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SPAR BUOY OCEANOGRAPHIC TELEMETRY SYSTEM OPERATIONAL MODIFICATIONS

E. DIVIS, T. HOPKINS, V. PFEIFFER, AND D. CARLSON

December 1979

OCEANOGRAPHIC SCIENCES DIVISION
DEPARTMENT OF ENERGY AND ENVIRONMENT

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ABSTRACT

Complete velocity field measurements in the open ocean have to date suffered from the lack of real time fixed reference points. In the past, difficulties have been experienced with near shore standard current measurement instrumentation sampling techniques. However, a great many difficulties are also encountered with near shore current measurements because of the problems encountered in designing an ideal instrument which would be able to record the whole spectrum of sampling interests, such as current, temperature, conductivity and wave recording. Records of longer duration, spar buoy deployment are being effectively used at Brookhaven National Laboratory using remotely controlled real-time telemetry transmissions from in situ electromagnetic sensors, monitored and continuously averaged over long periods of time (i.e., in the range of hours, days, or weeks). With this system, it is possible to avoid the probability of distortions being introduced by standard sampling techniques. The present system, including various modifications has been in operation since late 1976 with a record of 90 to 99% recovery of countless units of data points, also confidence in the reliability of data output has increased along with the data recovery.

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I. INTRODUCTION

Brookhaven National Laboratory has been deploying Spar Buoy Oceanographic Telemetry Systems in coastal waters off Shinnecock, New York, since 1976. To be able to judge effectively the relative values of new offerings we must have in mind basic standards, for a known figure is of no value unless it is compared to a known value.

In this report, the mechanical and electronic performance of the Spar Buoy System, SBOTS (Spar Buoy Oceanographic Telemetry System), is evaluated, with special reference to modifications and repairs that have enhanced the probability of continued success, both in operational deployment and data recovery (previously reported by Dimmler, Rankowitz et al.¹).

To invest the SBOTS system with a reliability which would anticipate all possible hazards would be desirable, although impossible; as an adjunct to this goal we present a brief description of the repairs, modifications, and changes which have been initiated to increase reliability during deployment.

II. MECHANICAL SYSTEM

Mechanically, the Shelton Spar Buoy* is a connectable, segmented, buoyant structure consisting of 2-1/2-in. standard PVC pipes of appropriate lengths with patented "J"-lock interconnections on which electromagnetic oceanographic sensing devices may be mounted. The spar buoy is capable of standing vertically in a water column and providing a nonrotating linear support for instrumentation. The system presented here has a 5-instrument array plus the data processor (the heart of the system) mounted in protective cages coaxially within the overall length of the segmented system. This system provides a buoyant semirigid member of predetermined length, anchored by the battery container (power supply and anchor).

The original galvanized eye bolt terminations have been replaced with two newly designed identical mating castings of 316 stainless steel, called decouplers. These now form the interconnecting device transmitting the torsional tension loads throughout the length of the spar system. The newly fabricated stainless steel decouplers also provide a corrosion-free interlock attachment and have the added value of eliminating excessive movement or "play" from the linear support.

Compass cages were installed above the data processor within the system, thereby improving reliability and accuracy of heading information; spars were reworked accordingly to provide this conformity.

A safety tie line threading the length of the spar system was added prior to deployment. This served to tether the system to the battery container as protection against instrument loss.

The antenna housing of the spar buoy has been retrofitted to guard against failure of cemented fiber glass joints in heavy seas and inadvertent water leakage into the antenna housing section, with consequent damage to the telemetry transmitter and receiver equipment and loss of data. To negate this risk, a complete rework of the spar antenna section was undertaken which involved isolation of the upper antenna housing from the lower transmitter receiver section with a series of O-ring seals and expansion plugs. In addition, to further strengthen the antenna housing and prevent its rotation within the Type III cage, "clam shell" collars have been devised which are

* Deep Ocean Works Systems, San Pedro, CA.

fastened to the cage assembly by J-shaped threaded rods. These collars are attached via the rods to the cage assembly forming a nonrotating and strengthening feature to the antenna housing assembly.

The power supply consists of 16 lead acid cells with a 349-A capacity at an 8-hr discharge rate.* The batteries are installed within a steel, epoxy-coated container, utilizing a pressure-equalizing-type system. A uniquely designed system, the housing consists of two nested loosely fitted upper and lower sections which when mated provide free flooding about a labyrinth entrance. Prior to deployment, the container is partially filled with mineral oil (Exxon Marcol). The arrangement is such that as the container is lowered seawater enters from the bottom raising the mineral oil ahead of it to form a protective shield above the cell terminal hardware. Flexible battery vent tubes are directed to a trapped air pocket at the domed top of the container for cell venting.

The following procedures have been implemented to further improve the mechanical reliability of the battery system:

1. Batteries are recharged as soon as practicable after launching. This prevents complete discharge of battery cells and possible cell damage.

