A new deep-sea underwater camera

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Abstract—A deep-sea underwater camera containing several new design features is described. It is capable of taking up to a hundred pictures at one lowering in depths up to 5,000 m.

Some examples of its use in biological and geological surveys of the ocean floor are presented.

INTRODUCTION

OUR knowledge of the ocean floor has, until recently, been obtained by sounding, sampling and the measurement in situ of certain bulk physical properties such as density and elastic moduli. Many interesting features, however, can only be recognized by visual means and this is best done, if one has not the facilities of a bathscaphe, by remote photography or television. Although great advances have been made in the techniques of underwater television, it is still restricted to comparatively shallow depths.

In designing a deep-sea camera that is to be thought of as a tool, the guiding principles throughout were simplicity, ease of handling and flexibility in application. For these reasons, the camera was made as small as possible and all casings were made of light alloy so that it could be carried by two people and lowered on 4 mm hydrographic wire. 35 mm film was used so that it could be processed by standard techniques.

DESIGN

The three principal units which comprise the camera are the photographic unit, the electronic flash light and the acoustic signal generator or " pinger." The latter unit is necessary for transmitting the information to the surface that the camera has touched the bottom and taken a picture. The three units are mounted in a frame of aluminium alloy consisting of two lengths of scaffold tubing with spacers. The whole camera is eight feet long and one foot wide. The total weight in air is 87 lb (40 kg) and in water 41 lb (19 kg), (excluding the trigger weight). In normal operation the camera is actuated by the release in tension of a spring in the bottoming switch when the trigger weight and sampler touch the bottom. These are suspended beneath the camera so that pictures may be taken of the bottom at any given distance. The geometry of the camera assembly and the length of trigger line determine the focal settings and enable the size of objects in the field of view to be estimated.

The cases containing the photographic unit and the light unit are both mounted so that they can be pointed in any direction and can be interchanged in position. The electronics for the pinger unit are contained in one of the scaffold tubes forming the frame and the transducer and reflector point upward towards the surface. The whole assembly can be seen in Fig. 1, as it is being recovered after a station.

When taking photographs of the bottom, the camera is lowered until the bottoming signals are heard, and the first flash is triggered. (A picture is not normally obtained from this first touch of the bottom since the first frame has been exposed to daylight on the way down.) The camera is then raised a few fathoms and lowered again to take a picture after one or two minutes. This operation is repeated to give a series of photographs of the bottom while the ship drifts. A sample of the bottom (about 100 c.c.) is taken with a snap sampler when the camera first touches the bottom.

(*a*) *The photographic unit*

The photographic unit, Fig. 2a, was designed specially for the purpose and was required to fit into a 3 in. diameter tube. There is no shutter, the exposure being determined by the flash. After each picture has been taken, the film is transported automatically by an electric motor operated by 6-volt dry batteries. The time required for a new frame to come into position can be varied from 5 seconds to 1 minute by suitable gear selection. The camera wiring is shown in Fig. 3. On closing

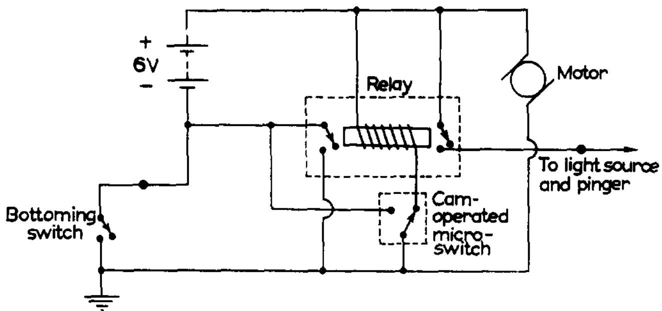


Fig. 3. Diagram of the camera circuit. In the rest state of the circuit, the bottoming switch and both relay contacts are open and the microswitch is made to the right. On closing the bottoming switch, the relay is energized and its contacts closed. triggering the light source and pinger, and shunting the bottoming switch. At the same time the motor is started and the film transported. After 3 seconds, the microswitch is switched to the left position by the film transport and the relay contacts open. After 12 seconds, a new frame is in position and the microswitch is switched to the right again. Provided the camera is off the bottom and the bottoming switch is open, the circuit returns to its initial state.

the bottoming switch, a 6-volt pulse triggers the light unit and the pinger and thereby takes the picture and signals to the surface. The film transport is operated until a new frame is reached when a cam-operated switch stops the motor. The film capacity is 5 metres equivalent to about 100 frames.

