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THE NEL TYPE III DEEP-SEA CAMERA

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Underwater Photography Lab. p. 17

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

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THE PROBLEM

Investigate problems in sea-floor oceanography through suitably devised means, methods and equipments. This report discusses the development, design and use of the NEL Type III Deep-Sea Camera to study micro-relief features of bottom sediments.

RESULTS

The development of the camera provides an improved tool for the study of deep ocean-floor environments. At least twenty-four bottom pictures can be obtained on a single lowering of the camera to a depth of 20,000 feet from small vessels equipped with light winches and 3/16-inch-diameter wire lowering ropes. The compact, watertight arrangement of the camera, illumination unit, electronic flash tube, tripping switch and lowering frame has reduced the total weight to only 125 pounds in sea water. This has resulted in lower costs of operation, maintenance, and replacement. The wide-angle lens, faster film, and electronic illumination employed in the NEL Type III Deep-Sea Camera are producing sea-floor photographs of greater definition and better contrast.

RECOMMENDATIONS

1. Continue investigation of methods of indicating bottom contact. Complete the development of an electro-mechanical device, to be attached to the dynamometer in the lowering equipment, to give good bottom-contact indications for water depths in excess of 12,000 feet.
2. Develop and package a camera with a wide-angle lens and larger film size to be used with a 300 watt/sec flash.
3. Investigate the use of correcting lenses and filters.
4. Investigate the availability, cost, and use of some form of plastic rope of neutral buoyancy for lowering the Type III Camera. Such a rope would also help to solve the problem of bottom indication.
5. Develop a direction control for the NEL Type III Camera to extend its usefulness in the solution of problems dealing with current direction, sources of material supply, and gradients of submarine slopes.

ADMINISTRATIVE INFORMATION

The work was performed under IO 15401, NE 120221-34 (NEL L4-1), from July 1954 to November 1955. This report was approved for publication 13 March 1957.

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INTRODUCTION

The increasing use of photography in studies of ocean-floor environments created the demand for a small, portable camera unit to replace the heavier, more cumbersome underwater cameras previously developed at NEL.¹ (See list of References at end of report.) Field exploration with the heavier cameras, one of which weighed over 2000 pounds, required the use of a vessel equipped with a strong winch, booms, and a heavy wire lowering rope. The lowering rope most widely used is of 3-by-19 stranded wire, 3/16-inch in diameter, with a breaking strength of 3340 pounds. The NEL Type III Deep-Sea Camera was designed for safe lowering on such a rope to a depth of 20,000 feet, and its over-all submerged weight in water is 125 pounds, which satisfies the applicable safety and working load requirements.

GENERAL DESCRIPTION OF THE CAMERA

The NEL Type III Deep-Sea Camera consists of a watertight arrangement of a spring-wound 35-mm robot camera, a 2000-volt electronic power source of commercial design, a flash tube in a clear plastic envelope which is mounted within a water-filled aluminum reflector, and a small oil-filled tripping switch (fig. 1). A rigid lightweight frame of steel serves to hold the watertight case and junction box which house the camera, flash unit, and electrical power supplies in the proper oblique relationship to the ocean floor.^{2,3} The watertight case which is mounted near the top of the frame is a thick-walled cylindrical tube of forged aluminum with an internal diameter of 9 inches and an internal length of 14 inches. It is equipped with a clear quartz port in the detachable head to allow the self-contained camera to look out. The illumination control unit and all necessary power supplies are packaged with the camera for more

Figure 1. NEL Type III Deep-Sea Camera.

efficient operation, maintenance, and repairs (figs. 2 and 3). The stainless-steel junction box, located directly below the aluminum camera case and supported by the light steel frame, serves to hold the protected flash tube, aluminum reflector, and the oil-filled tripping switch. A thick-walled stainless steel tube connecting the box and camera case carries and protects the necessary electrical wires. A mechanical tripping device, which employs a free-swinging lead weight, is attached to the frame below the junction box to activate the electrical tripping switch. Operation of this switch by bottom contact at 30-second intervals permits at least 24 successive photographs to be taken on a single lowering of the camera. Figures 4 and 5 show the electrical components and self-explanatory circuits employed. Detailed plans and specifications of the equipment are available upon request.

Figure 2. Camera and power supply unit in camera case.

Figure 3. Camera and power supply unit.

CAMERA, SOLENOID, FLASH UNIT, BOTTOM
CONTACT SWITCH, SOLENOID BATTERY,
FLASH TUBE HOLDER & FLASH TUBE

Figure 4. Schematic diagram of electrical units assembly.

Figure 5. Schematic diagram of circuits of NEL Type III Deep-Sea Camera.

