

Survey Technology for Ocean Engineering Applications

K. ASHOK KUMAR, S.G. DIWAN AND P. CHANDRAMOHAN
National Institute of Oceanography, Dona Paula, Goa- 403 004, India

ABSTRACT

Various types of sophisticated instruments available at the National Institute of Oceanography, Goa, India, for obtaining precise information on waves, ocean currents, water level variations, meteorological parameters, etc. are described.

INTRODUCTION

Non-directional wave measurement

Non-directional wave measurement is highly useful for design specifications for coastal and offshore structures, construction and development of harbours, understanding coastal processes and taking coastal protection measures. For measuring non-directional waves, Datawell waverider buoys and wave and tide gauges of M/s Interocean are being used widely.

(A) *Datawell waverider buoy* — The waverider buoy (Fig. 1) is available in 70 and 90 cm diameter, is spherical in shape, freely floating on sea surface, and is moored at the desired wave measurement location. It has a flash light unit for navigational purpose, an antenna of 2 m length, transmitting wave information continuously at 80 mW power level; phase locked receiver dependable reception over 50 km (over sea) is obtained if the man-made noise level at the receiving site is low and the wave height is below 10 m. Battery life is 9 months for 70 cm and 18 months for 90 cm diameter buoy [4]. The receiving units, such as WAREP along with DIMA or DIWAR with PC, are located on the shore or platform or ship within 50 km of the moored waverider buoy.

Mooring of the waverider buoy is accomplished with a rubbercord of 15 m length and 3.5 cm thickness connected to the stabilising chain of 5 kg weight. This stretches three times of its length and keeps a moored waverider buoy from being pulled under by passing waves. The other end of the rubber cord is connected by a spliced karat rope (12 mm) to the subsurface float. The other end of the float is connected by a karat rope to a 12 mm galvanised chain shackled with the anchor

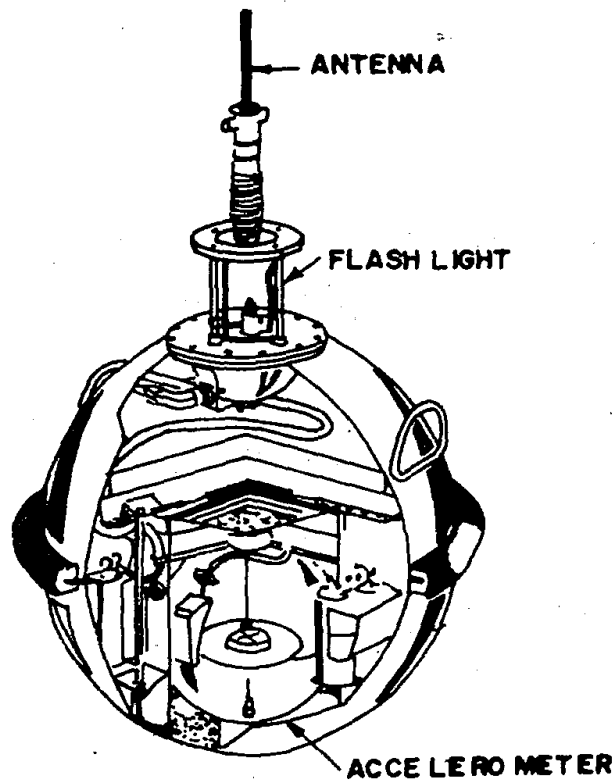


Fig. 1 — Waverider buoy

end. Subsurface buoy is recommended for rocky or sandy sea beds. For deeper water, higher buoyancy float is recommended. Anchor weight of 300 - 400 kg is used.

A mechanised boat, usually a trawler having a derrick boom and a 2 tonne winch is employed for handling waverider buoys. The size of the boat can be 12-16 m. The anchor last method is adopted for waverider deployment. The buoy is first dropped from the stern of the boat with the boat moving at about 2 knots speed. The connected mooring, as described above, is paid out manually under moderate tension. Anchor is dropped at the end. The buoy is recovered from the same boat and most of the times the same boat is used for watchkeeping on waverider buoy [10].

(B) *Interocean wave and tide gauge* — WTGS4-ocean waves produce measurable pressure fluctuations beneath them. Under certain circumstances, these can be related to wave height and tide. M/s Interocean have introduced WTGS4 (Fig. 2), a new generation wave and tide gauge incorporating advanced features using microprocessor control for ease of operation [12]. It is a rugged cylindrical shaped instrument having 25 cm diameter and 43 cm long housing, rechargeable 12 V sealed lead acid battery with electronics housed in it. The

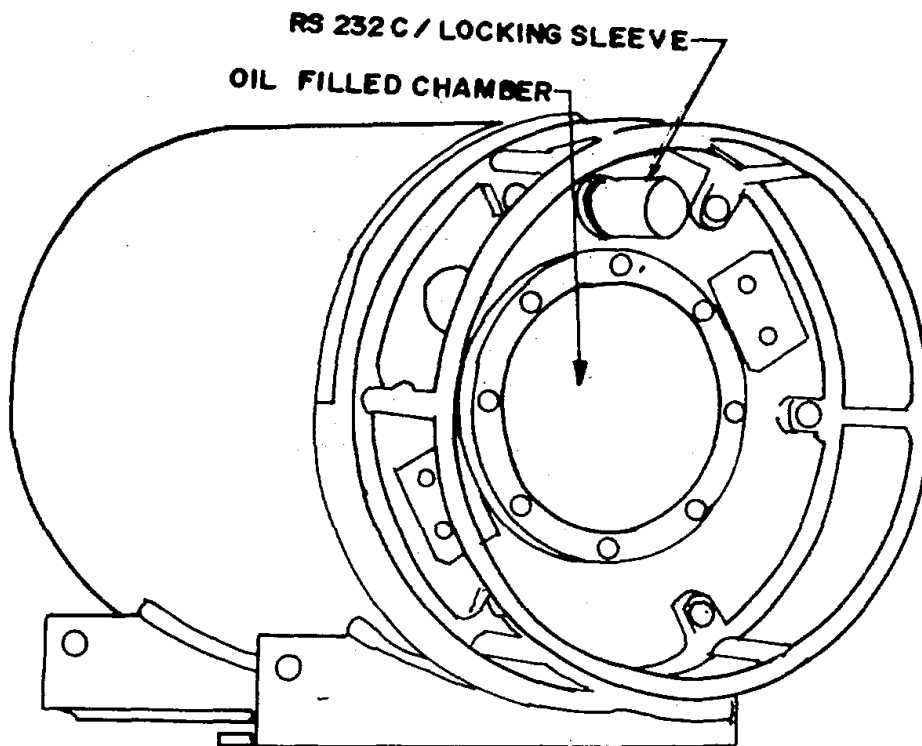


Fig. 2 — Wave and tide gauge - WTGS4

weight of the instrument in air is 25 kg, while weight in water is 6.4 kg. The instrument case material is 6061-T6 aluminium (hard anodized).

The instrument can be moored/mounted vertically or horizontally with an endurance of continuous logging for 533 hours when the battery is fully charged. The maximum installation depth is 20 m. The unit should be lowered at the rate of not greater than 10 m per 15 min. A faster rate could cause damage to the internal transducers.

