



## DEEP WATER MOORINGS FOR OCEANOGRAPHIC INSTRUMENTS

T. BALASUBRAMANIAN AND B.U. NAYAK

National Institute of Oceanography  
Goa, India

### ABSTRACT

Continuous as well as long-term recording of the various oceanographic parameters such as currents, waves, temperature, salinity, pressure etc., require self-contained compact systems capable of unattended operation over several months. The use of such instruments at sea has necessitated the development of suitable mooring systems which can safely be used in the turbulent ocean environment. The object of this paper is to present the experience gained by the authors in this specialised area. Various mooring configurations and hardware components such as surface buoys, sub-surface buoys, mooring cables and release techniques required for a good mooring system have been presented. A discussion is also included on the problems associated with the difficult task of mooring the instruments at sea under varying oceanographic and meteorological conditions.

### INTRODUCTION

There is an increasing interest in the collection of oceanographic and meteorological data for better understanding of the ocean environment. For countries like India, having a vast coastline, it has become most important to collect data on nearshore as well as offshore areas for planning, designing, constructing, operating and maintaining various coastal and offshore facilities. The complex and dynamic nature of the ocean can only be understood if various ocean environmental parameters are properly measured and analysed. At present most of these observations are being made by ship-borne instruments. However, there is a great need today for collecting continuous data on oceanographic parameters like waves, currents, salinity, temperature, pressure etc. Unmanned automatic instrument systems and data buoys are becoming increasingly popular in addition to oceanographic research vessels. Design of moorings for installing these buoys should be such that

they withstand the hostile forces of the sea. They should be so designed that the installation and recovery of the buoys become relatively easy. An attempt is made to give a brief account of various mooring configurations and the operational problems involved in their use.

### MOORING CONFIGURATIONS

For continuous measurement programme at sea, the following aspects should be considered:

- a) stability of the mooring
- b) optimum engineering design of the mooring
- c) the potential of the mooring system to measure marine characteristics, and
- d) the ability of the mooring to remain at sea for long periods.

The following types of buoy configurations (Fig. 1) satisfy the above conditions: (i) the slack wire system (ii) semi-taut wire system, and (iii) taut wire system.

Slack wire system is one in which the vertical array of sensors are suspended by a surface floating buoy and moored by a cable whose length is considerably greater than the depth of water at the measuring station. A semi-taut system is one in which the buoyancy of the sub-surface buoy keep the line below it under tension so that the instrument installed below this sub-surface buoy are under tension of the sub-surface buoy while the cable connecting the subsurface buoy to the surface buoy is slack. The taut wire mooring system has only a surface buoy which is moored by a taut cable to the ocean bed (Fig. 1). Each of these systems has its own merits as well as demerits.

The choice of the mooring system to be adopted is governed by the purpose and the ocean environmental conditions. For example, the slack wire system may be ideal if only surface measurements are required. The taut wire system is useful for underwater measurements. In deep waters, however, installation, operation and maintenance of a taut mooring system is difficult and can become a problem. Generally speaking, the slack and the taut moorings are less expensive than the semi-taut mooring, and for this reason they are usually preferred. However, in deep water the semi-taut system is more reliable as it takes full advantage of the fact that the ocean, essentially, has a two layered structure--the upper layer representing a turbulent high current area and the lower representing a calm environment with reduced currents. Tests and experience have shown that the semi-taut wire system of mooring using a sub-surface buoy is less susceptible to failure.

#### HARDWARE COMPONENTS

##### Surface Buoys:

There are different types of surface buoys currently in use. The main purpose of a surface buoy is to indicate the location of the instruments installed for recording the oceanographic information. The surface buoys can be of different shapes. Discoid type, spheroid type and the catamaran float type are the most common. The discoid type is made of fibre glass reinforced plastic and

is usually of the shape of an inflated truck tyre. It is fitted with a tripod tower which houses a blinker which flashes light signals in the night. The bottom of the buoy has a galvanized iron wire which is connected to the mooring. This type of buoy is useful if measurements are to be done close to the surface. The catamaran type of the buoy is made of some light material with a mast inserted at its centre. Usually the length of the mast will be 3 m above water surface and on its top is placed a blinker or a radar reflector.

