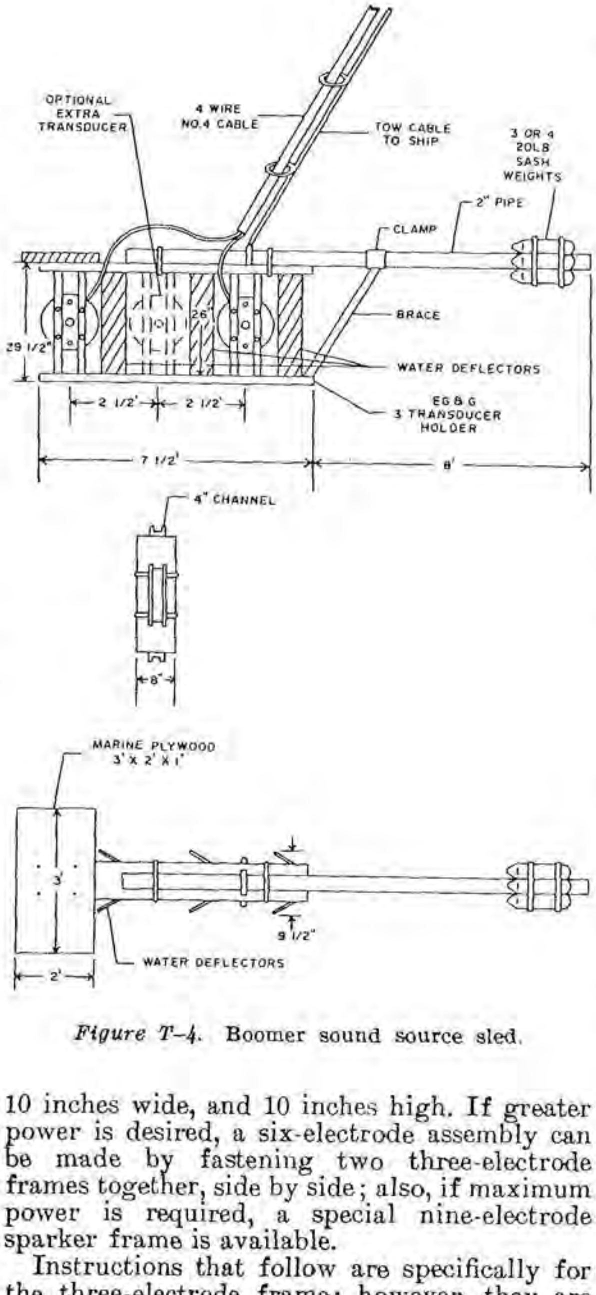


Figure T–4. Boomer sound source sled.

