NEL REPORT 1215

DEPTH REGULATION OF LOWERED OCEANOGRAPHIC EQUIPMENT

Describes an experimental sensor and winch control equipment that eliminates most of the unwanted vertical motion of the suspending cable

C. J. Shipek and E. C. Evans • Development Report 1215 • 27 March 1964

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA 92152 • A BUREAU OF SHIPS LABORATORY

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THE PROBLEM

Investigate Navy problems in sea floor oceanography through suitably devised means, methods, and equipment. Specifically, develop a method for controlling the depth of deep-sea cameras and other oceanographic equipment lowered from floating platforms.

RESULTS

1. An experimental, low-cost, depth regulation equipment has been developed. It consists of a bellows-type depth sensor together with phase and power amplifiers, servo units, and hoist-train equipment previously installed on USS MARYSVILLE (EPCER 857).

2. Dockside tests of the equipment with a small portable electric winch were successful. They indicated that up to 85 per cent of unwanted vertical wire motion can be eliminated when lowering oceanographic devices from floating platforms.

3. Sea tests were not attempted because the sensor and the phase and power amplifiers had not been constructed for normal shipboard use.

RECOMMENDATIONS

1. Investigate the possibility of adapting standard U. S. Navy hoist-train servo systems to depth regulation equipment, in particular on oceanographic winches.

2. Investigate the application of depth regulation and dynamic stress control equipment to various types of military operations requiring the lowering and deep towing of underwater devices.

3. Redesign and package the experimental equipment to provide a portable prototype depth regulator capable of being installed on any standard hydrographic winch for shipboard use. Perform tests under rough sea conditions to substantiate the value of depth regulation.

4. If use of the depth regulator proves successful at sea, install a depth regulator on the dredging winch of the AGOR 5 (USNS DAVIS). This would facilitate the safe handling of heavy transducers and of the NEL Type VII Deep Sea Camera and Survey System, and also make it possible through accurate lens-to-target control to obtain a continuous stereophotographic record of the sediment-water interface.

ADMINISTRATIVE INFORMATION

Work was performed under SR 004 03 01, Task 0539 (NEL L4-1) during the period September 1961 to May 1963. The report was approved for publication 27 March 1964.

The equipment described is covered by U. S. Patent No. 3,088,710 dated 7 May 1963, issued to the authors (see Patent Gazette, Vol. 790, No. 1, General and Mechanical, pages 187-188).

The authors wish to thank E. C. Buffington, E. L. Hamilton, E. C. LaFond, and G. H. Curl for reviewing the manuscript.

CONTENTS

ILLUSTRATIONS

THE PROBLEM OF DEPTH CONTROL

The collection of oceanographic data often requires that underwater equipment be maintained at a constant height above the sea floor or towed at a constant depth below the sea surface level. Measurements of temperature and light intensity, collection of water samples, acoustic ranging and listening with lowered transducers, recordings of wave movement, and underwater photography are some of the operations that require depth regulation.

Varying sea surface conditions, however, impose great difficulty in maintaining depth control. The wind-stirred surface of the ocean causes ships to roll, pitch, yaw, surge, sway, and heave. Figure 1 (adapted from a sketch by R. Marra[1]) shows how wave action moves a vessel.

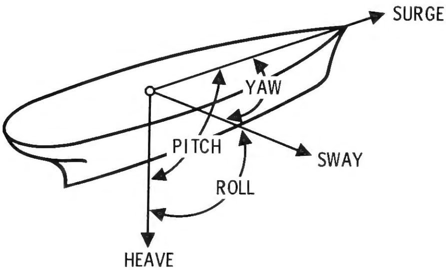

Figure 1. Ship motion.

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1. Pearlman, M. D., "Waves, Ships and Seaworthiness," Sea Frontiers, v. 9, p. 310-316, Christmas 1963

Many attempts have been made in the past to dampen such ship motion for purposes of personal comfort, military operations, and scientific research. Bilge keels, gyro stabilizers, hydraulic systems, flow tanks, and mechanical devices have been used to lessen the effects of roll and pitch. But heave of the vessel itself, caused by the periodic passing of wave troughs and crests, has never been appreciably reduced.

In a different approach, efforts have been made, and some with moderate success, to remove or reduce excessive pull or tension changes in wire lowering rope. Spring accumulators and hydraulic pistons mounted on fair leads and head sheaves, air systems, and accelerometers have been employed by oceanographers and engineers to provide constant wire tension in many marine operations. None of these attempts has been 100 per cent successful. Accumulators and hydraulic pistons have only dampened the resultant overload strains and movements to some degree. Differential systems employing compressed air springs and sheaves have been defeated by friction, phasing, and timing, and other systems by cost, weight, and size.