- 1a. Batteries are recharged as close to launch date as practicable to insure their readiness.

2. Sludged sediment accumulated during deployment is cleaned from the battery container; electrolyte levels of cells are rechecked; hydrometer readings are taken of cell values. All cells are washed with an acid-neutralizing solution of baking soda and water; all cell terminal hardware and connections are cleaned and checked for damage and security.

3. Solid dust caps, electrolyte filler caps have been fabricated to prevent inadvertent leakage of mineral oil into cell electrolytic compartments.

4. Portable battery charger has been designed which provides a trickle charge, "top off" of cells prior to launching, thereby guaranteeing a maximum charge at deployment.

5. External fuses (pigtail, 3 A) have been added externally to battery container for ease of accessibility. Pigtails can be replaced underwater if necessary.

6. Stainless steel bell cranks have been fabricated to replace corroding carbon steel bell cranks.

7. Stainless steel bolts and double nuts have been installed to replace lifting yoke attaching pin previously secured by two "hairpin-type" spring clips which were corroding and causing the attaching pin to shift with possible loss of the spar itself.

III. INSTRUMENTATION

Essentially the instrumentation of the spar buoy system remains as originally conceived, with the exception of modifications and changes added through experience and scientific necessity.

A. Data Processor

The remote station data processor whose function is to service instrument sensors continuously and to reduce data as soon as possible at in situ locations. Through reduction of data in situ, it provides for less use of memory

* Oceanographic Battery Company, Annapolis, MD.

capacity at remote and central stations. The data processor will execute commands as requested by the central command station.

To prevent damage to power supply batteries due to overdischarge, a solid-state voltage cut-out was installed to insure the immediate disconnect of the power supply from the instrument system, in the event that positive voltage falls below 12 VDC. Additional frequency inputs have been added, with discriminator and precounter channels installed to provide for future instrumentation additions.

B. Sensor Packages

The current sensor and the conductivity and temperature sensors are mounted within a housing fabricated from an 8-5/8-in.-diameter PVC cylinder 15 in. long, with end caps at either end. The end cap from which the sensors extend is sealed with an O-ring seal which provides watertight integrity to the housing plus accessibility for maintenance. The compass and tilt instrumentations are mounted in similar housings.

C. Current Sensors

The Marsh McBirney* electromagnetic water current meter is based on the principle of magnetic induction. It can best be described as the interaction of three mutually orthogonal vectors, including the magnetic field, the water velocity and the generated emf., which give the instrument a cosine response, from which the flow rate and direction can be determined.

With the exception of continued calibration and verification runs to substantiate collected data, the only significant modifications to the current sensor have been those to improve reliability.

In order to reduce magnetic drive noise inherent within the current meter, the magnetic ground and signal ground have been modified. This modification consisted of returning the two grounds to the data processor through two independent conductors, thereby reducing the noise level appreciably. Also, a voltage regulator added to the reference voltage supply has considerably improved the zero drift of the instrument.

D. Temperature Sensors

The Ocean Data Equipment Corp.** sensor consists of two thermistors and two precision resistors which produce an output voltage linear with temperature. To date, with the exception of probe replacement and/or maintenance, there have been no significant changes or modifications.

E. Conductivity Sensor

The Ocean Data Equipment Corp. conductivity sensor is an electrodeless, inductively coupled cell consisting basically of a transformer with the water acting as a one turn coupling. The proportion of the drive signal coupled to the output is directly related to the conductivity of the water and the level of the drive signal. Except for routine maintenance and repairs, no significant changes have been introduced into the system.

* Marsh McBirney Inc., Gaithersburg, MD.

** Ocean Data Equipment Corp., Newport, RI.

F. Compass System

The original compass system which proved to be operationally inadequate for accurate data acquisition has been replaced by the Digi-Course* Model 215 Optically-incoded Magnetic Heading Sensor gimbled to accommodate $\pm 45^\circ$ roll and pitch. This provides the buoy system with improved resolution of 1.4 degrees and a repeatability of $\pm 0.7^\circ$, and gives us accurate magnetic heading data for buoy orientation.

G. Tilt System

The tilt system used is a Humphrey Inc.** standard pendulum type with 0.2° resolution, ranges of $\pm 45^\circ$, mounted one per spar buoy within the compass housing, and having an accuracy of $\pm 1.0\%$ static error band.

H. Depth Sensors

Para Scientific Inc.† 4060 digiquartz depth sensors have been added to our present spar data acquisition system. Since these units have a frequency output ranging from 40 H at zero pressure to 36 H at full scale, it was necessary to modify the data processors to accept output of this frequency. The modification consisted of feeding the signal from the sensor to a discriminator, then to a pre-counter. These outputs are then directed to the data subsystems in the same manner as if they were the output of a voltage-to-frequency converter (Figures 1 and 2).

