ϕ_n	=	angle of catenary with horizontal at buoy (degrees)
η	=	axis parallel to the longitudinal axis of the YRSDs
θ_q	=	azimuth angle of mooring leg (degrees) q = 1, 2, 3, 4, 5, 6
θ_R	=	azimuth angle of resultant force (degrees)
Φ	=	complex bottom angle (degrees)
ξ	=	axis normal to the longitudinal axis of YRSDs
Ψ	=	angle of bottom with horizontal in Y-Z plane (degrees)

MOORING SYSTEMS USED IN THE EASTERN ATLANTIC

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Abstract

A description is given of both deep-sea and shallow-water moorings that have been used during the sea mount expedition of the German R/V METEOR in 1967. The oceanographic problems are stated according to which the mooring configurations were chosen. Design characteristics which increase the reliability of instrument moorings are described in more detail, as are the operations of launching and recovering of the systems.

Several types of oceanographic buoy moorings were used during the sea mount expedition (ATLANTISCHE KUPPENFAHRTEN 1967) of the German R/V METEOR to the eastern Atlantic ocean from January to August 1967. An essential part of the physical oceanography group's program was the attempt to investigate the influence of the sea mount topography on the dynamics of the surrounding ocean waters. In addition, three other problems were studied:

1. Short-time variations of the Mediterranean water outflow.
2. Vertical distribution of internal wave motion in deep water.
3. Relations of bottom currents to the structure of sediments at the shelf edge.

The mooring design was chosen according to the requirements of these oceanographic problems.

The intent of this paper is to discuss the moorings set during the first part of this expedition (January to March 1967) which were designed to study problems 1 through 3 outlined above. Certain design characteristics pertinent to the reliability of deep-ocean moorings will be emphasized.

To investigate short-time current variations of the Mediterranean water in the deep Atlantic ocean (problem 1) west of Gibraltar, a deep-sea mooring was needed with current meters in the Mediterranean water between 700 and 1000 meters depth as well as above and below this water-mass for comparative measurements. The current meters were placed in a way which at the same time allowed determination of the vertical distribution of internal wave motion (problem 2). The type of mooring selected to satisfy these requirements was essentially a taut-wire mooring containing six self-recording current meters plus auxiliary equipment. In order to measure currents at the shelf edge (problem 3) a combined taut-wire and slack-wire mooring with one current meter five meters above the bottom was chosen.

Three shallow-water moorings have been set at the shelf edge off Portugal and off Morocco (Fig. 1, Stations A). A deep-sea mooring was launched at a depth of 2450 meters off the Portugese Cape S. Vicente (Fig. 1, Station B). These types of moorings were similar to those which have formerly been used for measurements in the Baltic (G. Dietrich and G. Siedler, 1963) and in the Red Sea and the Gulf of Aden (G. Siedler, 1967). The moorings to be discussed now were more complicated and involved more equipment than those previously set. Therefore an attempt was made to increase the probability of instrument recoveries.

Deep-sea moorings can be constructed in many different ways, but all systems known to date show an insufficient overall reliability over an extended period of time. The user of such moorings has to anticipate that a considerable percentage of these systems will suffer from damage of cables or malfunction of instrument components. Failure of one part in the system very often leads to a loss of the whole mooring unless alternate methods of recovery are planned.

Let us examine some of the possible ways of retrieving a mooring. It can be picked up from a permanent surface buoy attached to the top of the mooring line, a permanent surface buoy connected to the anchor of the main instrument assembly by a ground line, or a subsurface buoy which floats up to the surface before the recovery procedures begin. The last operation may be achieved by employing timer or acoustic releases at the anchor or at the sub-surface float. A greater probability for a recovery will be obtained by tying two or more of the above independant methods together to form a mooring system. Even after the breaking of cables or connections there may still be a chance to retrieve the instruments through emergency procedures. The success of these dragging operations depends on knowing the orientation of at least a part of the remaining buoy system. This can be achieved by laying a ground line in a given direction or by producing a vertical line by the methods described below.