Directional wave measurement

In designing harbour construction and jetties and to study sediment transport along the shore, directional wave information plays an important role. This measurement is carried out using WAVEC, directional waverider buoy and S4 currentmeter.

(A) *Datawell WAVEC buoy* — The WAVEC buoy is discus type in shape with a central cylindrical S.S. housing and a top float (Fig. 3). The total hull diameter is 2.5 m and the height without antenna is 1.7 m. The total weight of the buoy with mooring cross is approximately 730 kg [7]. Floating segments and top float material is polyethylene foam with yellow polyurethane coating. It has a flash light unit for navigational purpose and a 2m whip antenna to transmit wave and wave direction information to shore-based receivers. Special attention has been given

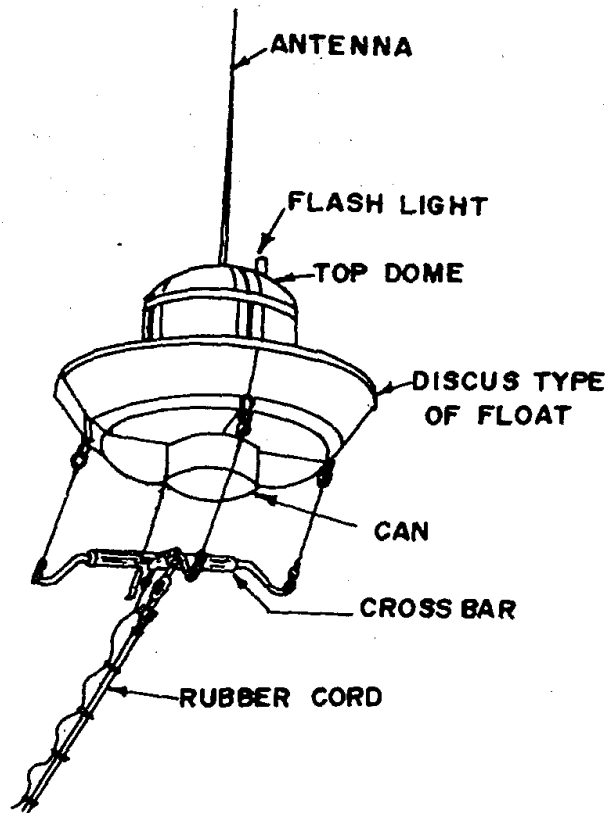


Fig. 3 — Wave buoy

to an optimum buoy shape to minimise trim angle dependency for relative current speeds up to 4 knots. Natural buoy heave frequency is about 0.5 Hz and natural pitch/roll frequency is about 0.7 Hz. Sensors used are Hippy 120-pitch, roll and heave and a fluxgate compass.

The mooring used is of single point type with a stabilizing chain connected to a rubber cord of 15 m with a safety polypropylene rope. This is followed by a 22 mm polypropylene rope connected to the anchor end. The anchor weight is about 1500 kg connected to suitable terminals of polypropylene rope. The mooring length can be suitably chosen, depending upon water depth.

The transmitter transmits six digital data channels (raw) of pitch, roll, heave and three compass signals. The total buoy power consumption is 1.3 W. Minimum life time of the batteries is about seven months.

The directional wave recording equipment, DIREC, is designed for reception and digital data processing of WAVEC data. It contains a radio receiver, a microcomputer and real time clock/timer and two communication RS-232 ports. The DIREC gives the original wave and slope north and slope west data and co and quadrature spectra averaged from good blocks of 256 data samples over half

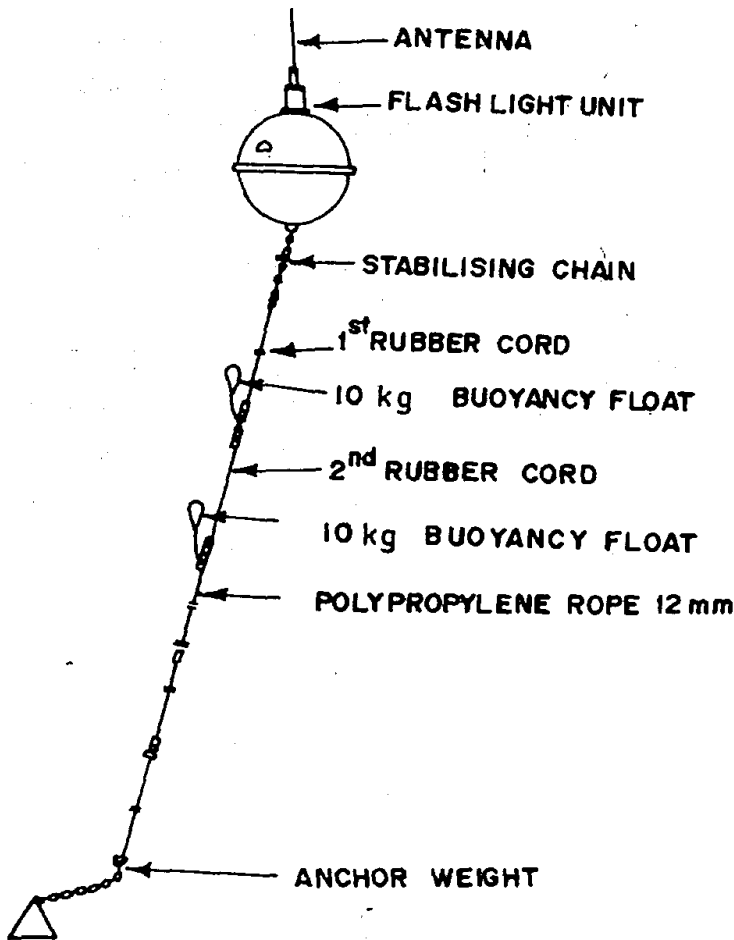


Fig. 4 — Moored directional waverider buoy

an hour period. The DIREC is interfaced to an IBM compatible PC. The software computes from co and quadrature spectra the characteristic figures of angular and frequency distribution of wave energy.

(B) *Datawell directional waverider buoy* — The directional waverider is a spherical 90 cm diameter buoy which measures wave height and wave direction. It is powered by 85 Leclanche cells and has a 12 month battery life, weighing 190 kg [8]. It has a flash light for navigation purpose and whip antenna for continuous transmission of wave and wave direction information. The buoy contains heave-pitch-roll sensor Hippy-40, three-axis fluxgate compass, two fixed X and Y accelerometers and a temperature sensor. The directional waverider has microprocessor-based electronics and it transmits the signals in 27-40 MHz bandwidth. It is fixed with a 5 kg chain ballast attached to the mooring eye. A single point vertical mooring with two standard rubber cords ensures sufficient symmetrical horizontal buoy response also for small motions at low frequencies

(Fig. 4). The low stiffness of the rubber cords allows the directional waverider to follow waves up to 40 m. The buoy has 2350 Newtons buoyancy and works safely in currents up to 6 knots. For mooring in depths < 35 m, each rubber cord terminal has to be attached with a 10 kg buoyancy float. The end of the second rubber cord will follow polypropylene rope, multiplait, 12mm diam. mounted on PP terminals with rope length of water depth plus 8 m. The rope terminals are fitted with sinker of approximately 500 kg of chain. The anchor last method is used for deployment of the directional waverider.