OPERATIONAL INFORMATION

Selection of Subject Material and Field Coverage

Deep-sea photography with the NEL Type III Camera provides no pre-selection of underwater subjects for study. Critical areas for study or investigation are selected by latitude and longitude from existing bathymetry and navigational charts. Locations for lowering the camera are determined by geographical position and by depth to specified bottom features such as canyons, basins, escarpments, slopes, and ridges. Figure 6 shows how the variable tripping wire and weight are adjusted to the fixed tripping wire to give the desired subject distance, in water, of 6 feet, when the camera is preset with an angular divergence of 30° from the vertical. Assuming use of 35-mm film and a robot camera fitted with a lens of 30-mm focal length, the resulting field coverage will be an elliptical area 5.7 feet long by 4.7 feet wide, or approximately 21 square feet. A special scale is used to make measurements of detailed features within a $7\frac{1}{2}$ -by- $7\frac{1}{2}$ -inch photographic enlargement when the degree of magnification and the camera-to-subject distance (after proper corrections for water refraction) are known.

Figure 6. Diagram of field of photographic coverage.

Successive photographs taken at regular intervals along the bottom provide field coverage over an area determined by the set and drift of the lowering vessel. Features made visible by the development of the photographs obtained are then studied to help reveal the nature of environments. The most efficient use of the deep-sea camera is obtained by proper planning of ship time in selected areas of study. Depth is still the primary factor in determining where photographs can be taken, how long it will take to get them, and how many can be obtained on a single lowering of the camera.

Camera Settings, Film and Optics

Camera settings are made in advance before each lowering when corrections for water refraction, turbidity, depth, picture size, and subject distance can be taken into consideration. A fast lens of short focal length has been used extensively in the 35-mm robot camera and has given highly satisfactory results.⁴ A shutter setting of 1/25 second permits easy synchronization with the short (1/1500 second) duration of the flash and exposes the film properly for clear, sharp negatives.

Tri-X film has been found most suitable for underwater use and is now employed almost exclusively for black-and-white bottom studies. It is a very fast panchromatic film of moderate grain, with wide exposure and development latitude, and provides maximum detail and depth of focus in the field of photographic coverage.⁵

To correct for the higher index of refraction introduced by the air-to-quartz-to-water interfaces it is necessary to correct the true camera-to-subject distance for work under water. A standard rule for corrections is: set the lens for a distance equal to three-fourths the actual distance.* For normal use, at depths where no extraneous light is present, the lens is set at f8 for an apparent camera-to-subject distance of 6 feet; for more light the lens is opened to 6.3 and for less light stopped down to 11 or 16.

High-speed Ektachrome film, Daylight, has worked well for color. For best results the camera lens is opened to f2.8 and the subject distance adjusted to insure adequate lighting on the subject. Field testing is recommended to determine the best camera settings to use at specific preset subject distances.

Figure 7 illustrates the optical relationships between air, quartz, and water interfaces inherent in the design of the camera unit. The lens of 30-mm focal length has an angular field coverage of 57.6° in air. The net refractive effect of the clear quartz window (index of refraction 1.54) and salt water (index of refraction 1.33) narrows this angular field coverage to 42.4° which results in a loss of 15.2° field angularity.⁶

Filters are not employed on NEL deep-sea cameras at the present time because of their absorption throughout the spectrum.⁷ Also, a large part of the photography being done with the Type III Camera is in deep water where turbidity is low. To place the camera closer to the subject in areas where the turbidity is high a wide-angle lens system can be employed.⁸

Field Illumination

A 2000-volt Heiland-Wilcox P-2 Flash unit and a Kemlite V4X flash tube provides flash illumination.⁹ Figure 5 shows the basic electrical circuits employed. The flash tube is enclosed in a clear plastic envelope capable of withstanding hydrostatic water pressures in excess of 10,000 lb/sq. in. The water-flooded aluminum reflector in which the tube is mounted is designed to provide illumination with a minimum of back scattering (see fig. 6).

* See ref. 6, pp. 3-4.

Figure 7. Optics for NEL Type III Deep-Sea Camera.

The Kemlite flash tube and those of comparable design give off light of a spectral quality approaching that of daylight. The short duration of the flash (1/1500 sec) will stop fast action and freeze normal camera movement. This results in pictures of sharp definition. Also, light from the flash tube provides the duration and spectral intensity required for color film.⁹ The Heiland-Wilcox illumination is a repeating type capable of being operated at 15-second intervals. Figure 4 shows in schematic form how the electrical components are assembled to function with a 35-mm robot camera as a compact unit. For faster repairs and exchange of parts and batteries, matched Jones plugs have been utilized. To insure maximum light intensity, pictures are taken at not less than 30-second intervals. The flash unit is operated on a set of two 2-volt Willard wet cells wired in series. They can be recharged many times.