Two interchangeable lenses have been used, both Dalmac Anastigmat $f/3{\cdot}5$ of 5·1 cm and 3·5 cm focal lengths. These cover an angular field of view in water of 37° and 47° respectively. The chromatic aberrations introduced by using underwater a lens designed for use in air, have been improved by the addition of a Thorndike correcting lens (THORNDIKE, 1955). This lens which is of zero mean power, but of finite dispersion, is mounted in the water in front of the window in the camera case.

(*b*) *The light source*

A low voltage operating repeating electronic flash unit is used for illumination. The power is supplied by nine 30-volt deaf-aid batteries in series forming a battery pack that plugs into the top of the flash unit. The circuit used is that recommended by the British Thomson-Houston Co. Ltd., for their 100 joule Xenon Tube F.A.10.

The charging time between flashes is limited by the internal resistance of the batteries and therefore depends on their age. With new batteries, 90 per cent of the full charge is reached in 40 seconds. The unit is shown in Fig. 2b.

A silvered reflector is used to spread the light as uniformly as possible over the area photographed.

(c) *The pinger*

The circuit for the pinger unit is shown in Fig. 4. This is essentially the same as that described by SWALLOW (1955), but with a modified repetition system. A ping

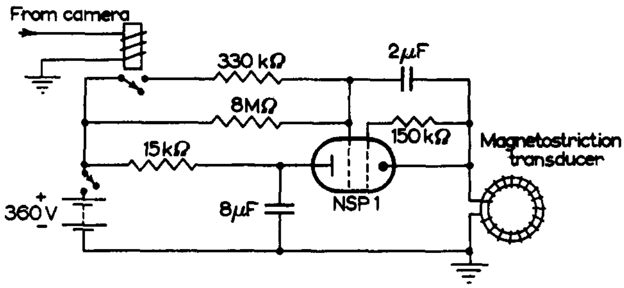


Fig. 4. Diagram of the acoustic signal generator circuit.

is transmitted every 6 seconds while the camera is in the water and can be heard through the hydrophone beneath the ship. When the camera triggers on touching the bottom, a lower resistance shunt is introduced in the repetition timing circuit and the pinging rate is increased to two a second. This high rate lasts for about 25 per cent of the time taken for the new frame to come into position, i.e. for about 3 seconds in normal operation when the film transport time is 12 seconds. If the camera is still on the bottom 12 seconds after triggering then the cycle is repeated and the winch operator is thereby informed that it must be raised further to clear the bottom.

The correct signals will be sent from the camera only if it is working correctly. It therefore gives great confidence to hear the correct signals and to know that all is well. In the event of anything going wrong, one can recover immediately and save not only time, but possible damage to the camera by prolonged immersion in water if a leak has developed.

The transmitted power from the pinger was found to be improved by a sonic reflector of $\frac{1}{4}$ in. (8 mm) aluminium plate. Under reasonably quiet conditions and using a directional hydrophone for listening it is possible to get clear signals from a depth of 4,800 metres.

(d) *The bottoming switch*

The bottoming switch, Fig. 6, consists of a microswitch operated by a cam on a spring-loaded shaft running through the switch unit. To the end of the shaft is attached the trigger line and trigger weight (which also incorporates the sampler). The switch unit is cased in Perspex and is oil filled.