(C) *Interocean S4 currentmeter* — The S4 currentmeter (Fig. 5) is of spherical shape of 25 cm diameter with weight in air 11 kg. It has electromagnetic sensors and a fluxgate compass for wave direction measurement and to record tide and current in wave breaking zone. It has six alkaline D type cells which gives 480 hours of continuous data logging [11]. The data is stored in CMOS static RAM. After recovery of the moored unit, it is interfaced to an IBM compatible PC through S110 interface to retrieve data.

It can be attached to a fixed offshore structure at a convenient distance of 3 m away to reduce the magnetic influence on the measuring system. It can also be moored in a chain of acoustic release and a subsurface buoy with maximum depth of 70 m.

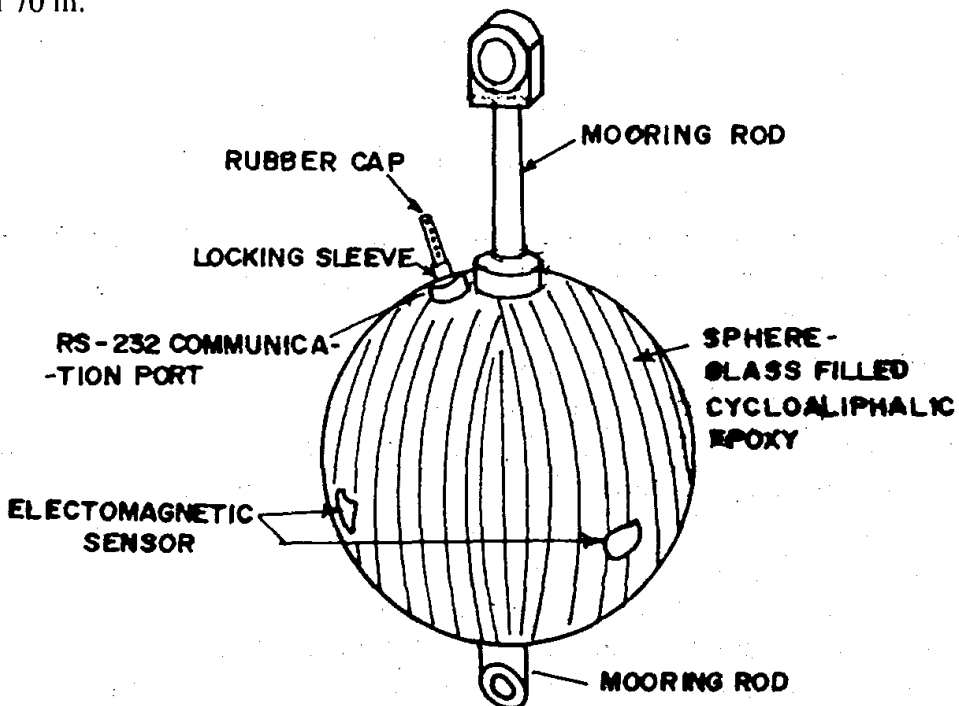


Fig. 5 — Interocean S4 currentmeter

Measurement of ocean currents

Ocean current measurements are essential for the design of submarine pipelines, marine outfalls, coastal processes, dredging operations, etc. To measure these currents, Aanderaa RCM-4/RCM-5, Simrad UCM-30, Interocean S4 currentmeters are among some of the currentmeters widely used by oceanographers.

(A) *Aanderaa RCM-4/RCM-5 currentmeter* — The instrument consists of a cylindrical underwater package with sensors (Fig. 6), a gimble and vane assembly to be fitted to the instrument housing, to be attached to the mooring assembly. The recording unit consists of electronics, encoder, quartz clock having selectable sampling intervals from 0.5 to 180 min, non-magnetic 9V battery and 0.25 in magnetic tape to record the data and acoustic transducer for data telemetry over a limited distance [1]. It has temperature, conductivity, pressure, direction and speed sensors. The 10 bit binary word decoded by the encoder is recorded on the magnetic tape. After recovery of the instrument, the data on magnetic tape is read on Aanderaa Tape Reader 2650 interfaced to an IBM compatible PC.

This currentmeter is moored below the wave zone in 'U' or 'I' type of mooring (Fig. 7). The 'U' anchoring is suitable for shallow water, while 'I anchoring' can