In order to provide a vertical line the buoyancy of the deep-sea moorings has been distributed by using subsurface floats at several depths. As long as the cable breaks above the lowest float, there will always remain a net buoyancy producing a vertical line. In addition, inverted grapnels have been inserted into the line to hold the tow cable after contact. Other more common features of our instrument moorings will be discussed shortly.

The shallow water system (Fig. 2) was a taut-wire mooring with two subsurface floats to which a slack-wire marker buoy was connected. Ball float clusters have been used for all subsurface floats during this expedition. The advantage of such clusters is that they will maintain buoyancy in the event of flooding of individual balls. Corrosion protected

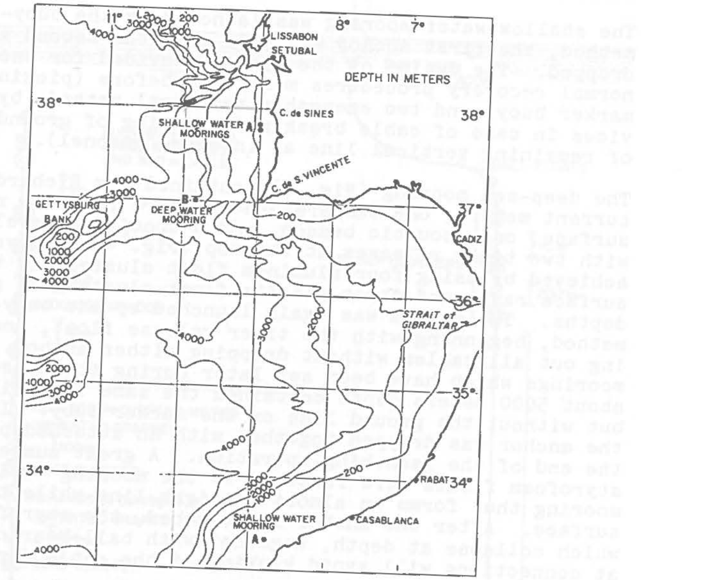

FIGURE 1. LOCATIONS OF CURRENT METER MOORINGS (R/V METEOR CRUISE NO 8, JANUARY TO MARCH 1967).

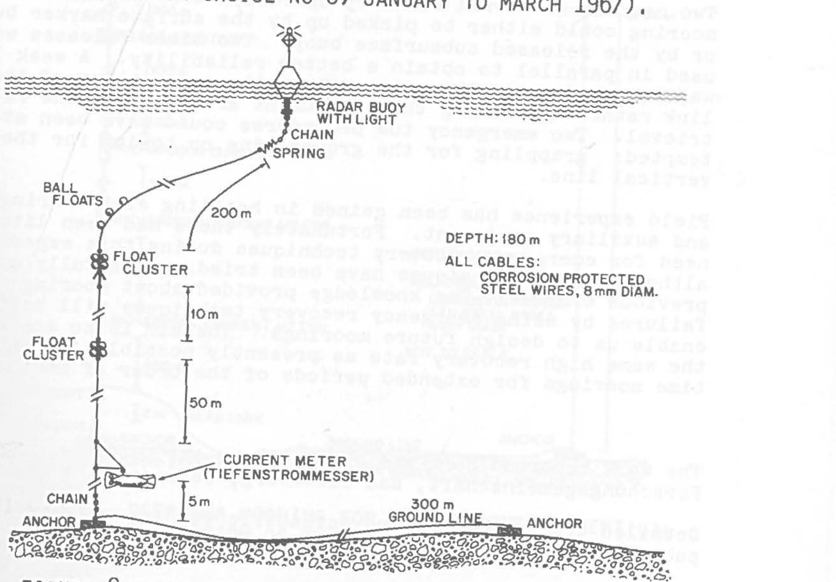

FIGURE 2. SHALLOW-WATER MOORING FOR BOTTOM CURRENT MEASURENENTS ON THE SHELF.

steel cables have been applied throughout this work.