IV. TELEMETRY COMMUNICATIONS

The communications between the central command station and a remote station are accomplished in a command/response dialogue. Using a command transmitter at a frequency of 217 MHz, the central station transmits a command block with a bit rate of 8 H and a block length of 16 words times 32 bits to all remote stations. The command transmission is repeated 128 times bit and frame synchronously for redundancy and verification. The antenna of the central station is mounted on an available meteorology tower, 575 feet above sea level, which allows for a range of about 30 miles within a 90 degree angle. Each remote station receives the command block via a remote command receiver mounted into the fiber glass housing of the in situ spar buoy. If the remote station address matches the command address, the block content is decoded and processed. The 6-watt telemetry response transmitter of the corresponding station then is turned on and a response block of 64 words times 32 bits is transmitted back to the central command station. This has been previously reported by Dimmler, Rankowitz, et al.¹

V. OPERATIONS - DEPLOYMENT AND RECOVERY

Essentially the deployment and recovery procedures remain as originally conceived. The spar buoy is launched and retrieved from the deck of a 135-foot vessel (LCU). Assembly of the spar is completed upon the deck of the vessel prior to deployment and disassembly takes place upon deck after

* Digi Course, Inc., New Orleans, LA.

** Humphrey, Inc., San Diego, CA.

† Para Scientific, Inc., Redmond, WA.

recovery. Certain minor refinements suggested through operating experience have been initiated to shorten the time required for the launching operation. Prior to deployment, the cages are preassembled at Brookhaven National Laboratory. The instrument packages are installed into the cages, all the necessary wiring from the instruments are clamped or taped into position, and the completed cage assemblies are then placed into specially fabricated and numbered wooden carrying cases for protection during shipment to the launch site. In addition, assembly check-out and pressurization of the antenna spar section are completed at this time and it is placed into special handling cradles for transport. At this point, all wiring to the data processor is connected and coiled into place for ease of assembly at spar assembly and deployment aboard the launch vessel. In utilizing this system of preassembly, considerable time (money) is saved during spar buildup aboard the launch vessel.

VI. CALIBRATION FACILITY

How precise are the data obtained in the measurements, what are the sources of error, and how can they be evaluated and minimized? Precision is understood to be agreement among themselves of a series of measurements, calculations, or results.

Information has been accumulated from numerous successful spar deployments and various calibration facilities. Evaluating these results for precise data analysis and avoiding errors that may derive from various sources, such as inherent instrument error and inaccurately calibrated instruments, are necessary for accurate data flow. To date the manufacturers of oceanographic hardware have appeared to keep pace with the rising needs of the oceanographic community; the problems encountered are not with instrumentation, but with the accuracy of the calibration. How precise is the standard, to what degree can it be relied upon, where can an instrument be taken for proper and reliable data standardization and calibration? With these questions in mind we have attempted to build a facility for pre- and post-launch calibration of our instrumentation units for accuracy of data output. It is hoped that problems of error inherent in the spar system stemming from instrumentation mounting problems and torsional rotation along the linear axis of the spar will resolve themselves through the implementation of previously mentioned mating decouplers installed throughout the length of the spar system. Data telemetry problems can be resolved technically through operating experience and modification. Those systematic and random errors involved in current meter output are the problems we are striving to correct through use of the calibration facility, permitting us the privilege of pre- and post-deployment documentation. Zero velocity and gain are documented prior to deployment. Immediately after system recovery we run each instrument in our still tank and flow tank, again documenting the results. In this manner of pre- and post-documentation, we can resolve possible data discrepancies incurred during operational deployment. While the ultimate calibration facility is far from being attained, the attempt at standardization and accuracy of calibration is a step forward toward this goal.

Our present calibration facility consists of a still tank, flow tank, and temperature and conductivity tank.

The present current meter calibration facility consists of a recirculating tank constructed of PVC pipe 10 inches in diameter and 12 feet in length. A 110-VAC motor provides the power for the system. To insure constant voltage

and regulated flow, a constant voltage line regulator was placed into the power circuit. The propeller which provides the flow output is belt driven, and with a step system of pulleys the flow speed of the tank may be regulated to $\pm 2\%$. In order to maintain a fixed water level within the tank, a continuous supply of water is fed into the system from a reservoir mounted atop the tank, permitting it to drain off at a fixed and previously determined level, which assures us of constant levels for our calibration. The data are documented in this manner.

The data processor is used in the same way as in the buoy system; the PDP 11 computer is on the line and the flow tank data are telemetered to the computer via this link in the same manner as if the system were deployed.

