WOODS HOLE OCEANOGRAPHIC INSTITUTION
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Underwater Camera Positioning by Sonar

by

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APPROVED FOR DISTRIBUTION Paul M Fye

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SUMMARY

A pulse sonar system is described for measuring the height above the bottom of an underwater camera and other equipment in the deep oceans. Using this method, cameras have been positioned for photography at depths to about 2,500 fathoms with a precision of about half a fathom. The measurement is achieved by a sonar "pinger" on the equipment, which sends precise 1 pulse-per-second signals to the surface both directly and by reflection from the bottom.

INTRODUCTION

One widely-used method of bottom photography is the "bottom trigger" system whereby a switch closes when the bottom is touched by a switch below the camera. This system is sometimes called the "Pogo stick camera". The entire device is then raised until free of the bottom in preparation for a subsequent photograph. With the camera at great depths the operator on the deck may not be aware of bottom contact if he is using a steel cable because of the great weight of the cable in the water. A sonar sounding device has been used by Edgerton[1] and Thorndike[5] to emit a "ping" which notifies the winch operator that a photo has been made. The sonar can be operated continuously at a slow pulse rate but is shorted out by the bottom switch, again indicating to the winch operator that the camera has bottomed. The operator then has an opportunity to hear his subject until the moment that the bottom has been reached.

The sonar device described in this paper is designed to monitor the camera-bottom distance, so that the operator can hold the camera at about the right distance above the bottom without the necessity of contact. The camera is arranged to expose photographs at 12-second intervals for a period of about two hours. Some of the pictures will be taken higher than desired due to ship motion, and others lower, with, however, many at the desired distance.

The sonar system operates as follows. A (pulse) sound transducer mounted on the camera sends 12 kc pulses up and down. The "up" signal goes directly to the surface, while the "down" signal is delayed by going from the camera to the bottom and then to the surface. Two "pings" arrive at the surface, separated in time by the travel time of the sonar signal through twice the camera-bottom distance. Thus,

$$D = \frac{vT}{2} \text{ feet}$$

where v = 5,000 ft/sec
T = time in seconds between pulses received at the surface
D = camera-bottom distance in feet

As an example, suppose the minimum distance to detect is 2.5 feet, then the minimum time to be detected is

$$T = 1 \text{ millisecond}$$

Such a short time measurement requires an oscillograph or a high-speed recorder.

The pulse length of the ping should be short; otherwise, when the camera-bottom distance is short, the "up" ping will still be recording when the "down" ping arrives. Thus a pulse length of less than 1 millisecond is desired to measure distances of less than 3 feet. The "up" ping should be about 1/10 the intensity of the "down" ping, since the echo from the bottom is reduced in intensity by reflection. The two pings should be of about the same intensity when they reach the surface and are recorded.

SONAR PULSE CIRCUIT

Several electrical circuits to operate sonar transducers at great depths are shown in Figs. 1, 2, and 4.

The nickel transducer shown in Fig. 1 was used on the CALYPSO in the Mediterranean in 1954. The camera was lowered until the "ticks" were stopped by the short-circuiting switch suspended below the camera. Then the cable was pulled up slowly until the ticks started again. In this way, the operator could hold the average distance at the desired value.

For the examples in Figs. 2 and 4, an Edo transducer of the ADP crystal type was mounted in an aluminum housing with oil filling and with an 11-inch diameter rubber cover. The sound pulse through the back was reduced by the use of absorbing material (1/32" Phenolic) between the crystals and the aluminum plate of 1/2" thickness. The ADP crystals are identical to those used in the Edo type AN/UQN transducer and were installed at the Edo factory.

A pulse type of driver consisted of a 2-microfarad capacitor discharged through a strobotron tube (OA5) into a matched transformer and the crystal. Early units used the strobotron also as a self-oscillator (Figs. 1 and 2). However, the flashing rate had considerable jitter and was influenced by the voltage. This was not important when the "up" signal was used to trigger an oscillograph for measuring purposes. However, when noise became large enough to trigger the scope, then the need for precise triggering became apparent. Later models (Fig. 4) have a timer (A. W. Haydon Company, No. D-7909 S/N 101 6 v dc) to give 1-second pulses with an accuracy of about two parts in ten thousand. This is ample for use with various types of sonar recorders that are standard equipment on oceanic research vessels. There may be a drift of the two systems which results in slanting records across the recorder. However, the observer can spot the two pings and discriminate visually against marks made by the random noise.

The primary open circuit inductance of the pulse transformer is 30 microhenries; short circuit, 6.5 microhenries; and open circuit secondary, 26 millihenries, as measured on a General Radio bridge type 650A at 1,000 cycles.