The shallow-water mooring was launched by the buoy-first method, the first anchor was paid out, the second anchor was dropped. The design of the system provided for one of the normal recovery procedures mentioned before (picking up of marker buoy) and two emergency retrieval methods by towed devices in case of cable breaking (grasping of ground line or of remaining vertical line at inverted grapnel).

The deep-sea mooring (Fig. 3) contained six Richardson-type current meters, one temperature-pressure recorder near the surface, one acoustic beacon, and a specially developed buoy with two timer releases at the top (Fig. 4). Buoyancy was achieved by using four aluminum float clusters in the near-surface range and three plastic float clusters at greater depths. The system was again launched by the buoy-first method, beginning with the timer release float, and paying out all cables without dropping either anchor. Other moorings which have been set later during the expedition at about 5000 meters depth contained the same taut-wire system, but without the ground line or the marker buoy. In this case the anchor was dropped together with an attached parachute at the end of the launching operation. A great number of small styrofoam floats were fastened to the mooring cable. The mooring thus forms an almost straight line while towed at the surface. After the anchor is launched, the styrofoam floats, which collapse at depth, together with ball-bearing swivels at connections will avoid kinking of the cable during the launching procedure.

Two methods of normal recovery operation were possible. The mooring could either be picked up by the surface marker buoy or by the released subsurface buoy. Two timer releases were used in parallel to obtain a better reliability. A weak link was attached above the main anchor allowing parting of the link rather than along the instrument array during the retrieval. Two emergency tow procedures could have been attempted: grappling for the ground line or towing for the vertical line.

Field experience has been gained in handling such moorings and auxiliary equipment. Fortunately there had been little need for emergency recovery techniques during this expedition, although these techniques have been tried successfully on previous cruises. The knowledge provided about mooring failures by using emergency recovery techniques will better enable us to design future moorings. The aim is to achieve the same high recovery rate as presently possible for short-time moorings for extended periods of the order of months.

The work reported here was supported by the Deutsche Forschungsgemeinschaft, Bad Godesberg, Germany.

Detailed cruise reports and scientific results will be published in: Meteor-Forschungsergebnisse, Berlin