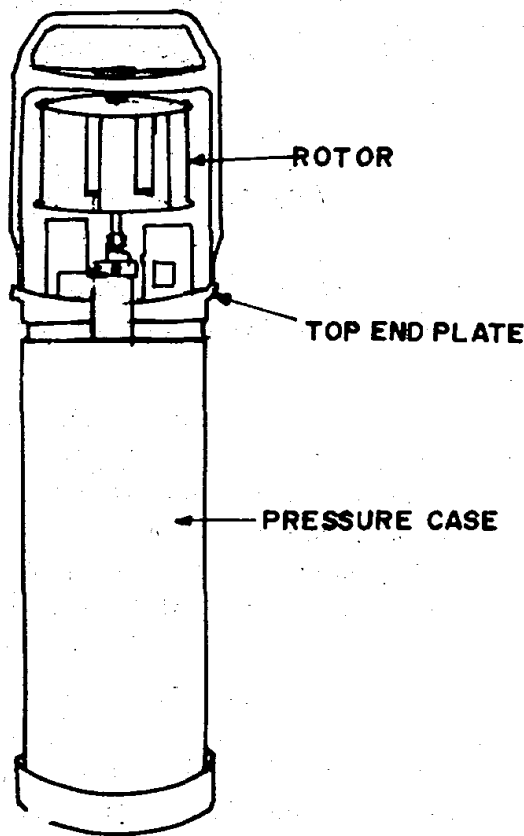


Fig. 6 — Aanderaa currentmeter RCM-4/RCM-5

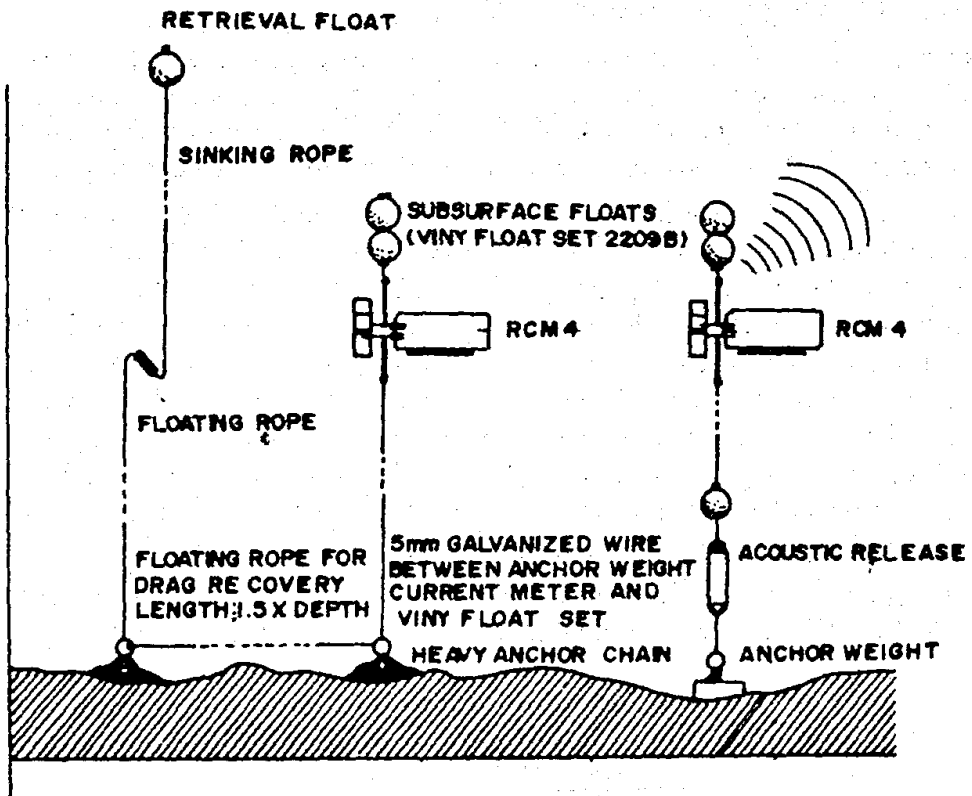


Fig. 7 — Aanderaa currentmeter mooring

be used for depths up to 2000 m for RCM-4 and 6000 m for RCM-5 along with a suitable acoustic release.

(B) *Interocean S4 currentmeter* — In addition to directional wave and tide information, as explained earlier, this equipment gives vector averaging current speed and direction.

(C) *Simrad UCM-30 ultrasonic currentmeter* — During the last decade, acoustic currentmeters have shown proven reliability. Acoustic signals are used in different ways. But the most important method is pulse edge detection, which is used in Simrad UCM-30 currentmeter Fig. 8. UCM-30 is a vector averaging currentmeter providing integration of velocity data prior to record on tape. The UCM-30 is a self-contained digital cassette recording and lithium battery pack and can be used in the wave zone [16].

The currentmeter comprises a protective cage for acoustic sensors. The UCM-30 consists of two units interconnected *via* a flat cable and mounted into a common 4.5 inch pressure tube of chromium plated brass material. The two units are called as the upper unit and the lower unit respectively. The upper unit carries the battery pack, the digital tape recorder and the control circuits needed to drive the tape recorder. It also contains the temperature and pressure sensors. The lower unit contains current sensor, compass, sensor interface electronics and programmable

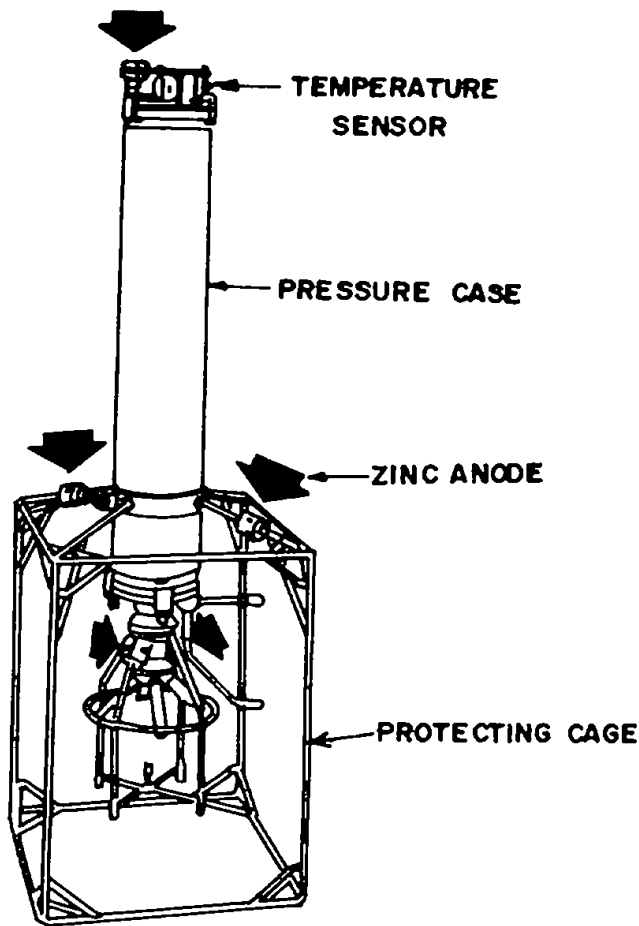


Fig. 8 — Simrad UCM-30 ultrasonic currentmeter

logic control circuits. The UCM-30 can be moored up to a maximum depth of 500 m either in 'I' or 'U' mooring.

Measurement of tides

The variation of tide level determines the location of various shore-based structures, harbours, jetties, etc.

(A) *Aanderaa water level recorder WLR-5* — The aanderaa water level recorder WLR-5 (Fig. 9) contains a quartz clock which triggers at preset time intervals, a 9V non-magnetic battery and 0.25 in magnetic tape recorder to record the data. The pressure and temperature sensors and acoustic transducers are mounted on the surface of the equipment [2]. Paroscientific pressure sensor model 2400A/2900A is used in this system. It has an accuracy 10 times better than that of regular pressure sensors. The temperature transducer is a thermistor. WLR-5 can be moored in vertical or horizontal direction by mounting it on a permanent fixture to be rested on the ocean floor, or it can be moored in any chain of other oceanographic equipment up to a maximum depth of 270 m.

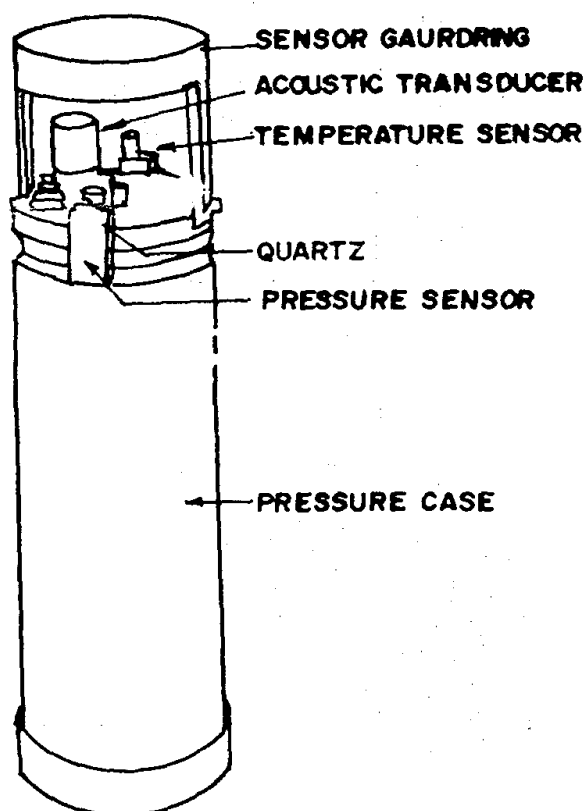


Fig. 9 — Aanderaa water level recorder WLR-5

(B) *Interocean wave and tide gauge* — This system is used as described earlier, under “Non-directional wave measurement”.