(*e*) *The pressure cases*

The cases for the photographic unit and the light unit are cylinders of aluminium alloy of 3 in. (7·5 cm) internal diameter and $\frac{3}{4}$ in. (1·9 cm) wall thickness designed to withstand 10,000 lb/sq. in. (700 kg/sq. cm.). The end caps screw into the cases and are sealed by trapped O-rings in the caps bearing on the flat end surfaces of

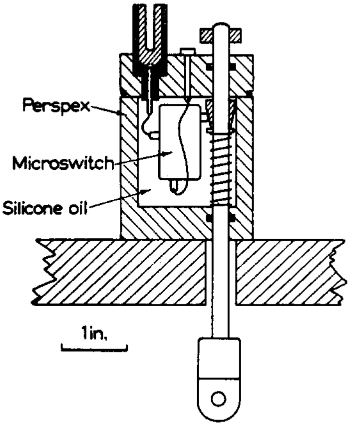


Fig. 6. The bottoming switch.

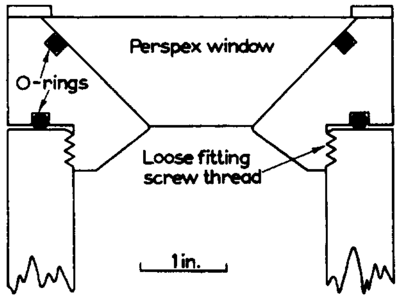


Fig. 7. The window end-cap of the camera pressure case illustrating the method of sealing.

the cylinders. It is essential, however, in this type of high pressure seal for the screw threads to be sufficiently slack to allow the pressure on the end caps to close the gap between the cap and the cylinder (Fig. 7). If this condition is fulfilled, then the cap need only be screwed on hand tight and the O-ring does not then suffer unduly.

The window for the camera is made of Perspex in the form of a truncated cone (Fig. 7). This fits accurately into a recess in the end cap and is sealed near the base of the cone by an O-ring. With this form of support, the distortion of the window under pressure is reduced to a minimum.

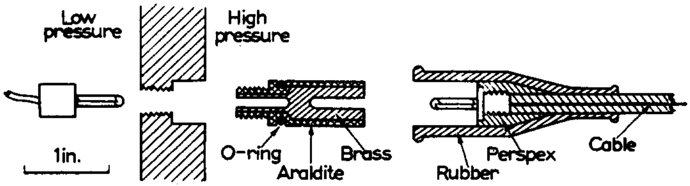


Fig. 8. An expanded diagram of the method of bringing electrical leads through a pressure case.

The flash tube is protected by a conical glass dome of $\frac{1}{4}$ in. (8 mm) thickness cemented by Araldite D cold-setting resin to the end cap. These Pyrex glass domes, which are commercially available for chemical use, have been tested in a pressure tank up to 13,500 lb/sq. in. (950 kg/sq. cm) without collapsing.

The scaffold tubing of aluminium alloy (HE 10 WP 1·9 in. O/D 7 gauge) forms the pressure container for the electronics of the pinger. The ends are sealed with plug type O-ring seals. Tests on the collapsing pressure of this type of tubing gave a value of 8,700 lb/sq. in. (610 kg/sq. cm) which was somewhat less than expected. Because of this the depth to which the camera has been lowered was limited to 5,000 metres (equivalent to 500 kg/sq. cm).

Fig. 8 shows the method that is used to bring electrical leads through the pressure cases and how the connections are made. The centre part of the pressure plug is set in Araldite D and then machined. Mechanical support is provided by the brass centre and the necessary insulation by the Araldite. The seal to the case is made with an O-ring and the plug can be screwed in and out by hand. The outside connection to the pressure plug is made by a push-on rubber covered electrical plug. When the connection is made the air inside is virtually eliminated and the seal is made by the slightly extended rubber on to the Araldite insulation. This system enables the pressure plug to be changed in a matter of seconds if damaged, and the leads to be disconnected for testing. When tracing faults in the camera operation this is invaluable. The plugs have been tested up to 13,500 lb/sq. in. (950 kg/sq. cm) without any appreciable loss in insulation.