After a brief pulse of current into the matching transformer primary, the secondary of the transformer and the ADP crystal oscillate as a tuned circuit with a frequency of about 12 kc. An oscillogram of the voltage across the transformer is shown as the oscillogram, Fig. 6, where the peak voltage is about 5,000 volts.

Figure 7 shows the appearance of the "up" pulse and the reflected "down" pulse after being amplified by a two-stage transistor amplifier, which has a 12 kc tuned circuit in the output. The bandpass of the receiving system is about 1,000 cycles. The "down" pulse has been reflected from a wooden floor, which probably is more reflective than the ocean bottom. The pulse width of the received signal is about 6 cycles, which lasts about 1/2 millisecond.

The primary turns of the transformer were varied in order to maximize the output signal. It was found that a primary, open-circuit value of about 30 microhenries seemed to be best for the components in the arrangement.

SONAR OUTPUT

Mr. Frank Massa of the Massa Laboratory at Hingham, Massachusetts, measured the output as follows (referred to 1 dyne/cm^2):

"up" ping	83 db at 5 ft (peak)
"down" ping	108 db at 5 ft (peak)

RECORDERS AND RESULTS

The Edo Corporation supplied one of their modified Fishscopes as an indicator to Cousteau for use on the CALYPSO. This instrument had a 5-inch cathode-ray tube with adjustable sweep circuits for depth measurement. An amplifier tuned for 12 kc received a signal from either the Edo type AN/UQN transducer on the bottom of the CALYPSO or from a Glenco microphone that was suspended in the water below the ship. It was hoped that this lowered microphone would reduce the ship and wave noise. A two-stage transistor amplifier in a glass tube was adjacent to the Glenco microphone to increase the signal strength before being transmitted up the cable to the ship.

The cathode-ray recorder was used on the CALYPSO in 1955 with good success at depths of several thousand meters. However, at the deepest test in the Mediterranean, some 4,000 meters, difficulty with electrical noise from the ship was very serious, making the operation marginal.

In 1956 in the Romanche Trench (7,000 meters), difficulty was experienced with the coupling transformer that drove the transducer. This transformer was potted in plastic. Distortion with pressure was probably responsible for short circuits in the transformer, resulting in weak signals. The transformers are now oil-immersed in a plastic tube which is sealed at both ends with rubber stoppers.

During a cruise of the USCGC YAMACRAW from W. H. O. I. in August 1957, further tests of the sonar on a camera were made by Hersey, Backus, and Edgerton at depths to 1, 500 fathoms. The signal was detected on an AN/UQN receiver, which was mounted on a chain over the side of the ship. The signals were recorded on the Precision Graphic Recorder[4]. The above tests were successful in permitting the winch operator to hold the underwater camera within six feet of the bottom, even while the ship was drifting with the surface current and the camera was trailing behind at an angle.

Further tests were made by Graham in the Indian Ocean in 1958 from the ATLANTIS, where 2, 433 stereo photograph pairs in seven lowerings were made at depths to 1, 200 fathoms. Experiments by Hersey in the spring of 1959 on the USNS CHAIN showed that the camera-bottom measuring system was successful at 2, 600 fathoms. A record from the YAMACRAW cruise of October 1958 (Fig. 5) shows the camera when it was lost due to a cable break. On the record, one can see the camera as it descends to the bottom. The free-fall velocity of the camera is 4. 5 feet per second.

Hersey, after further tests on the USNS CHAIN where he used a sonar of the type shown in Fig. 4 on a bottom corer, reports that the pinger may well be loud enough to be useful in all ocean depths, given especially quiet receiving conditions.

Graham reports that in the Red Sea in 1958 the sonar depth indicator was routinely used to position Nansen bottles in hydrographic stations. In this way, it was possible to place the bottom bottle of the string at an exact known distance from the bottom of the sea without danger of getting it into the mud. The camera and sonar were used this way from the CHAIN as a bottom weight for the water bottle observations during the summer of 1959 in the Atlantic and Mediterranean. Some 16 lowerings were made with the camera during the cruise.

CONCLUSION

A battery-operated 12 kc sonar transmitter with a 1/2 millisecond pulse length in a pressure-resisting case has been useful for surface monitoring of a deep-sea camera to depths of about 2,600 fathoms. The system undoubtedly will find many applications in oceanography, since information of many kinds can be transmitted to the surface by sound pulses and sound echoes without electrical connections to the surface.

The authors acknowledge with appreciation the cooperation of the Edo Corporation; the O. F. R. S., Marseille, France; F. N. R. S. at the Arsenal Marine, Toulon, France; the National Geographic Society; the Research Laboratory of Electronics; Massachusetts Institute of Technology; Edgerton, Germeshausen and Grier, Incorporated; the Woods Hole Oceanographic Institution; Wilfred O. White and Sons, Incorporated; and numerous individuals. T. B. Smith, R. D. Ward, E. Landsman, V. Sundra, and G. G. Hayward helped with technical details of the measuring and recording methods.