Measurement of meteorological parameters

Aanderaa automatic weather station — The aanderaa automatic weather station DL-2700 (Fig. 10) is a self-recording 12 channel data logger which contains a 9V battery, magnetic spool for recording various parameters, such as wind speed, wind direction, relative humidity, air temperature, air pressure, rainfall, ground temperature, radiation, etc. The data logger is housed in a rectangular box. The sensors are mounted on the top of a mast. From sensors, a cable runs up to the data logger to record the individual parameters.

A new system, aanderaa automatic weather station 2700, contains a data storing unit (DSU), a sensor scanning unit to read a set of data and to transfer the same to DSU and an RS232 port to connect any IBM compatible PC, computing unit to process data and display in engineering units. In addition to a 9V battery back-up, a solar cell power module is attached for continuous power supply to the system. The system has provision for VHF transmission and receiving equipment for

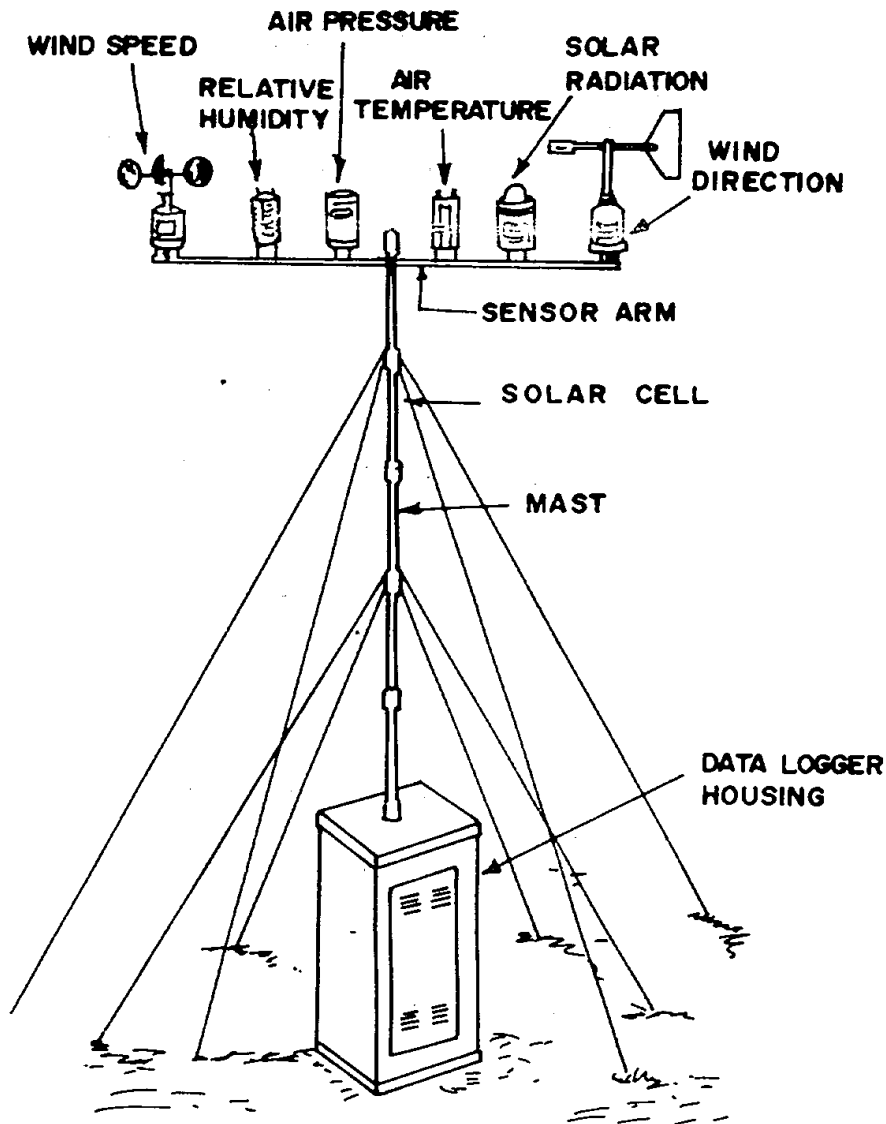


Fig. 10 — Aanderaa weather station DL-2700

remote operation. The weather station has to be installed in a place where there is least disturbance due to the surrounding environment.

Acoustic release

Oceano-acoustic release — The oceano-acoustic release RT-161 (Fig. 11) is designed for operation up to 6000 m water depth and is powered by 18 D type of cells and two 6F22 type 9V cells [13]. The releases are recoverable transponders which can execute acoustic remote controls, such as Enable, Disable and Release. They use CMOS technology to reduce power consumption to the minimum. This

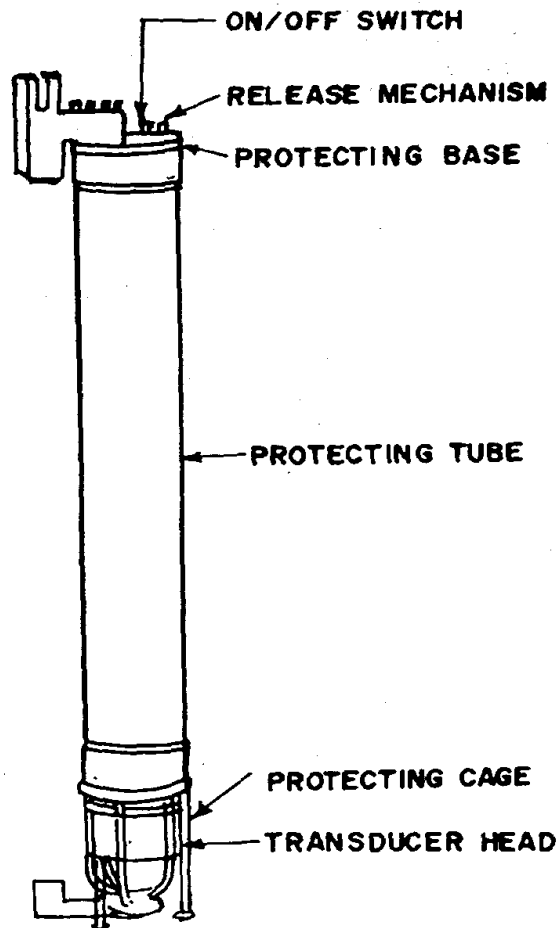


Fig. 11 — Oceano-acoustic release RT-161

is of 95 cm length and 13.2 cm diameter and is controlled by a deck unit model TT 201. The deck unit is connected by an acoustic hydrophone and the release transponder can be controlled by sending predetermined commands for enable, disable, range and release operations.

Depth measurement

Simrad echosounder-EY — The simrad echo sounder (Fig. 12) consists of a control cabinet with recorder/transmitter and receiver, and a transducer in a plastic blister mounted in a frame suitable for lowering from the fishing trawler [15]. The echosounder works on 12V battery and its power consumption is 25 W. The transducer 74AA is designed with an opening angle of 27° . The transducer element is of ceramic type with about 7.6 m cable permanently connected. The use of echosounder is necessary to know the bottom topography of the area of deployment of the equipment.

