A WAVE POWERED PROFILER FOR LONG TERM MONITORING

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I - Abstract

The collection of periodic profiles of oceanographic data at specific sites is a critical component of oceanographic monitoring programs. Typically, this type of work is completed by lowering instrumentation from ships but the cost of these operations has often meant that the temporal and spatial coverage of these surveys is less than ideal. As an alternative, moored profilers have been developed but the energy required to move a substantial package up and down a mooring wire can represent a major limitation.

A simple, economical and autonomous device to accomplish the task of completing a large number of profiles in a moored or drifting configuration has been developed at the Bedford Institute of Oceanography. This system overcomes the limitation of previous self-contained profiling devices by deriving the power needed to move vertically in the water column from the energy of surface waves. A one way clamp provides the mechanism by which wave action acting on a surface float sends a buoyant instrument package down a mooring line. Once at the bottom and when a profile is desired, the clamp is released allowing the instrument to float to the surface.

Some data from field trials as well a description of the principle of operation of the device are presented.

II - Introduction

It has long been recognized that using one instrument package to sample vertically through the water column to obtain a complete profile produces a highly desirable data set for oceanographic research. A wide range of ship-borne devices are in use on most oceanographic vessels which are capable of returning high resolution profiles from the shallowest of areas to great depths. However, occupying such stations over extended periods of time with a surface vessel is costly and as a consequence, the task of obtaining long time series data sets falls to self-contained instruments mounted on oceanographic moorings. Data recovered by this method, for the most part, is discrete in nature with instruments placed at depths of interest and giving only a partial picture of the complete profile of physical properties. Sampling density may be improved by increasing the number of instruments in the mooring but this is a costly alternative which also increases mooring complexity and potential for failure.

In an attempt to combine the continuous nature of ship-borne measurements with the long term capabilities of instrumented moorings, a class of instruments known as profilers has been developed. These instruments have met with varying degrees of success and acceptance and have employed various types of driving systems (1 - 5). In almost all cases, the operative word when describing the action of a profiler is "drive" since energy must be expended to get the device to rise or fall in the water column. The deeper the device travels and the longer it is intended to stay on station the greater is the impact of this energy requirement and its effect on the size of the system.

To meet a program requirement at BIO for long time series data from the near surface to near bottom of Davis Strait, the profiler concept was considered. However, the operational depth combined with required operational life, driven by the remoteness of the area, meant that conventional designs would be inadequate for the task. As design alternatives were being evaluated, a new method for powering a profiling device was discovered.

III - The Concept

The surface of the ocean is seldom still, particularly in the higher latitudes. It is possible to take advantage of this surface perturbation, in conjunction with the mass of a submerged body, to utilize a practical energy source for propelling a sampling system up or down a vertical cable on a regular basis. This concept employs the fact that a submerged body has, besides its own intrinsic mass, an added mass which represents the mass of fluid entrained by the body. This added mass can be significantly greater than the mass of the body itself. When a force acts on this submerged mass, it will be accelerated in the direction of that force or conversely, if the submerged mass is moving, it will continue to move unless acted upon by

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configuration. The design is now at a stage where operational instruments are being evaluated as part of a package intended for an operational oceanographic program.

IV - Final Design and Operation

The profiler is a self-contained system. The program which controls the operation of the device consists of a "C" program which resides on an ONSET (Pocasset, MA) Model 8 data logger/controller. A menu driven sampling scheme is established prior to deployment of the device including such parameters as "Top Trigger Depth", "Bottom Trigger Depth", "Cycle Period".

The preset top and bottom cycle endpoints are controlled by monitoring the output of a pressure transducer mounted in the control electronics housing. When the device hits the top trigger point, an electric motor, connected to an instrumented cam, is energized to engage the one way cable clamp causing the profiler to "climb down" the cable to a mechanical stop. External instrumentation is turned off during this part of the cycle and throughout the contiguous "sleep" cycle. Depth may be monitored during the climb-down cycle for engineering design purposes, but in a fully operational configuration the system would enter a low power mode until the start of a new cycle.