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-

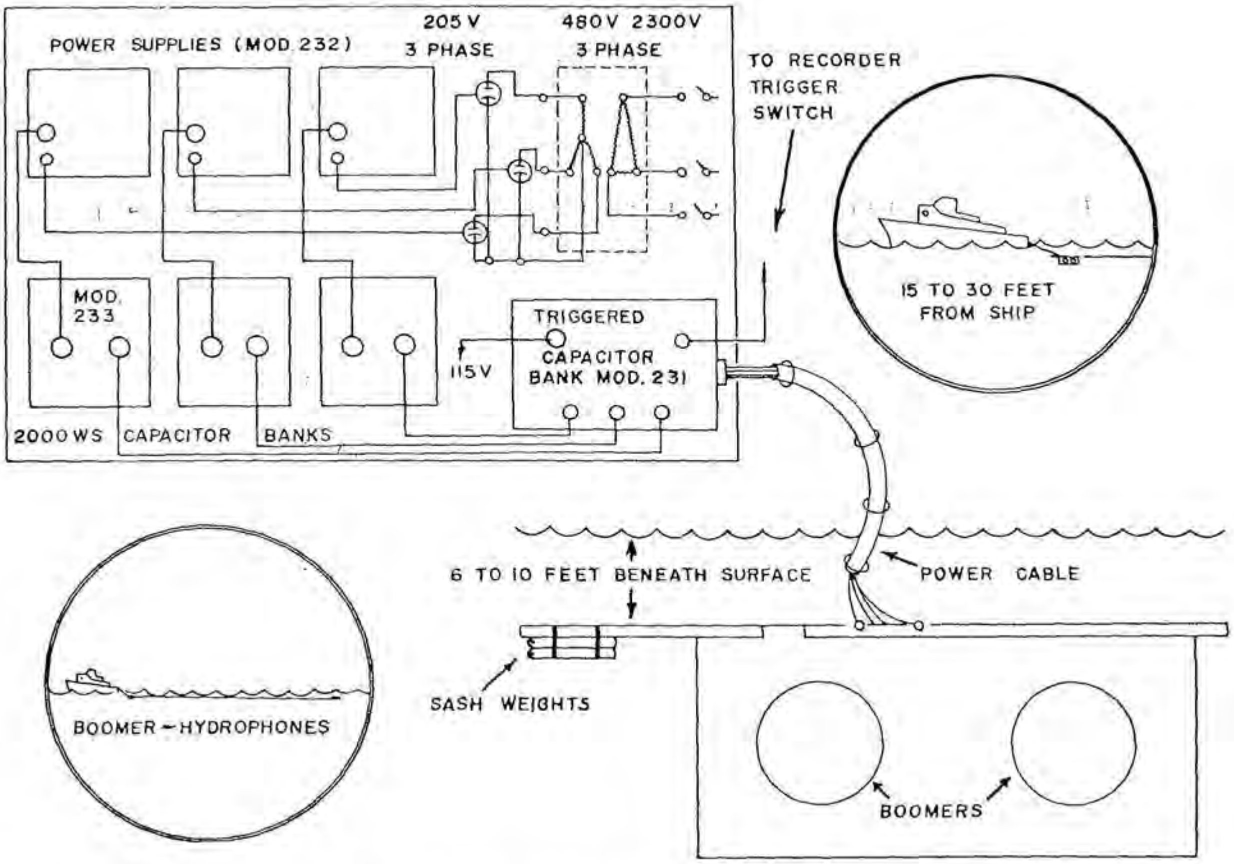


Figure T–5. Block diagram of Boomer and triggered capacitor bank.

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.

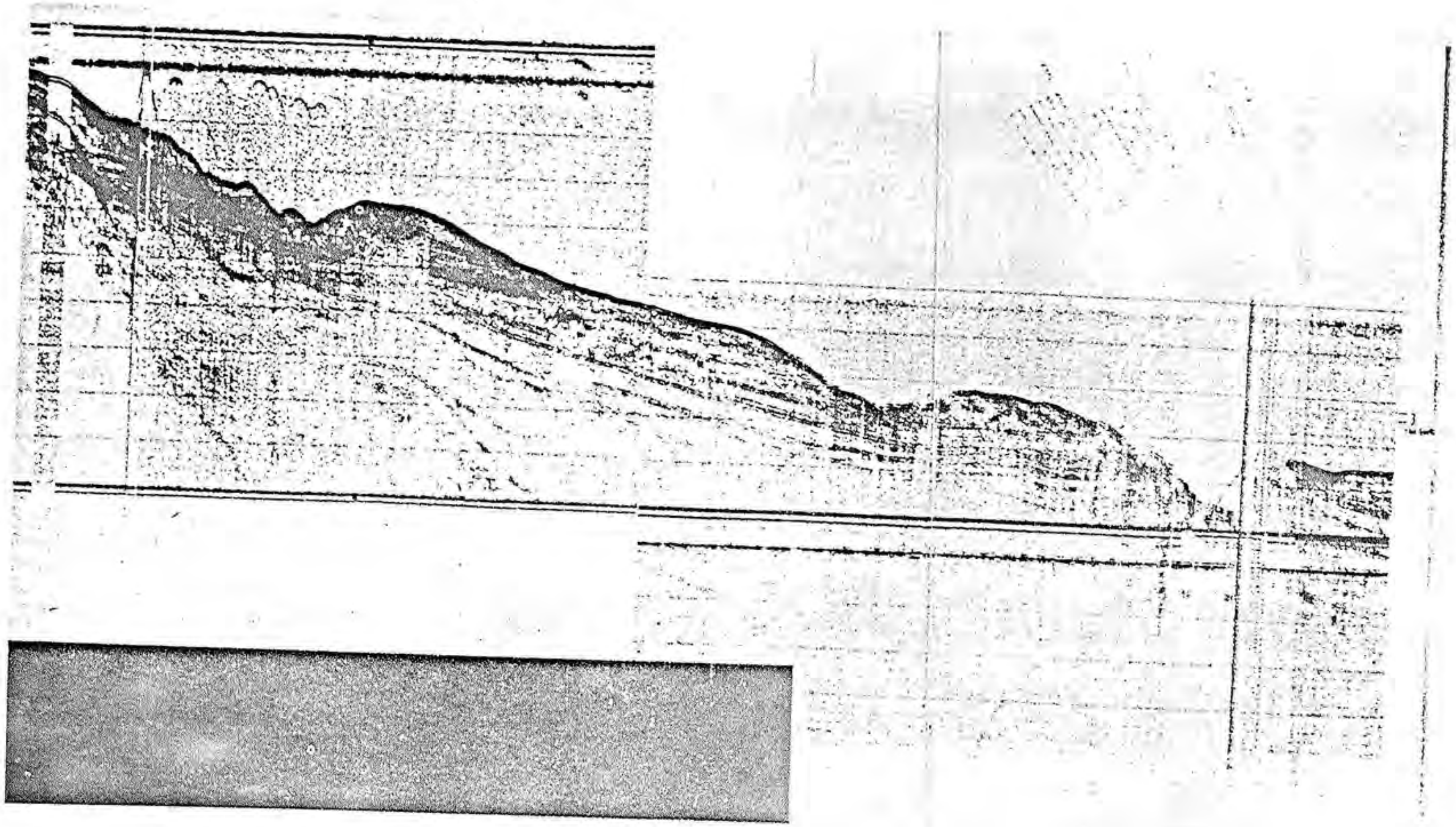


Figure T–6. Seismic profile strip charts, assembled to show continuous profile.