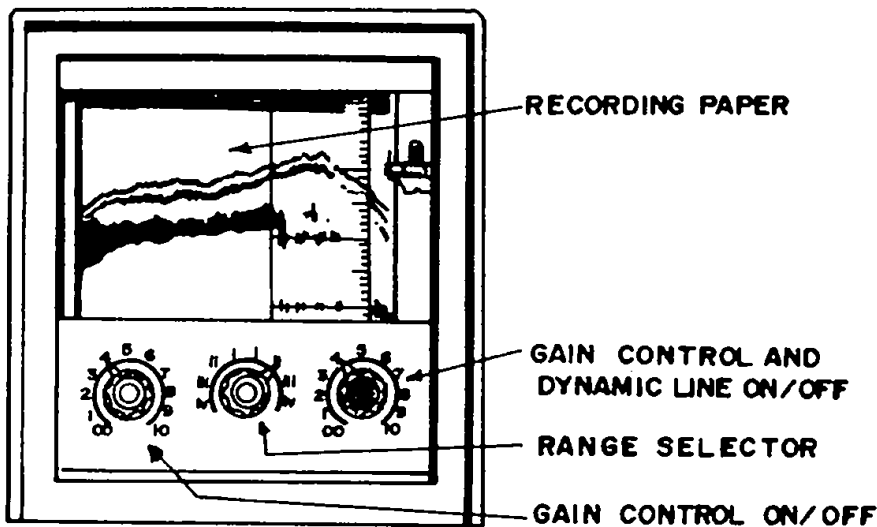


Fig. 12 — Simrad echosounder EY

PRINCIPLES, CALIBRATION AND SOFTWARES

Datawell waverider buoy

Principle — The accelerometer sensor senses vertical motion of the buoy. The acceleration signal is double integrated giving a displacement which is related to wave height. The DC signal analog of wave height is converted to FM square wave signal with frequency 259 Hz at zero wave height. It varies by 1.86 Hz per metre deviation of water surface. This FM square wave modulates the transmitter, whose frequency lies between 27.5 to 28 MHz with 80 mW transmitter power dependable reception over 50 km (over sea) is obtained.

Calibration — To calibrate the overall waverider system, it is necessary to give the buoy a precisely known vertical motion or a circular motion with the rotational axis in the horizontal plane. An accurate way of doing the latter is by placing the waverider on the rim of a wheel in such way that the waverider keeps its position vertical during rotation of the wheel (Fig. 13). A simple calibration can be carried out by suspending the waverider on the rubber cord and maintaining constant vertical oscillations. This vertical motion is measured precisely on a scale and compared with the displacement given by the WAREP recorder. The error is incorporated while analysing the data.

Software — The software supplied by the manufacturers for DIWAR interfaced to IBM compatible PC computes spectral plots of energy density and other parameters like H_s -significant wave height, H_{max} , T_z -zero up-crossing wave period, T_{Hmax} -wave period corresponding to maximum wave height, e -spectral width parameter, S_t -wave steepness, T_p -peak period associated with maximum spectral density, E_m -maximum spectral density, and Q_p -peaked parameter.

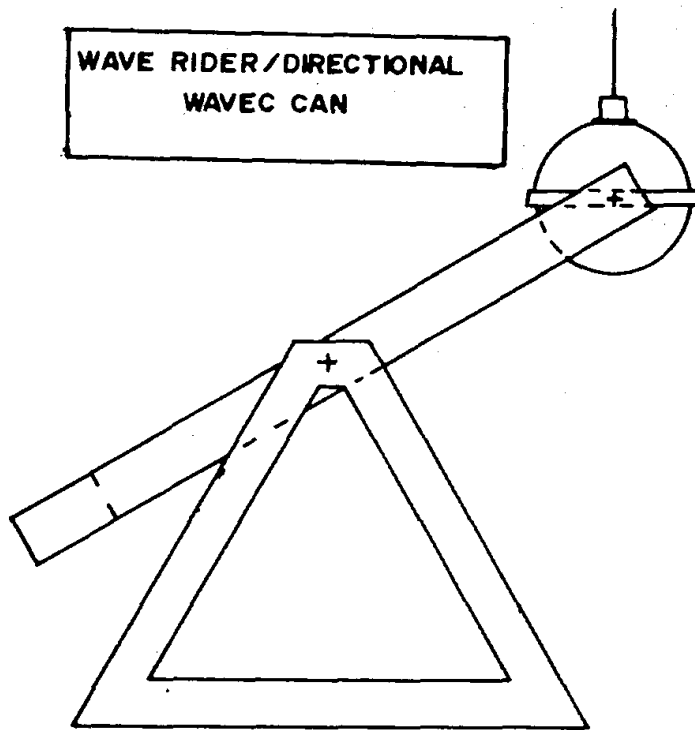


Fig. 13 — Typical calibration system for waverider/directional waverider/wavec can

Interocean wave and tide gauge WTGS4

Principle — The sensor is a temperature compensated silicon semiconductor strain gauge. Tide sensor is a 60 m full scale sealed reference transducer. Wave sensor is a ± 10 m differential transducer. Sensors are isolated from seawater by an oil filled chamber with 10 cm diameter diaphragm. The system is insensitive to clogging due to biofouling or silting. The measuring range of tide is 0 to 20 m and wave is ± 10 m. A low pass hydraulic filter of 16 min time constant at sea level makes measurements insensitive to mounting orientation. It filters wave influence on the tide sensor and also provides depth compensation for wave sensor.

Calibration — After long use, the instrument can be calibrated in wave tank.

Software — Software supplied by the manufacturers, WTGAPP, computes average wave height, maximum wave height, significant wave height, average wave period and tide information.

Datawell wavec buoy

Principle — Hippy-120 sensor measures heave, pitch and roll. The accelerometer sensor measures the acceleration of the wave and twice integration of acceleration gives heave, the vertical motion.

Pitch-roll — An alternating magnetic field H1 is generated parallel to the pitch axis and another field H2 at different frequency parallel to roll axis by means of

two coils A and B fixed to housing perpendicular to each other [7]. This gives slope north and slope west and direction can be derived from this information. A three-axis fluxgate compass derives reference north with respect to buoy orientation.

Calibration — It is same like waverider buoy calibration system.

Software — The directional receiver (DIREC) is interfaced to IBM compatible PC. The software gives parameters, such as energy density spectrum, mean direction and beam width with frequency, wave parameters, such as Hs-significant wave height, Tz-zero up crossing period, Tm-mean wave period at spectral peak, Em-maximum spectral density, Dm-wave direction at spectral peak, Qp-spectral peaked parameter, St-wave steepness, e-spectral width parameter, S.N- Slope of water surface south north, and S.W-Slope of water surface east-west.

Datawell directional waverider buoy

Principle — The directional measurement is based on the translational principle which means that horizontal motions instead of wave slopes are measured. As a consequence, the measurement is independent of buoy roll motions and, therefore, a relative small spherical buoy can be used. The on-board microprocessor enables calculations in the buoy. From the accelerations measured in the X and Y directions of the moving buoy reference frame, the accelerations along the fixed, horizontal, north and west axes are calculated. All three accelerations (vertical, north and west) are then digitally integrated to displacement and filtered to a high frequency cut-off at 0.6 Hz.