Bottom Contact and Weight-Strength Relationships Between Camera and Lowering Rope

Positive contact with the bottom is essential to successful sea-floor photography. Although there are various methods for obtaining contact, most are ineffective in depths exceeding 1000 fathoms. A simple yet effective slack-wire technique employed at the U. S. Navy Electronics Laboratory utilizes sensitive tensional changes in the 3/16-inch-diameter wire lowering rope to detect the moment at which the camera reaches the sea floor.

The twenty-four possible bottom photographs can be taken at intervals of not less than 15 seconds by raising the camera unit clear of the bottom between each activation of the tripping switch. Under normal weather and sea conditions this slack-wire lowering technique has been used successfully to 12,000 feet.

The over-all design was made consistent with the limitations of the 3/16-inch-diameter, 3-by-19 wire rope used for lowering purposes. This size and type of stranded rope has become standard in many phases of oceanographic field work. A 20,000-foot length of this wire rope weighs slightly over 1100 pounds in sea water and has a breaking strength of 3340 pounds. A minimum 2½-to-1 safety load factor, required to allow for overloads caused by excessive ship rolling and pitching, limits the weight of the lowered camera unit to 125 pounds. Loss of this static load from the total wire-weight out, when the sea floor is reached, enables a specially constructed mechanical-electrical dynamometer placed in the fair-lead system of the wire lowering rope to detect small tensional changes in the latter and convert them into electrical signals. Table 1 gives the weight-strength relationships needed to safely lower the camera to a depth of 20,000 feet. Figure 8 illustrates a typical deck arrangement for making a lowering from a vessel.

Steady drag forces due to wind and to sea currents, and the dynamic tensional changes in the wire rope caused by roll and pitch of the vessel during inclement weather, are compensated for in the circuitry of the bottom indicator.

TABLE 1. Weight-strength relationships for lowering NEL Type III Deep-Sea Camera.

Depth (ft)	Wire Wt. in Air (lb)	Wire Wt. in Water (lb)	Wt. Ratio in Water Wire/Camera	Safety Factor (Wire Rope)
1000	62	56	0.4	18.5
2000	124	111	0.9	
3000	186	167	1.3	
4000	248	223	1.8	
5000	310	279	2.2	
6000	372	335	2.7	4.9
7000	434	391	3.1	
8000	496	446	3.6	
9000	558	502	4.0	
10,000	620	558	4.5	
11,000	682	614	4.9	3.3
12,000	744	670	5.4	
13,000	806	725	5.8	
14,000	868	781	6.3	
15,000	930	837	6.7	
16,000	992	893	7.2	2.7
17,000	1054	949	7.6	
18,000	1116	1004	8.0	
19,000	1178	1060	8.5	
20,000	1240	1116	8.9	

Wire rope = 3/16" diam. 3 × 19 preformed galvanized plow steel

Nominal breaking strength = 3340 lb

Wt. of wire rope in air = 62 lb per 1000 linear ft

Wt. of wire rope in water = wt. in air less 10%

Wt. of NEL Type III Deep Sea Camera in air = 215 lb

Wt. of NEL Type III Deep Sea Camera in water = 125 lb

Figure 8. Plan view of a typical deck arrangement for lowering camera and indicating bottom contact.

Maintenance and Care of Equipment

To reduce the costs of operation, maintenance, and replacement of parts, metals resistant to salt-water corrosion have been utilized as much as possible. Aluminum parts exposed to salt water are anodized and coated with light-weight silicone oil. In fittings where dissimilar metals come into direct contact, frequent rinsings with fresh water and periodic applications of silicone oil are made. The useful life depends directly upon the attention given to such maintenance.

Willard wet cells employed in the illumination unit are given normal battery care and kept in a clean, charged condition. When not in use the cells are removed from the battery compartment of the unit and stored in a charged condition in a safe location where they can be recharged and observed for the need of additional electrolyte. The 22½-volt dry cell in the BC unit which activates the camera shutter solenoid is replaced periodically when in constant use or when its tested voltage drops below normal operating requirements. Silica gel from the compartment located on the base of the camera and power-supply unit is removed and dried periodically to provide maximum protection from moisture resulting from condensation. The 35-mm robot camera when not in use is stored in a moisture-free container to keep it operable. Excessive amounts of moisture or lint in the shutter mechanism will cause malfunction of vital parts. Maximum illumination from the flash tube requires a polished reflector (aluminum, in this case). The clear plastic flash-tube envelope is cleaned carefully to guard against excessive scratching which weakens the plastic and impairs the optical properties. "O" rings are checked periodically for scratches and flattening and renewed when defects are detected to insure

watertight integrity. The clear quartz window in the camera case is examined frequently for flaws and strain cracks caused by excessive applications of high pressure, sharp blows, or improper mounting. It is advisable to allow the camera case to warm up gradually on deck after each deep lowering before opening-up procedures are commenced. This will reduce or eliminate condensation of moisture on camera parts and electrical supplies.