Sometimes, the surface buoy may have to house different sensors and instruments for various measurements as in the case of a meteorological data buoy. In such cases, the surface buoy can be of the spheroid type. The buoy is constructed by welding two hemispheres. As the buoy has to be thick, the theoretical design is based on Lamé's equation for thick wall spherical shells wherein the external collapse pressure is given by

$$P = s f_c \frac{R_2^3 - R_1^3}{3 R_2^3}$$

where  $P$  = external collapse pressure  
 $f_c$  = ultimate compressive strength  
 $R_2$  = outside radius  
 $R_1$  = inside radius

For calculating a safe working depth, a factor of safety of approximately 2 is adopted.

##### Surface Buoys:

A subsurface buoy has to offer maximum lift for the minimum drag and it must be capable of withstanding high external hydrostatic pressure. The best shape to fulfill these conditions is a sphere. The diameter of spherical buoys presently in use vary from 300 mm to 1200 mm. The materials used to date are steel, glass reinforced plastic, fibre reinforced plastic, high strength aluminium alloy etc. Generally, the design of a subsurface buoy is based on thin spherical shell theory and collapse of such a buoy will be due to elastic buckling rather than yielding.

The collapse pressure is given by

$$P = \frac{2tf_c}{r} \frac{m}{2(m-1)}$$

where  $P$  = external collapse pressure

$t$  = wall thickness  
 $f_c$  = ultimate compressive strength  
 $r$  = inside radius  
 $m$  = Poisson's ratio

A factor of safety of 2 is usually adopted for calculating the safe working depth of the subsurface buoy. In shallow depths the sub-surface buoy is generally not required. The taut wire or slack wire mooring system is used.

#### Mooring Cables:

Cables made of galvanised steel wire, polypropylene, nylon or terylene ropes and a combination of these have been widely used. All these cables mentioned above have good tensile strength. Most of the mooring failures have generally been due to snapping of cables. In fact, cable failure remains the primary cause of deep sea mooring losses. Galvanised steel wires have solved the serious problem of fish bite, but has introduced new problems in the form of corrosion, fatigue and kinking. Synthetic fibre ropes remain very useful below the fish bite zone for surface as well as subsurface moorings. These ropes have a great structural strength and abrasion resistance. Various tests have revealed that a tough plastic jacket of polyurethane placed around the synthetic ropes would greatly reduce failures due to fish bite.

#### Anchors:

Anchors and anchorage systems are an important but generally neglected area of development in the greatly expanding field of ocean exploration and exploitation. The sophisticated instruments are to be installed at or below the sea surface, in depths and locations not normally associated with the usual moorings. The main criteria for deep ocean anchors are that they be capable of directly embedding into the sea bed without being dragged and capable of resisting uplift plus lateral loads from all directions without reducing its holding capacity. Other desirable attributes are that the anchor be light weight, well configured for handling and lowering, simple in operation, economical in regard to materials and construction and

readily adaptable to different ocean environment. At present, for the mooring design, scrap materials like engine and railway wagon wheels or concrete blocks or barrels loaded with scrap iron, concrete etc. are generally used as anchors.

#### Release Devices:

Once a mooring is put into operation it has to be retrieved sometime later. There are various types of release mechanisms of which the acoustic release is gaining importance and popularity. The other types used are the winching method and mechanical release method. In the winching method, the surface buoy is first lifted followed by the sub-surface buoy, the recording instruments and finally the anchor.

In the mechanical release method and acoustic release method, the anchor is left at the seabed. Both these methods are reliable and recovery operation quicker. In both the systems the releasing mechanism is placed just above the anchor or sometimes below the last instrument. The mechanical release devices are self-contained and are used to release the mooring clamps at a pre-set time. The acoustic release device consists of two components--the ship borne interrogator and the subsurface unit. A coded acoustical command signal is transmitted from the research vessel to the subsurface release unit. This signal detonates a small explosive bolt and separates the mooring wire from the anchor. Once released, the unit acts as an acoustical beacon making it easier to locate the station when it pops up to the sea surface.

#### INSTALLATION TECHNIQUES

There are two basic methods of laying a mooring system (a) anchor first method and (b) the buoy first or anchor last or free fall technique.

#### Anchor First Method:

With this method it is possible to place a mooring very carefully at a specific position. The dead weight anchor is dropped first stopping when necessary for fixing the instruments or other components and the array is finally allowed to fall freely to the sea bed. The

problem with this method is that the full weight of the anchor and the instruments act on the wire giving high tensile force at the junction of the wire and sub-surface buoy during the installation. An important advantage of using this method is that the wire is maintained in a taut condition, which prevents kinking.