Calibration — For heave calibration refer waverider calibration system. To test and calibrate pitch-roll sensors, it is necessary to give the directional waverider a well-defined rotation around X-axis or the Y-axis. For this, a barrow like test frame with directional waverider stays stable in three positions can be used.

Software — The Wavedirection receiver (WAREC) is interfaced to IBM compatible PC, which controls data logging and processing. Using software supplied by the manufacturers, the data measured are spectral density, wave direction, bandwidth spectrum, Hs, Tz, data quality report, battery condition, and sea surface temperature.

Interocean currentmeter S4

Principle — The S4 currentmeter measures current by creating a magnetic field and sensing the voltage induced by the movement of water through the field. A CMOS microprocessor acquires instrument orientation from a fluxgate compass and computes earth reference current components in north and east co-ordinates. These current vectors are then recorded immediately (burst sample mode) or integrated over time and recorded (vector averaged mode).

Software — The S4 currentmeter is interfaced with IBM compatible PC through S110 interface. Using the software, the S4 currentmeter can be put ON or OFF, and data can be retrieved from the solid state memory. The software gives

the data in tabular or graphics form. It can be analysed for various statistical parameters for current speed, current direction, wave and wave direction and waterlevel variations.

Aanderaa currentmeter

Principle — Temperature can be measured by a thermistor, conductivity by electrodeless induction type conductivity cell, pressure by a potentiometer driven by a bordon tube, direction by a magnetic compass and speed by a rotor. These sensors are part of R-2R bridge network. A typical R-2R network is shown in (Fig. 14).

Calibration — The current speed and direction are calibrated in a towing water tank. The trolley speed is a measure of current speed and at the same time the currentmeter records current speed. The correction can be applied. Similarly, direction can be calibrated in the tank. Conductivity, pressure and temperature are calibrated in a separate STD bath.

Software — A separate Aanderaa tape reader 2650 is interfaced to IBM compatible PC to read the data recorded on magnetic tape. The associated software supplied by the manufacturers, P3059, transfers the data from tape to PC and analyses the data in statistical format. It gives different plots for all parameters.

Simrad ultrasonic currentmeter UCM-30

Principle — This currentmeter works on the travel time difference principle (Fig. 15), exploiting the interaction effects between a moving fluid and acoustic waves.

By exciting two piezoelectric transducers with sharp voltage steps of approximately 300 V at a repetition rate of typically around 20 excitations per second simultaneously, each of the transducers generates bursts of high frequency ultrasound, typically 4 MHz, at the same repetition rate [16].

If the transducers, the active parts of which are small discs of piezoelectric material, stay in the fluid at an internal horizontal distance I , it can be shown that the time difference ΔT between up and down stream sonic travel times, t_1 and

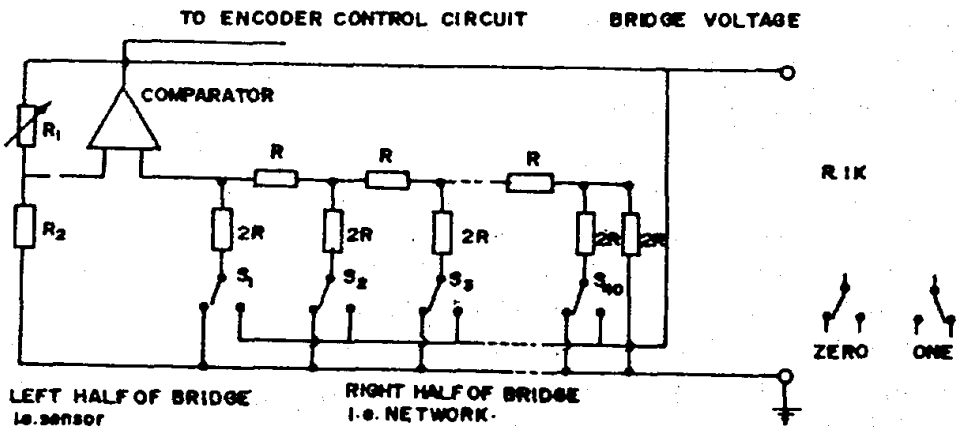


Fig. 14 — R-2R network measuring bridge

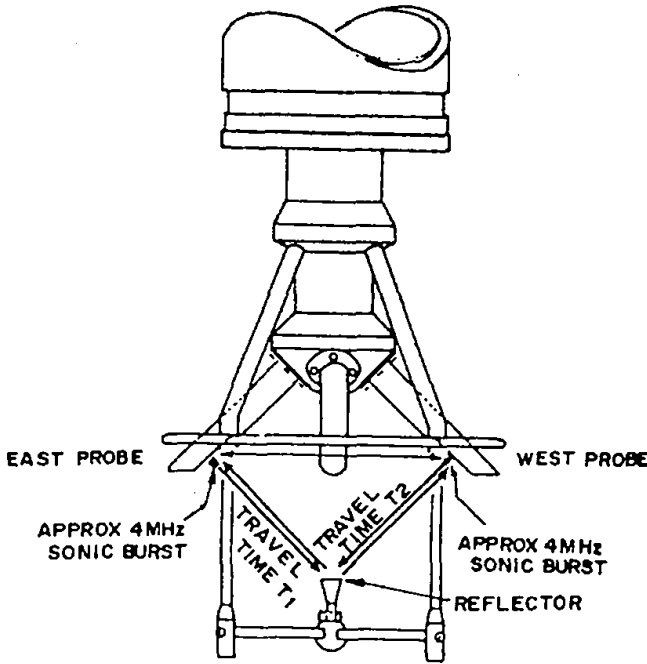


Fig. 15 — UCM ultrasonic currentmeter measuring principle

t_2 respectively, corresponds to the mean flow velocity along the sonic path according to the equation:

$$t_2 - t_1 = \Delta T = 2.I.V/C^2$$

where

I = the horizontal projection of the sound path

V = the mean flow velocity component along the acoustic path

C = the sound velocity through the fluid.

Calibration — It can be calibrated like any other currentmeter for various parameters.

Software — The recorded data cassette is run on a Simrad UCM-RT currentmeter tape reader model P1518E interfaced to OSBORNE computer. The software associated with the system reads data and presents it in HEX/DEC/ENGG units. It also checks the quality of the data and presents quality in percentage.