A particularly urgent need exists for a simple, effective, and almost frictionless device to provide depth control of deep-sea cameras. These cameras are self-contained units that are lowered to specific distances above the sea floor which they photograph at preset time intervals while being towed by drifting platforms (vessels). Camera lenses and electronic light sources are limited to short distances when used underwater because of the strong absorption and scattering of light by water and suspended particles.[2] To obtain good color rendition and sharp focus, it is necessary to shoot close-ups at carefully controlled

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2. Schenck, H., Jr. and Kendall, H., Underwater Photography, Cornell Maritime Press, 1954

target distances. To add to the optical problems caused by the water itself, the heave of the vessel lowering the camera to a position near the sea floor promotes erratic and sometimes violent depth changes. Up-and-down movements of the lowered cameras in excess of 12 feet are not uncommon, and surges up to 20 feet and more are possible during heavy sea surface action. The roll, pitch, yaw, and heave imposed on a surface vessel by wave motion often combine to produce a movement greater than the depth of focus of even the best wide-angle lenses and greater than the target distances desired.

To recapitulate, depth control is needed for increased safety and efficiency in sea floor photography and in other operations, in all but the calmest seas. For these reasons the Navy Electronics Laboratory undertook the development of the depth regulation equipment described in this report. The equipment provides automatic and high speed winch control regardless of the intensity, timing, and shape of the waves. The effects of heave are almost eliminated, and the camera tends to remain at a constant depth despite the changing depth of the lowering platform, the extent of surface wave penetration, the relative location of the depth sensor with respect to the lowered object, the weight and length of wire rope payed out from the winch drum, and the weight and shape of the lowered object.

The depth regulation equipment not only minimizes the effect of ship motion, but reduces the chance of damage to the wire and oceanographic equipment and makes possible the collection of scientific data unobtainable with older deep-sea winches. Lowering wires are kept under constant tension well below the region of overload, and should therefore last longer.

THE NEL DEPTH REGULATION EQUIPMENT

Description

The NEL depth regulation equipment (figs. 2 and 3) is based on a principle previously neglected in attempts to stabilize vertical wire cable movements. Since many of the earlier efforts had been defeated by the effects of friction and weight, it was decided to utilize the increase of water pressure with depth as a means of preventing the unwanted vertical wire motion.[3]

An experimental depth sensor (fig. 4) is used to convert the vertical ship motion into pressure changes. It is submerged at a depth equal to one-half of the wavelength of the surface waves (fig. 5). At this depth the orbital action of the surface waves particles is negligible,[3] and the changing wave motion has no effect on the sensor.

The depth sensor consists of a pressure bellows mechanically linked to a synchro motor. The shaft of the latter rotates in proportion to the vertical depth changes of the sensor which are synchronized with the vertical motions of the platform from which the sensor is suspended. When the platform moves downward, the sensor also moves down, experiences an increase in pressure, and causes a directional synchro movement. When the platform moves upward, the directional synchro movement is in the opposite direction. Thus, an increase in pressure on the sensor tends to raise the submerged equipment and a decrease in pressure tends to lower it.

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3. Sverdrup, H. U., Johnson, M. W. and Fleming, R. H., The Oceans, Their Physics, Chemistry, and General Biology, Prentice-Hall, 1942

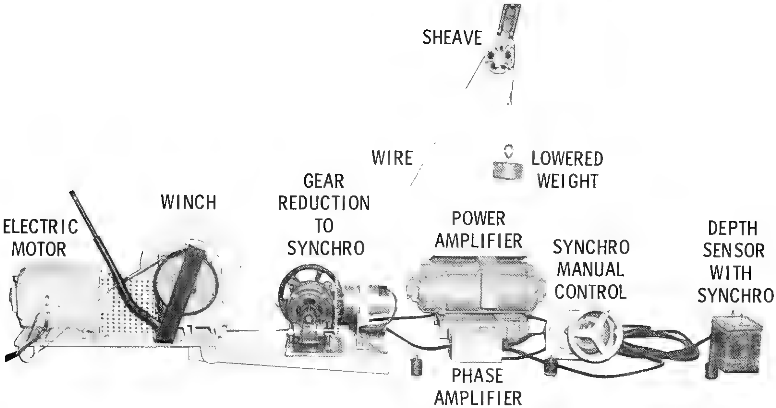

Figure 2. Oceanographic winch with depth regulation equipment.