#### Buoy First Method:

In this case the complete buoy and mooring assembly is formed before starting the installation work. The buoy assembly is lowered and only in the last, the anchor is dropped. When the mooring is being installed in deep water, the possibility of the ropes forming loops or kinks round the instrument is high. The relative motion of the system as soon as the anchor is dropped and before the vertical position is assumed can cause excessively high drag on the recording instruments. The past observations indicate that the buoy may be moving at a speed well over 2 m per sec before the wire assumes its vertical position. No doubt, as the present ships are well-equipped with cranes and good winching system, the anchor first method would be more advantageous and hence preferable.

#### WAVE RIDER BUOY MOORINGS

A wave rider buoy mooring has to be designed in order to fulfill the following basic conditions:

- a) It should maintain the buoy in the required position for a desired length of time.
- b) It should offer least possible interference to the surface free floating ability of the buoy.

Various users of the wave rider buoys have presented their own mooring systems, each claiming to be an improvement over the others. They are, however, very similar to each other. Fig. 2 gives a typical mooring system for a wave rider buoy in deep water. The buoy system incorporates a subsurface buoy which is connected to the anchor. The spherical subsurface buoy is usually placed at 30 to 40 m below the mean water level and should have an upward thrust of nearly 300 kg.

For the wave rider mooring as suggested in Fig. 2, the chain and the Datawell rubber cable are first connected with the help of a shackle. The other end of the rubber chord is connected to a subsurface buoy by means of a braided polypropylene rope having a density of 0.91. This forms the floating rope. The rubber chord is about 15 m long and the floating rope is about 50 m in length. The subsurface buoy is connected by means of a sinking rope. In general, a braided terylene rope having a density of 1.38 is used. To ensure stability of the anchor in rocky bottoms, a 13 to 20 mm galvanized iron chain with a dredge of 30 kg weight is attached to the anchor (Fig. 2).

A similar deep water mooring was designed and installed in the Norwegian sea off Trondheim in which the senior author participated. The depth at the site of study was about 150 m. The required mooring was designed and assembled in the laboratory. The connections were made at the site before lowering the wave rider buoy. The anchor first method was used for installation. The launching was done by a vessel about 20 m long which had a good derrick and winch facility. The wave rider buoy was later recovered. The recovery operation was just the opposite of launching, that is, wave rider was recovered first along with the chain and the rubber cable followed by the subsurface buoy and finally the anchor was lifted up.

For wave rider buoy moorings in shallow waters, reference is made to the papers presented in this conference, "Wave measurements off the Bombay coast" and "Measurement of waves, tides and currents in Mandovi estuary, Goa during the monsoon season" (Nayak and Anand, 1981 a and b).

#### Current Meter Moorings:

Two current meter moorings, one for measuring surface currents and the other for deeper currents were designed and installed and later recovered at the Trondheim fjords. Aanderaa recording current meters were used. The mooring arrangement is illustrated in Fig. 3. For measuring currents near the surface, the rig comprised of a surface float mounted with a blinker was used. The surface float was connected to the current meter by means of a

galvanised iron chain using a swivel. All the swivels used are the screw-pin type and are secured with galvanised steel wire through the eye of the pin and around the shackle. To ensure that the current meter was always vertical when measurements were taken, a fish (lead weight) weighing about 50 kg was attached to the bottom of the current meter. This fish was connected to the anchor (about 300 kg) by means of a polypropylene rope (85 m long) and for a small length at the bottom by a 13 mm galvanised iron chain (28 m long). The entire assembly was recovered after the current measurements.

The second mooring assembly for measuring the bottom and the mid-depth currents consisted of two Aanderaa current meters. The assembly consisted of a marker buoy with a radar reflector projecting about 3 m above the water surface. The surface buoy is connected to a subsurface buoy by means of a 5 m long rubber chord and a polypropylene rope (floating type) of length about 50 m. The purpose of the subsurface buoy was to provide the taut wire mooring for the current meters. The two current meters spaced 40 m apart were connected by means of a polypropylene rope which had a density greater than unity (sinking type). The current meter was connected to the AMF acoustic release mechanism which was attached to an anchor weighing about 300 kg. To prevent the anchor from swaying on the rocky bottom, a 13 mm steel chain with a dredge weighing 30 kg was attached to the anchor (Fig. 2). The entire assembly was designed to be recovered by activating the AMF acoustic release device located just above the anchor.