Aanderaa waterlevel recorder

Principle — The pressure sensor is a pressure controlled quartz crystal oscillator. When pressure is applied to the sensor, it shifts the frequency of oscillation. The shift in frequency is a measure of pressure. The temperature transducer consists of a thermistor located at the top end plate. It is associated with an oscillator circuit, which is included in the electronic board. The oscillator changes

Table 1- Equipment Used at Different Locations

Name of equipment	Location of operation	Duration of operation in months	Parameter
1. Datawell waverider buoy	Off Goa, Daman, Umbergao, Machilipatnam, Kakinada, Bombay High, Uran, Hazira, Kandla, Narsapur, Portnova, Jaitapur, Chilka Lake, Karwar, Dahanu	3, 6, 5, 7, 15, 9, 4, 6, 10, 10, 5, 11, 11, 23, 7	Non-directional wave
2. Interocean wave and tide guage WTG S4	Off Karwar, Chilka Lake	3, 3	Non-directional wave and tide
3. Datawell WAVEC buoy	Off Karwar, Dahej	48, 5	Directional wave
4. Interocean S4 currentmeter	Off Karwar, Chilka Lake	3, 3	Directional wave and vector averaging current speed and direction
5. Aanderaa current meter	Off Daman, Umbergao, Bombay high, Jaitapur, Karwar, Madras, Machilipatnam, Vishakhapatnam	3, 3, 1/2, 1, 2, 1, 1, 1	Temp cond, pressure, direction, and speed
6. Aanderaa water level recorder	Off Karwar, Jaitapur	1, 1	Tide, temp
7. Aanderaa weather station	At Daman, Hazira, Kavaratti	6, 6, 5	Wind speed, wind dirn, air temp, air pressure, rel. humidity, solar radiation, rain fall
8. Acoustic release	Off Daman, Umbergao, Madras, Machilipatnam, Vishakhapatnam	3, 3, 1, 1, 1	
9. Simrad echosounder	Off Goa, Daman, Umbergao, Machilipatnam, Kakinada, Kavaratti		Water depth

Table 2 — Equipment Mooring Configuration

	Name of equipment	Water depth	Type of mooring
1.	Datawell waverider buoy	a) >10 meters b) <10 meters	Single point mooring 'U' mooring
2.	Interocean wave and tide gauge WTG S4	Max. 20 meters	Bottom mounting in 'I' or 'U' mooring or attachable to any fixed offshore structure
3.	Datawell WAVEC buoy	>10 meters	Single point mooring
4.	Interocean S4 currentmeter	Max. 70 meters	'I' or 'U' mooring or attachable to any fixed offshore structure
5.	Aanderaa current meter		
	RCM-4	Max. 2000 meters	'I' mooring in deeper water
	RCM-5	Max. 6000 meters	'U' mooring in shallow water subsurface mooring
6.	Aanderaa water level recorder	Max. 270 meter	'I' mooring in deep water 'U' mooring in shallow water or attachable to any fixed offshore structure
7.	Directional waverider buoy	< 35 meters >35 meters	'U' mooring Single point mooring
8.	Simrad UCM30 currentmeter	Max. 500 meters	'U' or 'I' mooring
9.	Oceano-acoustic release	Max. 6000 meters	It can be accommodated in all types of moorings at anchor end

its output frequency as the resistance of the thermistor varies. At -3°C , the output frequency from the temperature transducer is 2048 Hz and at 35°C it is 4096 Hz.

Calibration — The instrument can be calibrated in a special environmental chamber similar to salinity, temperature, depth (STD) bath.

Software — The software P3059 explained in Aanderaa currentmeter can be used for analysis of data.

Aanderaa automatic weather station

Principle — A 12 channel data logger/scanning unit scans and reads a set of aanderaa sensors. It contains a 12 channel multiplexer, an R-2R network (Fig. 14) for analog to digital conversion and a digital control system which includes a microprocessor.

The R-2R network converts the sensor signals by successive approximation into raw data words in a 10 bit binary, which are fed to the PDC-4 and RS 232C output port.

Calibration — For calibration of wind speed, wind direction, air pressure, air temperature and relative humidity, the facilities available at India Meteorology Department, Pune, are used. Software P3059 is used for computation of data. For this DSU is connected to a DSU reader which in turn is interfaced to IBM compatible PC. This software analyses data in engineering units. The same software can be used for the data recorded by DL2700 on magnetic tape using Aanderaa tape reader 2650 interfaced to IBM compatible PC.

Simrad echosounder

Principle — The transducer is made of a ceramic material having the property of converting electrical energy to sound energy and *vice versa*. When an AC voltage (transmitter pulse) is applied to the transducer element, it generates sound waves in the water. When exposed to the reflected sound waves, the transducer element produces an electrical signal voltage, which is applied to the receiver. After amplification in the receiver, the signals are recorded in the echogram by means of the recording pen.

DISCUSSION

The equipment described above have been operated at various places off east and west coasts of India. The wave and current measuring activities started in early 1980 by using Datawell waverider buoys and Aanderaa currentmeters. With growing need for collection of information on directional wave, current, tide and meteorological parameters for ocean engineering applications, various sophisticated equipment as described above were procured and are being used to cater to the need of various agencies like ONGC, CEA, EIL, BPCL, INDIAN NAVY, IPCL and different port trusts. The locations at which various parameters collected using these equipment are given in Table 1. The successful time series data collected on these parameters has saved considerable amount of foreign exchange. The appropriate methodology for selecting various equipment and its mooring configuration is given in Table 2.

ACKNOWLEDGEMENT

The authors are grateful to Dr. B.N. Desai, Director, NIO, and Dr. B.U. Nayak, Head, Ocean Engineering Division, for their keen interest and encouragement.

REFERENCES

1. **Aanderaa Instruments.** 1981. Recording Current Meter Model 4 & 5: Operating Manual, Bergen, Norway.
2. **Aanderaa Instruments.** 1984. Water Level Recorder Model 5: Operating Manual, Bergen, Norway.
3. **Aanderaa Instruments.** 1990. Automatic Weather Station 2700, Data Sheet D152, Bergen, Norway.
4. **Datawell bv, Waverider 6000 series.** 1983. Operation and Service Manual for the Waverider, Haarlem, Netherlands.
5. **Datawell bv, WAREP Mark II-F.** 1979. Manual of Waverider Receiver, Haarlem, Netherlands.
6. **Datawell bv, DIWAR.** 1985. Manual of Digital Waverider Receiver, Haarlem, Netherlands.
7. **Datawell bv, WAVEC Buoy.** 1986. Manual for WAVEC Buoy, Haarlem, Netherlands.
8. **Datawell bv, Directional Waverider.** 1990. Operation and Service Manual for Directional Waverider, Haarlem, Netherlands.
9. **Datawell bv, WAREC.** 1990. Manual for the Wavedirection RECeiver, Haarlem, Netherlands.
10. **Diwan, S.G., A.K. Suryavanshi and B.U. Nayak.** 1989. Operational Experiences of Datawell waverider buoys: 193-199. La mer 27, Tokyo.
11. **Inter Ocean Systems, Inc.** 1987. S4 Current Meter: User's Manual, San Diego, USA.
12. **Inter Ocean Systems, Inc.** 1989. Wave and Tide Guage Model WTG/S4 version 3.11: Operation Manual, San Diego, USA.
13. **Oceano Instruments.** 1979. Acoustic recoverable Transponder, RT 1X1: Technical Notes, Antony CEDEX, France.
14. **Oceano Instruments.** 1981. Acoustic Telecommand TT201: General Technical Notes, Antony CEDEX, France.
15. **Simrad EY, Echo Sounder Model P845E.** 1977. Operator's Manual, Horten, Norway.
16. **Simrad Optronics.** 1983. Ultrasonic Current Meter UCM-30: Operator's Manual, Oslo, Norway.