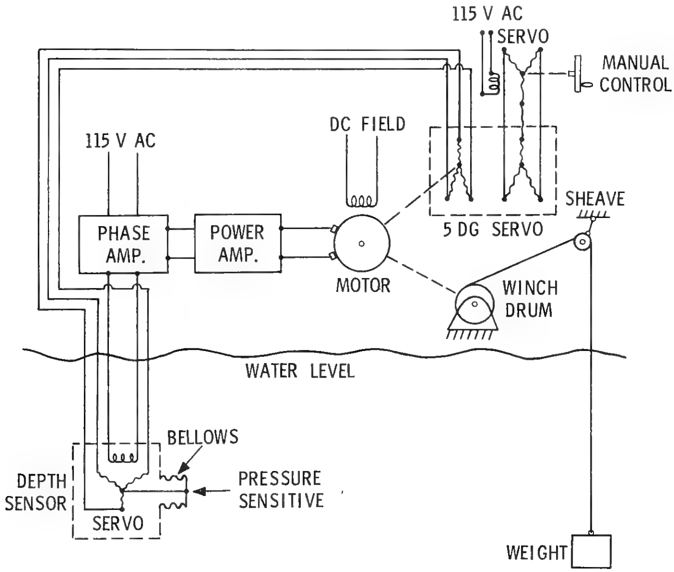

Figure 3. Schematic of depth regulation equipment.

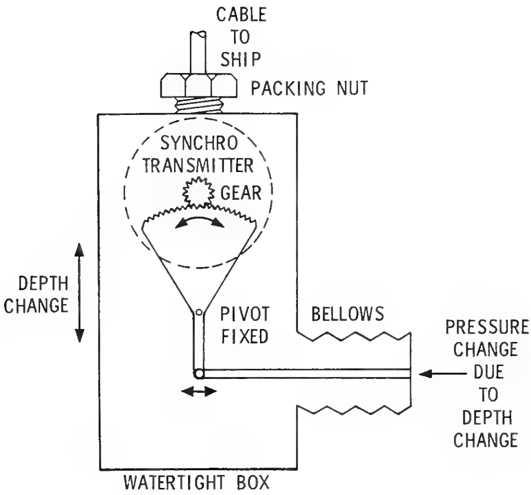

Figure 4. Depth sensor mechanical details.

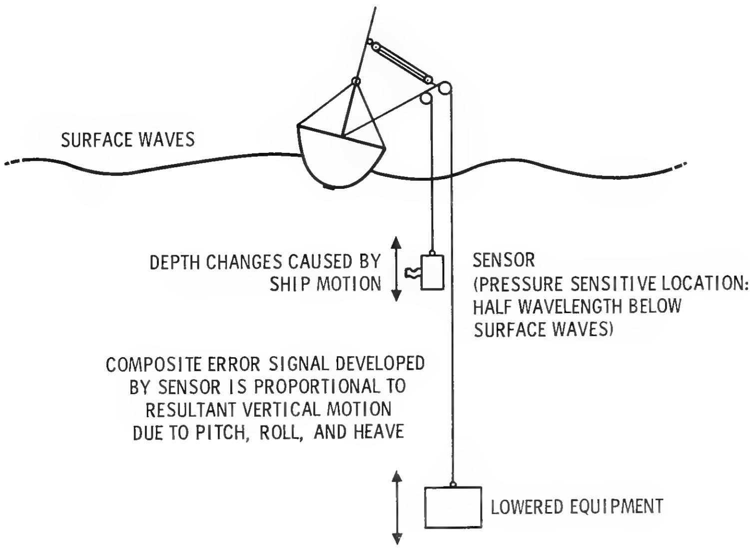

Figure 5. Depth sensor location and development of error signal.

The sensor actually develops an error signal which is amplified, reversed in phase, and presented to the winch motor through a phase amplifier and power control unit (fig. 5). A synchro motor similar to the one mounted in the sensor is mechanically geared to the winch drum in such a way that the error signal is balanced out as the winch motor automatically corrects for ship motion (fig. 4). It is, however, important to place the sensor over the side at a location close to where the oceanographic device or other equipment is lowered to enable the sensor to feel the same relative motion (fig. 5). Stretch in the lowering cable and sway and surge of the vessel tend to offset the degree of correction afforded by the generated signal, but the use of the depth regulation equipment removes violent tension overloads, thereby maintaining wire tension and stretch at stable values.