RESULTS OBTAINED WITH THE DEEP-SEA CAMERA

The camera has now been used on three separate cruises in R.R.S. *Discovery II.* In March and April 1956, preliminary sea trials took place in the neighbourhood of the Shetland Islands and the South Norwegian Sea. Seven stations were occupied but only three of these gave successful pictures, the failure in the other stations being due to the high turbidity in the water.

An opportunity for a more extensive test of the capabilities of the camera was afforded during the Geophysical cruise of July and August 1956, in the north-eastern Atlantic. Thirteen stations were occupied in depths of water varying between 110 metres and 4,824 metres. A total of two hundred pictures of the bottom was obtained. Of these about eighty showed bottom living fauna, the shallower stations in the vicinity of seamounts showing the greater proportion. At the majority of these stations a sample of the bottom was taken by the trigger sampler.

Since the photographic work in this cruise was an integral part of the other studies that were being made, a detailed discussion of the pictures obtained will be given in connection with the other results. However, a few of the more interesting photographs are reproduced here. (Figs. 9 to 13).

One picture, Fig. 13, demonstrated very clearly how much care has to be taken in the geological interpretation of photographs. This was taken near the top of a seamount 130 miles north of Madiera. When printed the picture showed broken boulders lying half covered with ooze. The boulders had clear markings on them in the form of parallel lines strongly suggesting bedding plants in a sedimentary rock. As this seemed unlikely, dredging was carried out at the same place and a boulder was recovered which bore similar markings (Fig. 14). These turned out to be corrugations on the cooling surface of a lava flow, the boulder being a highly vesicular basalt. On the bottom, the markings are probably accentuated by being filled with light coloured sediment.

In designing the camera, it was intended that it should be capable of adaptation to various underwater studies. An example of its use in midwater photography is described elsewhere in this volume (BAKER, 1956).

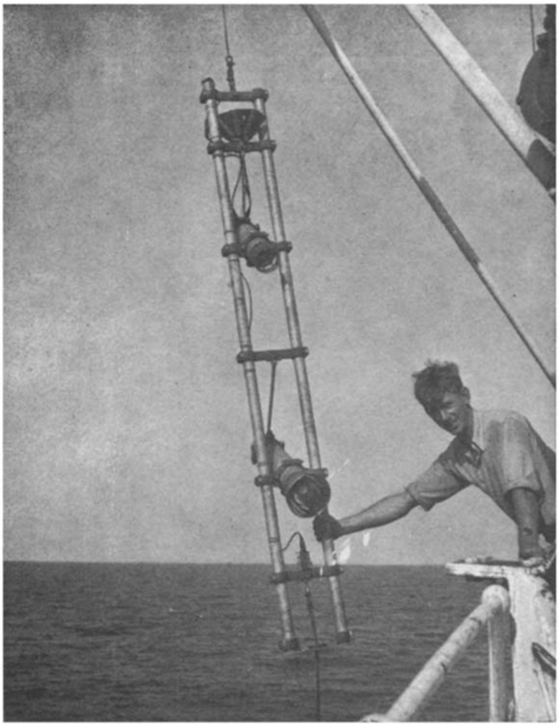
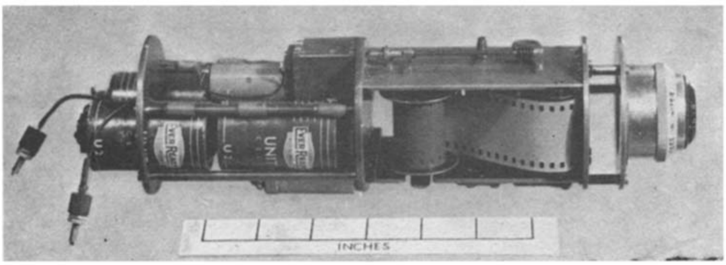
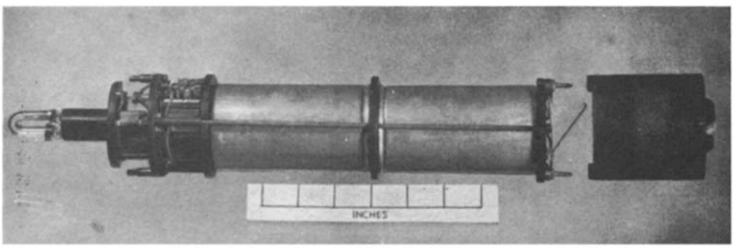