The second system consists of a voltage-to-frequency converter, a frequency counter, and a printer. A precision voltage source is used to calibrate the voltage-to-frequency converter. Five data points are taken on each channel of the current meter. Four of these are averaged together to determine the x and y component for each position. The exact positioning of the current meter in the tank is accomplished with an accurately calibrated indexing head containing a positioning pin for each 10 degrees of rotation. The tank speed is determined by running one of two current meters previously calibrated at a calibration facility where the current speed is known to be ± 1 cm/sec. The "standards" have been calibrated at the following facilities: (1) Johns Hopkins University, Baltimore, MD, using their flow tank facility; (2) the USGS Gulf Coast Hydroscience Center, located at the NASA-National Space Technology Laboratories (NSTL) Bay, St. Louis, MS. For unbiased verification of these "standard" (NSTL) calibration runs, the services of Evans Hamilton, Inc., Houston, TX, consulting oceanographers, were used to substantiate and document collected data.

A temperature and conductivity bath was fabricated from a 50-gallon plastic container which has insulation about its outside area for temperature control of the solution. In addition, three stirrers are mounted within the tank to provide constant mixing of the sea water bath. To verify temperature and conductivity, samples are taken periodically, using a calibrated digital quartz thermometer for temperature and a calibrated salinometer for conductivity. In addition to continuous monitoring of the bath for consistency of calibration verification, the temperature and conductivity sensors were calibrated for standardization at Northwest Regional Calibration Center (NOAA), Bellevue, WA. With this information as a standard for our own studies, we have composite studies of real data as opposed to calibrated data to form a basis for calibration accuracy.

VII. LIMITATIONS OF USE

While the SBOTS spar system represents a significant advance in mooring systems and improvements in real-time data collecting, requirement problems have arisen to justify concern about limitations inherent in the system.

1. Line of Sight Range (LOS). At the present time, our communications network is limited to a LOS range of approximately 30 miles maximum, presenting problems of further offshore deployment at greater depths.

2. Problems have occurred during subfreezing temperatures in spar deployment. As previously mentioned, in launching, the spar is trailed from the stern of the launch vessel in a layout position upon the surface of the water. At subfreezing temperatures, the decouplers forming the spar interlocking links have frozen, and as the battery container (anchor) was lowered,

decoupler articulation did not occur, which resulted in undue stress and damage to the PVC pipe in the area, aborting the launch until repairs were completed and temperatures were conducive to a successful launch.

3. Launch vessel requirements - As operational water depths increase and longer spar systems are required, the problem arises of spar "buildup" upon the deck of the launch vessel. Although previously four spars could be assembled in a one- to two-day period, and four spars could be launched successfully in one day, it is logistically impossible to assemble and launch the longer system in a minimum amount of time, partly because deck space is inadequate for spar layout and assembly. Through logistic manipulation this problem has temporarily been overcome, but if spar overall lengths increase further, vessel size will become an important factor towards a "minimum time" successful launch.

VIII. SPECIAL APPLICATIONS AND IMPROVEMENTS

A. Future Applications

The SBOTS system will include satellite communications via central command station and remote stations, providing unlimited applications regarding operating distance.

B. New Instrumentation

Fluorometer deployment for parameters of interest in biological problems such as nutrients, oxygen, and light.

C. Current Meter Model Improvement

Two future models of current meters have been designed and will be launched during the April 1979 MESEX experiment.

1. Marsh McBirney Model 515 water current meter has been redesigned by Marsh McBirney, Inc., not only to provide x-y data, but to include z output for vertical current measurements.

2. Dows/Hopkins current meter, a collaborative redesign of the Davis/Weller current meter, with Deep Oceans Works System and Thomas Hopkins of Brookhaven National Laboratory collaborating on the redesign. The Dows/Hopkins current meter employs four Davis/Weller fan systems with pairs mounted at 90° angles to each other and all fans looking down with respect to horizontal, with 90° between fans on both the vertical and horizontal planes. A compass and a tilt-meter are included to complete the reference to deduce the current velocity and magnitude in three dimensions.

3. Improvements to the remote power systems are presently being investigated. Redesign of battery layout, using the larger 1200-A/hr batteries, installed into the positive side of the circuit, with the smaller 340-A/hr batteries installed into the negative side, should improve power distribution to a point where the probability exists of extending operational deployment to triple its present longevity.

IX. CONCLUSION

The SBOTS system, in conjunction with the Shelton spar buoy, appears to be a viable method for obtaining oceanographic measurements from a fixed platform at LOS distances. With the advent of the satellite communications system, and with added technical implementation and refinements to the system, infinite ranges and depths should be available to the scientific community for obtaining in situ real-time data.

X. REFERENCES

1. Dimmler, D.G., D.W. Huszagh, S. Rankowitz, and J. Scott, A controllable real-time data collection system for coastal oceanography, Proc. Oceans '76 Conf., September 1976, p. 14E.

Figure 1. Important modifications to the Spar Buoy Oceanographic Telemetry System (SBOTS) since May 1977.

Figure 2. Present Spar Buoy Configurations