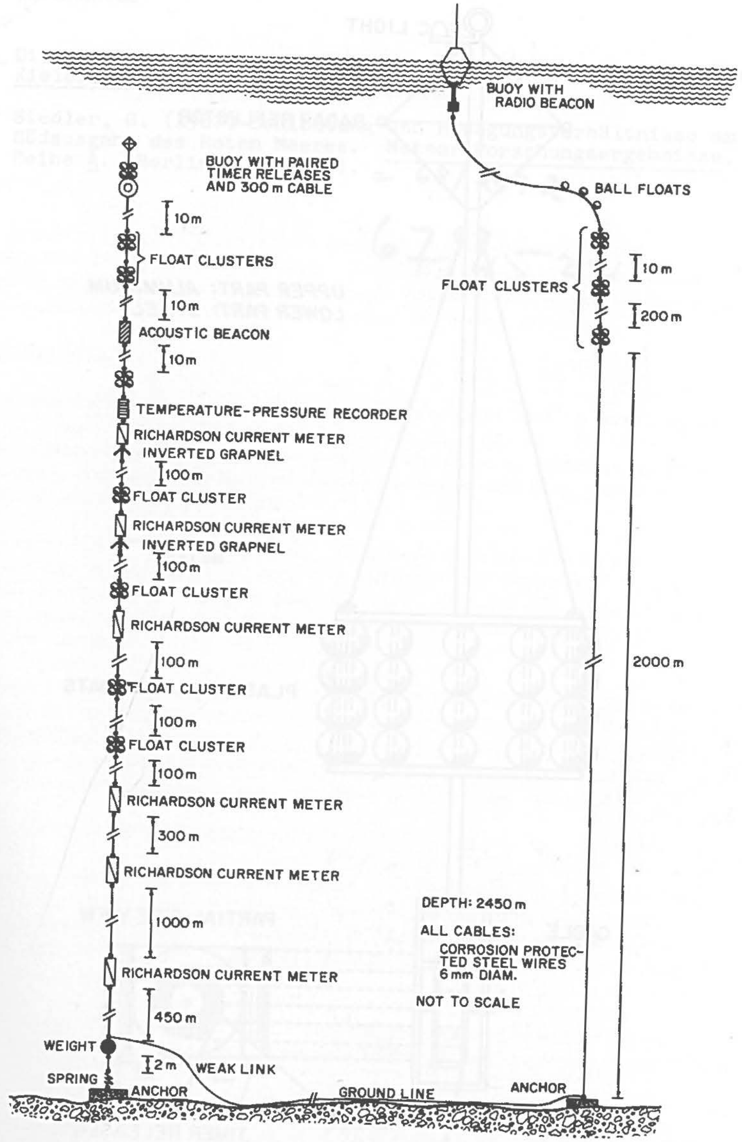

FIGURE 3. DEEP-SEA MOORING FOR MEASUREMENT OF VERTICAL VARIATION OF THE VELOCITY FIELD.

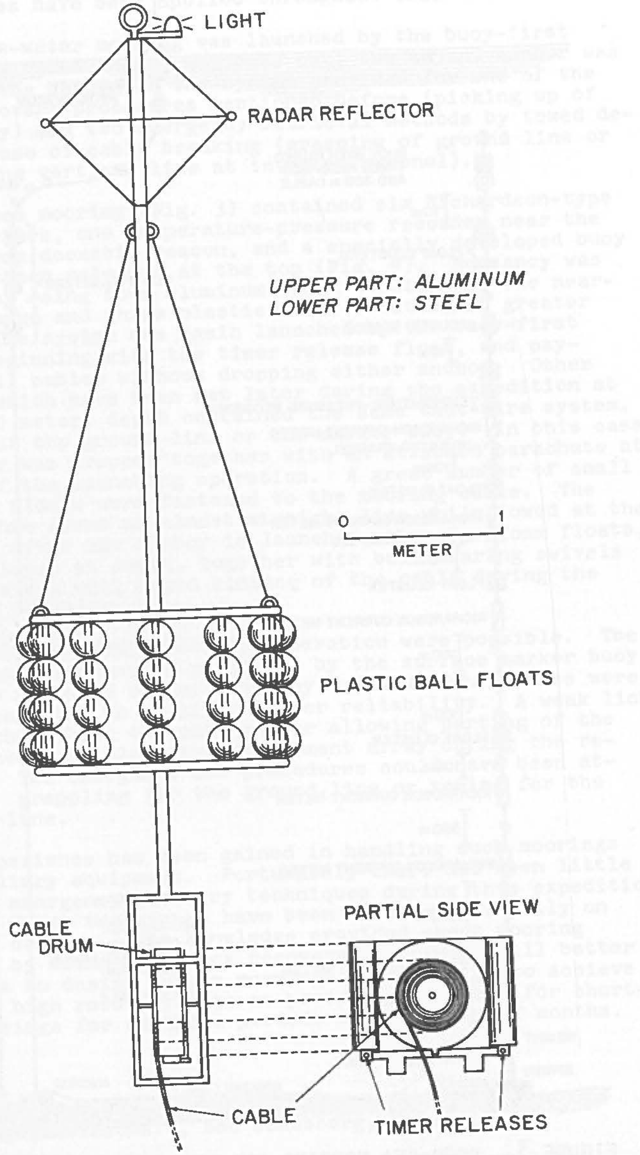

FIGURE 4. SUBSURFACE BUOY WITH A RADAR REFLECTOR AND TWO TIMER RELEASES CONTROLLING A CABLE DRUM. WHILE THE SUBSURFACE FLOAT IS RISING, THE CABLE IS REELED OFF THE DRUM.

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