Operational Factors

Factors to consider in the employment of the depth regulation equipment are:

(1) Under calm sea surface conditions, with the floating platform on an even, steady keel, the depth sensor feels no appreciable ship motion other than that caused by normal flotation and develops only a negligible error signal, with little correction needed.

(2) When objects are lowered over the stern of a platform, the roll effect is minimized, and the pitch and resultant heave require the greatest correction.

(3) When objects are lowered from a position amidships on either side of a floating platform, the pitch is minimized and roll requires the major correction.

(4) Heave of a vessel caused by passing wave action has to be corrected for, regardless of the location on the floating platform from which the equipment is lowered.

EVALUATION

Two dockside field tests were conducted with the oceanographic winch and experimental depth regulation equipment shown in figure 2. The depth sensor equipped with bellows and synchro motor was first lowered into 20 feet of water alongside a Navy Electronics Laboratory pier. Up-and-down manually controlled movements gave positive and linear signals from 0.1 to 2 volts per inch of depth change.

In another dockside demonstration, the experimental depth regulation equipment was attached to the oceanographic winch temporarily installed on USS MARYSVILLE (EPCER 857). Voltage signals comparable to those obtained in the sensor test were induced into the phase amplifier circuit to simulate pressure changes that would be encountered by a vessel under the influence of surface wave action. All synchro signals responded to the induced pressure changes, with 85 per cent or greater efficiency of signal range and reaction. Figure 6 illustrates in a general way how depth regulation reduces unwanted vertical motion.

Shipboard tests at sea have not been made because the equipment is an experimental one. Such tests await the construction of an equipment engineered for shipboard use.

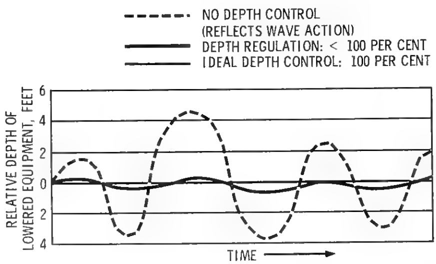

Figure 6. General depth control relationships.

DISCUSSION AND CONCLUSIONS

Adverse weather and sea surface conditions affect the motions of all floating platforms, particularly the smaller vessels. Oceanographic ships are usually designed to be just large enough to meet general needs, the shape, length, and tonnage all being adjusted to keep down the operating costs. Many such vessels, particularly of United States registry, are less than 200 feet long. Moderate to rough seas are therefore unkind to the people that operate them and to the scientific equipment lowered over their sides.

Although weather and sea state are given considerable attention in the planning of oceanographic studies, storms can never be completely avoided on long cruises. Man has therefore had to learn to live with and tolerate adverse conditions at sea in order to gather the data he needs.

The depth regulation equipment described in this report makes possible many oceanographic operations without any attempt to control erratic ship motions; instead the latter are sensed and corrected for in the winch operation only. Some examples of applications of the equipment follows.

Deep-sea cameras can be programmed, before they are lowered and positioned by sonar, for definite periods of hovering time at preselected target distances. Depth can be automatically controlled to 1 or 2 feet, regardless of sea surface state (fig. 6), permitting better bottom photo coverage with fewer blank frames. Film can thus be utilized more efficiently in the production of continuously recorded data.

Precise depth control is not limited in its use to underwater cameras. Water bottles, large and small, can be held to constant depth until tripped or activated. Other oceanographic equipments that require depth control are thermistor beads for temperature recording, salinity units, depth units, and current velocity meters. In the field of acoustics, heavy transducers can now be lowered safely to various depths and held there without fear of loss or damage. Constant tension can be maintained in mooring cables securing oil-drilling barges and other anchored platforms.

In some situations, the depth regulation equipment would permit deep-sea vehicles and sonar units to be towed at constant tension and depth. When sediment corers, grab samplers, heat probes, and dredges are being lowered to the sea floor, the use of depth regulation equipment would prevent premature contacts, unwanted touchdowns, disrupted coring sequences, and mistimed grab samples.

Depth regulation equipment can and should be incorporated into all new winches during manufacture. The resultant benefits in oceanographic work would be far-reaching. Rough, wind-stirred oceans would cease to be a controlling factor in the planning and accomplishment of underwater activities.

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UNCLASSIFIED

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2. Hoists - Control systems

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