Fig. 1. The deep-sea camera being recovered after a station. At the top is the acoustic transmitter, below it the camera housing and near the bottom is the light source.



(a) The camera unit.

Fig. 2.



(b) The electronic flash unit and battery pack.

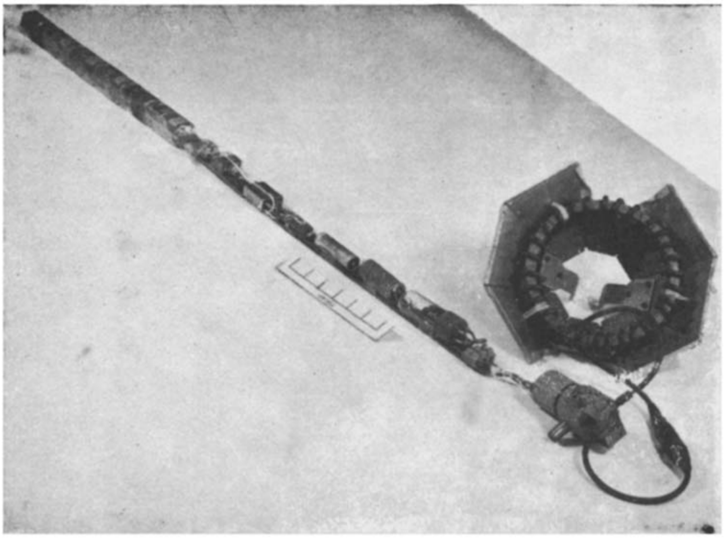


Fig. 5. The electronics and transducer of the acoustic signal generator circuit showing the reflector.

Fig. 9.

Station 3455.26. Position 34°53′N, 16°32′W. Depth 1,474 m.
Area of picture: 3 m by 5 m. Film H.P. 3: *f*/5·6: Range 5 m.
Outcrop of volcanic rock near the peak of a seamount north of Madeira. The lack of sediment cover suggests that currents are active. The fauna have been tentatively identified as follows: Chrysogorgid possibly *Isis* (top right): a Zeid fish possibly *Neocyttus* (middle right): a large Gorgonid or Anti-patharian (top centre): a spiralling Gorgonid related to *Iridogorgia* (lower centre): six sea anemones scattered on the rock.

Fig. 10.
Station 3455.20. Position 34°53′N, 16°32′W. Depth 1,550 m.
Area of picture: 3 m by 2 m. Film H.P.3: *f*/5·6: Range 3 m.
The camera is looking into the slope on the side of a seamount north of Madeira. Loose boulders are lying half covered by calcareous sediments.

Fig. 11.
Station 3455.15. Position 34°53′N, 16°32′W. Depth 1,620 m.
Area of picture: 3 m by 5 m. Film H.P.3: *f*/5·6: Range 5 m.
Sediment lying in a depression on the side of a seamount north of Madeira. The marking on the surface may be due partly to current action and a resultant sorting of grain size and partly to the tracks of benthic fauna.

Fig. 12.
Station 3461.1. Position 36°36′N, 17°13′W. Depth 4,685 m.
Area of picture: 3 m by 5 m. Film H.P.3: $f/6{\cdot}3$: Range 5 m.
Typical level bottom of globigerina ooze in the deep ocean basin north of Madeira. The many mounds are caused by burrowing fauna, possibly starfish. The track is probably due to a holothurian, producing footmarks separated by about three centimetres.