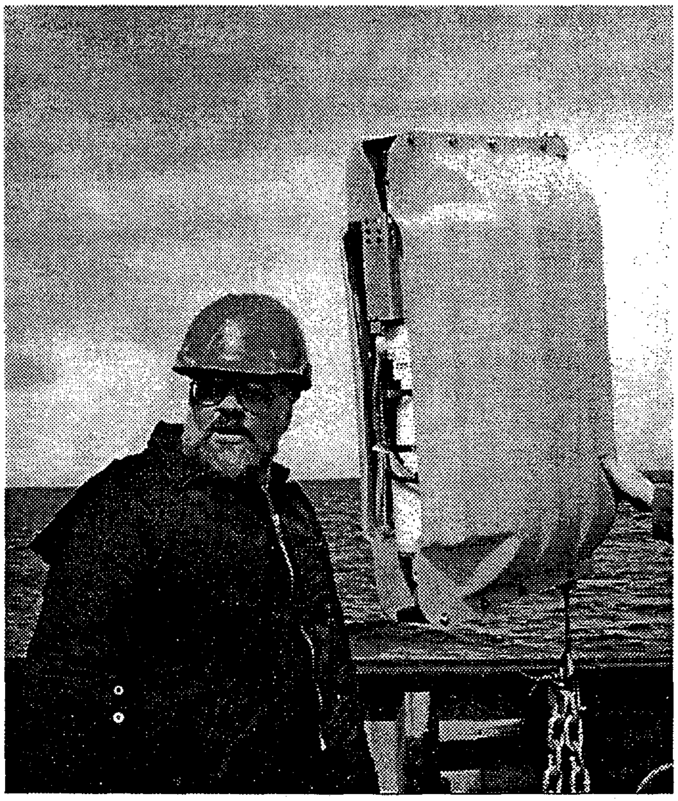

Fig. 3, The "Seahorse" Profiler showing the opening at the back where sensors are mounted.

While the range of instrumentation that the profiler is capable of carrying is not fixed, the current suite which is intended primarily for estuarian research consists of a Seabird (Bellevue, WA) Model SBE #19 (SeaCat) pumped CTD, plus WetLabs (Philomath, OR) fluorometer and SeaPoint (Kingston, NH) turbidity sensor. A major characteristic of any payload will be its actual weight in water. With the present buoyancy this limit should be in the order of 56 Newtons.

The latest package configuration is shown in Figures 3 and 4. The main buoyancy is one large spherical float which provides 120 Newtons of buoyancy. If a heavy payload is anticipated, a second smaller sphere giving an additional 24 Newtons of buoyancy may be fitted. There are two pressure cases; one for batteries and one for system electronics including the electric motor and cam control. A central framework supports all the various components including mooring line roller guides, the instrument payload and acoustic link transducer. The whole system is enclosed in a protective plastic housing which measures .59m wide x .94m high x .37m thick. In air, the package weighs 47 kg. and when submerged has an added mass of approximately 150 kg. With its current suite of sensors and in its current configuration, the profiler is capable of a six month deployment, completing cycles every four hours to a depth of 50 m. These operating characteristics should not be interpreted as limit values. The depth of excursion is easily modified with limits set only by the parameters of the mooring design and the working depth capability of the pressure cases and buoyancy.

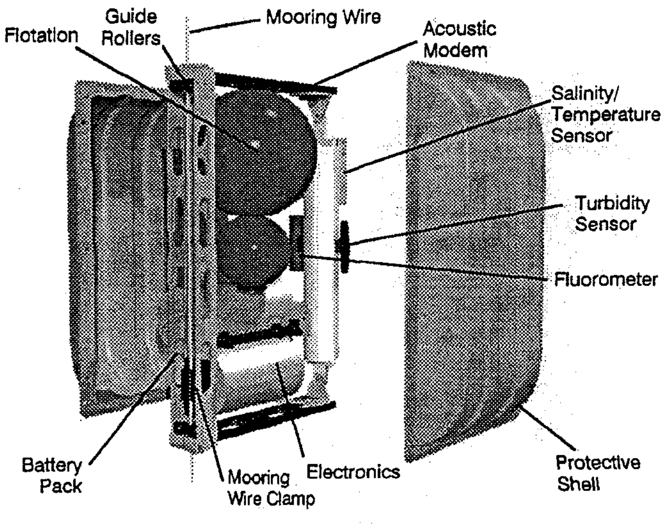

Fig. 4, Internal components of the "Seahorse" Profiler

This unit was deployed on a mooring at the Panuke oil field near Sable Island Bank on the Scotian Shelf and successfully completed 33 profiles to 30m with a cycle period of 2 hours. A typical pressure record showing part of the two and half day deployment is shown in Fig. 5 where the positively buoyant body is "pulled down" to the bottom of a cable with active oceanographic parameter sampling occurring during the buoyancy driven rise part of the cycle. This alternative was chosen because of the smoothness of the upward trip and also because it provides an opportunity to "sleep" the system at the bottom where biological growth and orbital wave motion is at a minimum. Since the instrumentation is only powered-up during the rise cycle, which is a relatively small fraction of the overall operation, the power consumption is kept to a minimum. The internal buoyancy was set at 24 Newtons. During the period of deployment, winds varied from light to 30 knots and seas from 0.5 to 2m. Of note in the diagram is the aggressive way that the profiler climbed down the mooring line with speeds ranging from 8.6 to 15.7 metres per minute. Rise speeds were consistently around 27.3 meters per minute and were exceptionally smooth which indicates that it is an excellent platform for taking oceanographic measurements.