#### HAZARDS AND REMEDIAL MEASURES

Various users have often reported the loss or damage to the instruments along with the buoys. Based on experience it can be said that a mooring failure is often due to (a) structural failure of some part of the mooring system (b) over running by vessels (c) stealing, and (d) vandalism. To ensure safety, a number of precautions are to be taken as mentioned below: use a marker buoy with a good blinker light, moor the buoy near a manned unit at sea

such as an offshore platform or a light ship, mooring near the wreck buoys and informing the local police and the people about the importance of the oceanographic data collection programme, etc.

The most likely phenomenon causing early failure of the mooring is the electrolytic corrosion between different metals in sea water. As far as possible, the same material should be used for connecting different components of the mooring. When it is necessary to couple different metals, an electrically insulating material should be used.

Another cause of early mooring failure is the corrosion of steel wire rope in the sea. It is advisable to provide a zinc protective coating on the wire rope to resist corrosion. Experience has also shown that steel wire ropes with nylon covering offers better protection against corrosion. Synthetic ropes are seldom corroded but are often prone to fish attack. These synthetic ropes, when covered by a jacket of polyurethane plastic, offer excellent protection against the fish bite.

The failure of moorings due to kinking is also high. Synthetic fibre ropes and wire ropes are apt to kink when the rope has an asymmetrical construction. Therefore, the braided and plaited ropes are not liable to kinking as they are not subject to torsion when loaded.

#### CONCLUSION

Different techniques are presently available for installing oceanographic recording instruments at different depths and environmental conditions of the sea. Depending upon the local environment and the type of data to be collected, the mooring should be properly designed and assembled. A discussion has been presented on the most common types of moorings, their installation techniques and the problems associated with them. Successful deployment of recording instruments is possible based on sound design, taking into consideration the environmental and operational conditions, and practical experience at sea.

ACKNOWLEDGEMENT

The authors would like to express their deep appreciation to Dr S. Z. Qasim, Director, National Institute of Oceanography for encouraging to write this paper. The senior author is particularly grateful to Prof. O. G. Houmb of the Norwegian Institute of Technology, for training him in this most interesting and important area.

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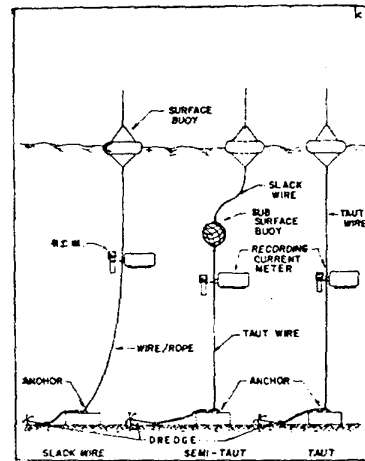


Fig.1 Three Typical Mooring Configurations

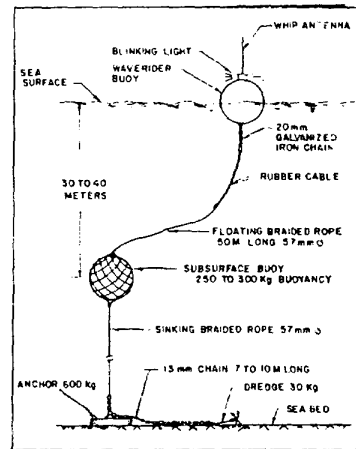


Fig. 2 Deep Water Mooring for Wave Rider Buoy

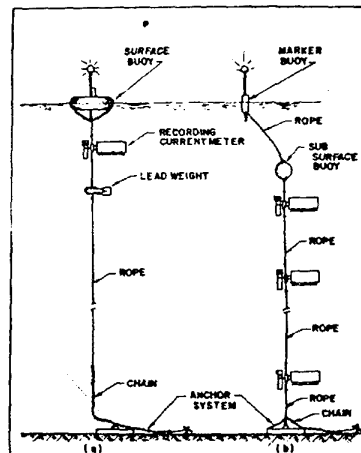


Fig. 3 Mooring Systems for Current Measurements: (a) Near the Sea Surface (b) At Mid-depth and Below