Limitations

Many factors work singly or together to limit the usefulness or effectiveness of all deep-sea cameras. Weather and sea conditions determine the feasibility of each operation. Underwater conditions such as sea-floor relief, depth, outcrops, rock or sediment type, bottom slope and contact act to limit or increase the number of pictures obtained on each lowering. Vital exposed moving parts of the camera unit, located within the open construction of the frame for protection may suffer occasionally from abrasion and contact with external objects. Deeper lowerings increase the chances for kinks and snarls in the wire lowering rope. Only rapid indication of contact with the bottom will provide the control to keep the wire lowering rope in good condition.

APPLICATION OF THE CAMERA TO THE STUDY OF OCEAN-FLOOR ENVIRONMENTS

The NEL Type III Camera now makes it possible to extend the study of marine environments to depths beyond the limitations of most existing cameras. Deeper bottom features of the continental shelf, continental slope, and abyssal deeps west of San Diego, California, are now being photographed to help reveal the nature of micro-relief on the ocean floor, movement and identification of materials settling to the bottom and the identification and distribution of biological life on, near, and in these modern marine sediments. As the camera continues to be a relatively inexpensive and practical means of investigating the small-scale features of the deep sea floor, improved photographic equipment helps to obtain views which exhibit the greatest amount of natural detail.^{10,11}

Bottom photographs are revealing how burrowing organisms, fish, and other biological life are mixing up and moving bottom sediments; how sediments are being moved along the bottom by currents and down-slope by slumping, sliding, and earthquake jarrings. Relative grain sizes of bottom materials are revealed. Greater bottom coverage per single lowering of the camera is revealing the distribution of specific bottom materials and biological life. Various forms of biological life living on, near, and in the bottom sediments are being identified from improved underwater photographs (fig. 9).

CONCLUSIONS

The development of the NEL Type III Deep-Sea Camera and its scientific application to the solution of ocean-floor environmental problems have been justified by the results obtained. The compactness, small size, light weight, and ease of operation and maintenance of the camera permit more extensive field work to be carried on by only a few operating personnel. Relatively small vessels equipped with only 3/16-inch-diameter wire lowering ropes and comparatively light winches are being utilized successfully for deep-sea photographic operations. Improvements in camera design, equipment, and operational techniques are continuously being made to further the needs of oceanographers engaged in the study of sea-floor features.

Figure 9. Underwater photographs of some typical sea floor environments taken with the NEL Type III Deep-Sea Camera. Each photograph covers approximately 21 square feet of the bottom at a water distance of 6 ft. Tri-X film with a speed of 200 was used with an f2.8, 3-cm wide-angle lens stopped down to f8. Strobe flash of 1/1500-second light duration provided the illumination.

Figure 9A. Brachiopod shells and rounded beach cobbles on a sandy bottom near San Clemente Island, Calif. Lat. 32°-55' 30"N, Long. 118°-34' 35"W. Depth, 396 ft. Note variety of rock fish in upper half of photograph.

Figure 9B. Holothurian and sea urchins on a pitted, silty bottom, with an eel-like fish above the ocean floor of Loma Sea Valley off San Diego, Calif. Lat. 32° - 42° $30'$ N, Long. 117° - $25'$ $10''$ W. Depth, 1656 ft. The tracks and pits in the sediments indicate extensive churning of the bottom materials by burrowing organisms.

Figure 9C. Rock outcrop with thin veneer of fine sediments on a bottom slope off the west side of San Clemente Island, Calif. Lat. $32^{\circ}50'N$, Long. $118^{\circ}39'W$. Depth, 3234 ft. This is an area of sliding, slumping, and periodic removal of slope sediments into deeper water. Note the deep-sea crab in middle foreground.

Figure 9D. Typical red clay bottom at the base of the Continental Slope off the coast of Southern California. Lat. $31^{\circ}10'N$. Long. $121^{\circ}7'W$. Depth, 12,780 ft. No biological life is visible in the photograph. The pitted sea-floor surface indicates extensive churning of the sediments by burrowing organisms such as worms.

RECOMMENDATIONS

1. Continue investigation of methods of indicating bottom contact. Complete the development of an electro-mechanical device, to be attached to the dynamometer in the lowering equipment, to give good bottom-contact indications for water depths in excess of 12,000 feet.

2. Develop and package a camera with a wide-angle lens and larger film size to be used with a 300 watt/sec flash.

3. Investigate the use of correcting lenses and filters.

4. Investigate the availability, cost, and use of some form of plastic rope of neutral buoyancy for lowering the Type III Camera. Such a rope would also help to solve the problem of bottom indication.

5. Develop a direction control for the NEL Type III Camera to extend its usefulness in the solution of problems dealing with current direction, sources of material supply, and gradients of submarine slopes.

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