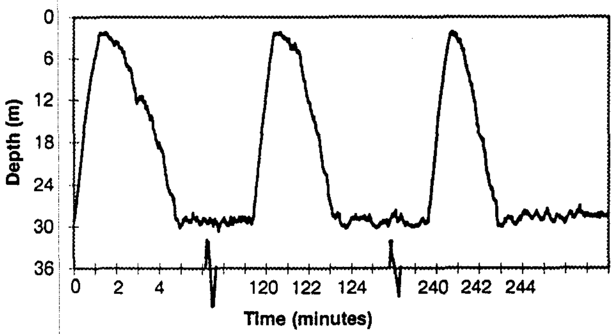

Fig. 5, Typical vertical motion of profiler from mooring on the Scotian Shelf showing Cycles 4, 5 and 6.

The data recovered by the profiler mounted Seabird CTD from cycle number two is shown in Fig. 6. Data from a Seabird CTD cast from the ship conducted at the same time is in excellent agreement.

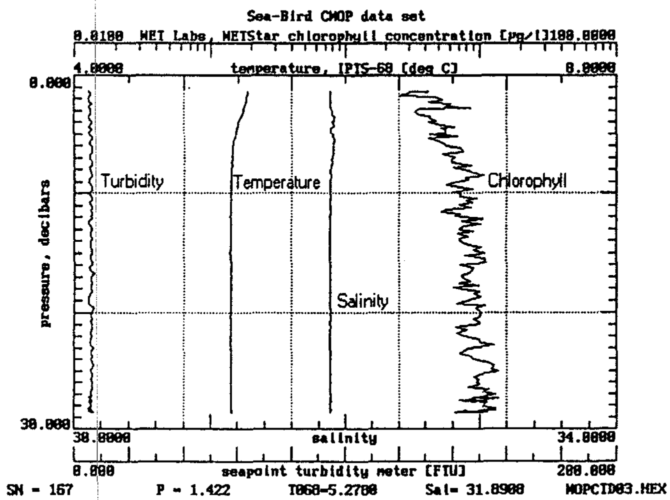

Fig. 6, Profiler Cycle #2, Seabird CTD, Turbidity Sensor and Fluoromter data from mooring on Scotian Shelf

Currently the profiler is moored in Bedford Basin and at time of writing has completed 180 sampling cycles. To evaluate performance, buoyancy is set at 40 Newtons so it is anticipated that all cycles will not complete the 30m programmed depth excursion due to very light wave conditions.

V - Future Plans

The concept has been patented and a manufacturing and marketing license has been awarded to Brooke Ocean Technology of Dartmouth N.S. who are producing the equipment under the tradename "Seahorse". It is anticipated that joint operations between BIO and the company to extend the operational capabilities of the system will continue.

The profiler will be operated in local waters for most of the summer of 1997 to monitor long term reliability of components. Frequent checks on the system will be made along with adjustments, notably the buoyancy, to evaluate performance under different operating conditions.

Tests to date indicate that wear in the clamp mechanism may lead to diminished performance so different materials and configurations will be tried. In particular the clamp will be modified to reduce the impact of very large waves by incorporating a mechanical acceleration limiter. Since the profiler has such a large payload capability, both in size and mass, different sensor suites such as an optical plankton counter, optical characteristic sensors and water velocity sensors will be evaluated for possible adaptation.

Immediate scientific operations include the occupation of a station at the mouth of Halifax Harbour as part of the Department of Fisheries and Oceans Zonal Monitoring Program and an installation at Country Harbour N.S. as part of an environmental impact study prior to a commercial development in the area.

Acknowledgement

In the creation of any new device, contributions are received from many people whose only interest is in helping to achieve a successful conclusion to a project or simply to offer help to a colleague. In this endeavour we have been extremely fortunate on both counts and the authors would like to thank Roger Cassivi, John Conrod, Steve DeBelie, Jean-Guy Dessureault, Murray Eisan, Dave McKeown and Simon Prinsenberg for their interest, support and contributions.

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References

1: John Van Leer et al, "The Cyclesonde", Deep Sea Research, 1974, Vol 21, pp 385-400.
2: John M. Dahlen and Shillingford, J.T., "An Upper Ocean Moored Current and Density Profiler Applied to Winter Conditions Near Bermuda", Journal of Geophysical Research, 1982, Vol 87, No. C10, pp 7879-7902.

3: C.V. Nelson, Chappell, R.G., “An Automatically Profiling Temperature Sensor for Upper Ocean Measurements”, Proceedings Oceans ‘82, pp 277-282.
4: Douglas C. Echert et al., “The Autonomous Ocean Profiler: A current-Driven Oceanographic Sensor Platform”, IEEE Journal of Oceanic Engineering, 1989,Vol 14, No. 2, pp 195-202.
5: R.E. Davis et al., “The Autonomous Lagrangian Circulation Explorer”, 1992, Journal of Atmospheric and Oceanic Technology, Vol 9, pp264-285