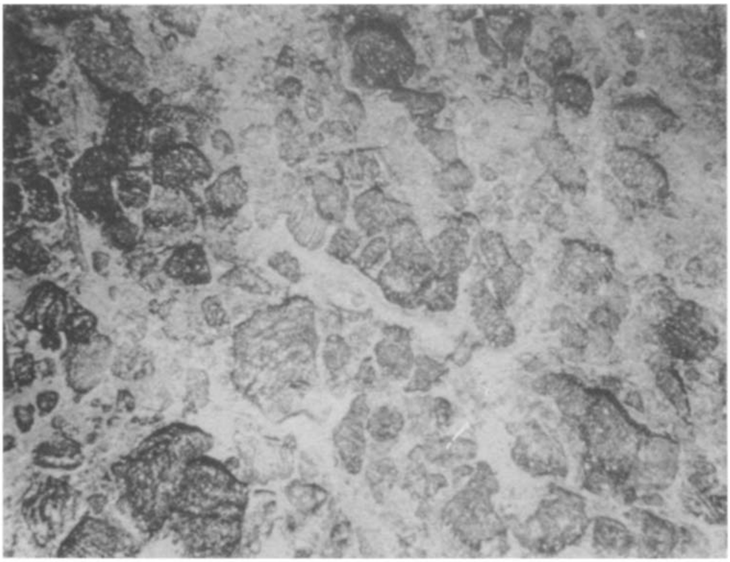


Fig. 13.
Station 3452.9. Position 34°52′N, 16°31′W. Depth 1,430 m.
Area of picture: 3 m by 2 m. Film H.P.S: $f/11$: Range 3 m.
The camera is looking into the slope on the side of a volcanic seamount north of Madeira. Loose boulders of vesicular basalt are lying half buried by sediment and pieces of broken coral. Note the striations on the boulders.

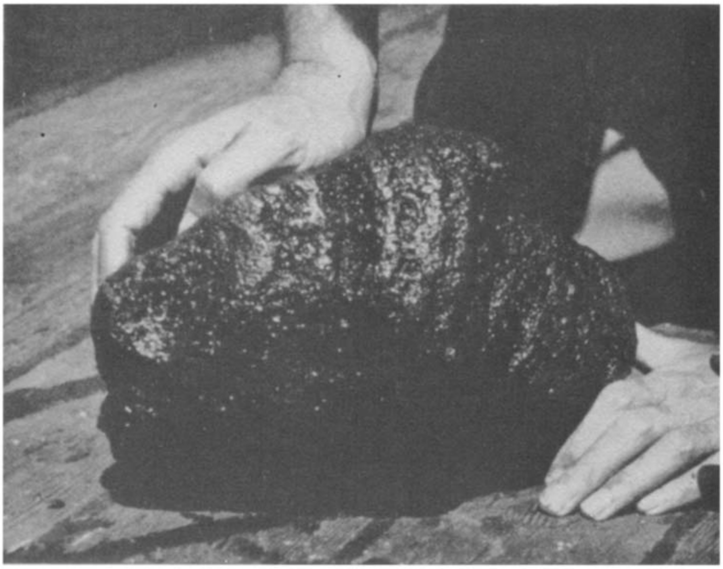


Fig. 14. A boulder of vesicular basalt dredged from the same position as the photograph of Fig. 13. Striations can be seen, similar to those in the underwater photographs.

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REFERENCES

BAKER A. DE C. (1957) Underwater photographs in the Study of Oceanic Squid. *Deep-sea Res.* **4**, 126-129.

SWALLOW J. C. (1955) A neutral buoyancy float for measuring deep currents. *Deep-sea Res.* **3**, 74-81.

THORNDIKE E. M. (1955) Color-Correcting Lens for Underwater Photography. *J. Opt. Soc. Amer.* **45**, 584-585.