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CAPTIONS FOR ILLUSTRATIONS

Figure 1 A bottom signaling sonar which emits pings at 1-second intervals until the bottom switch shorts out the pulses.

Figure 2 An Edo type X20100 transducer driven by a self-triggered strobotron circuit through a matching transformer at 12 kc with a 1/2 millisecond pulse length.

Figure 3 Details of a matching transformer for the pulse operation of the Edo X20100 transducer from a 900-volt strobotron circuit.

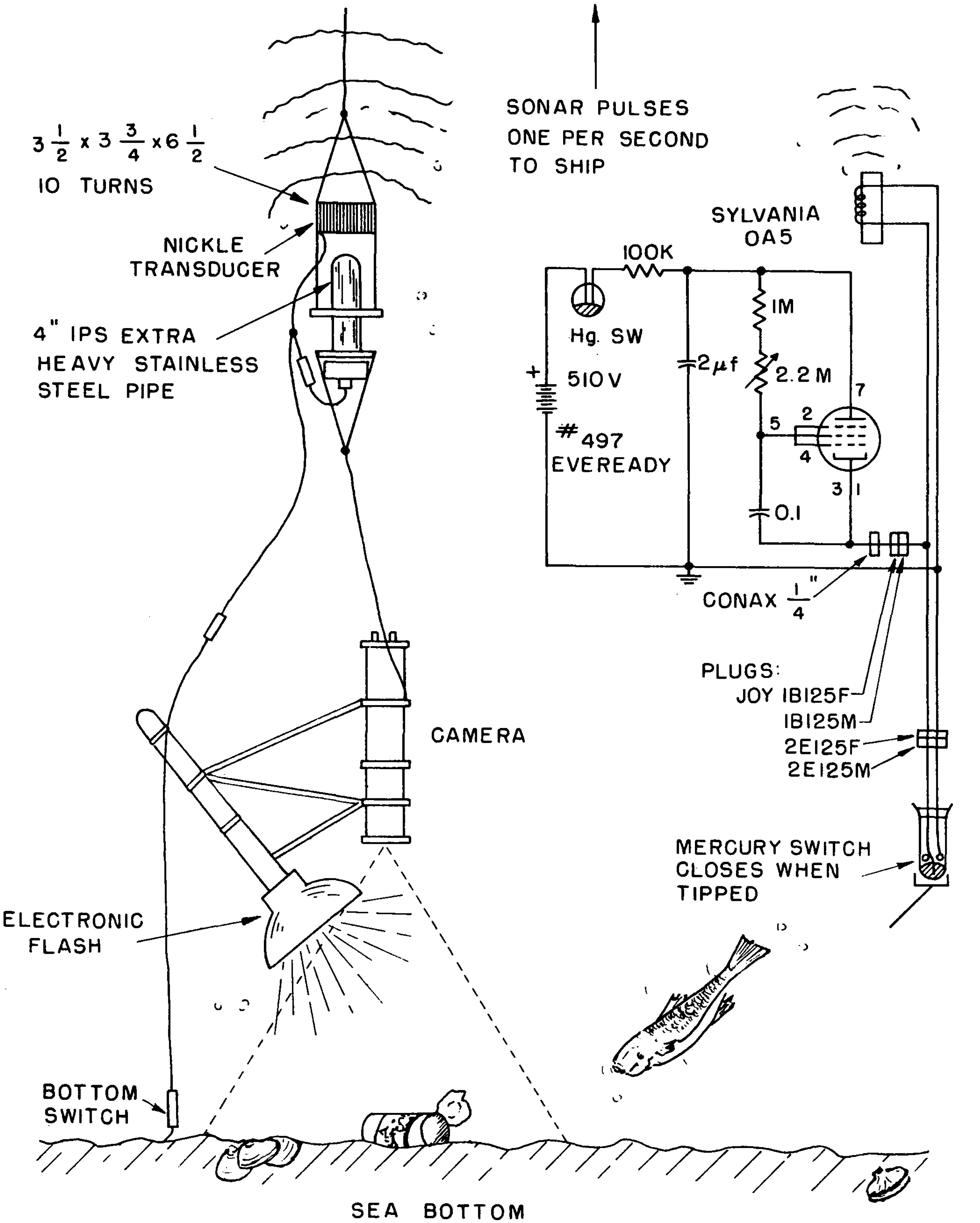
Figure 4 A deep-sea sonar transducer driver similar to that of Figure 2, except with precise timing for recording.

Figure 5 Chart from USNS YAMACRAW (W. H. O. I.) showing the free fall descent of a camera after a cable break. The velocity of the camera is 4.5 ft/sec.

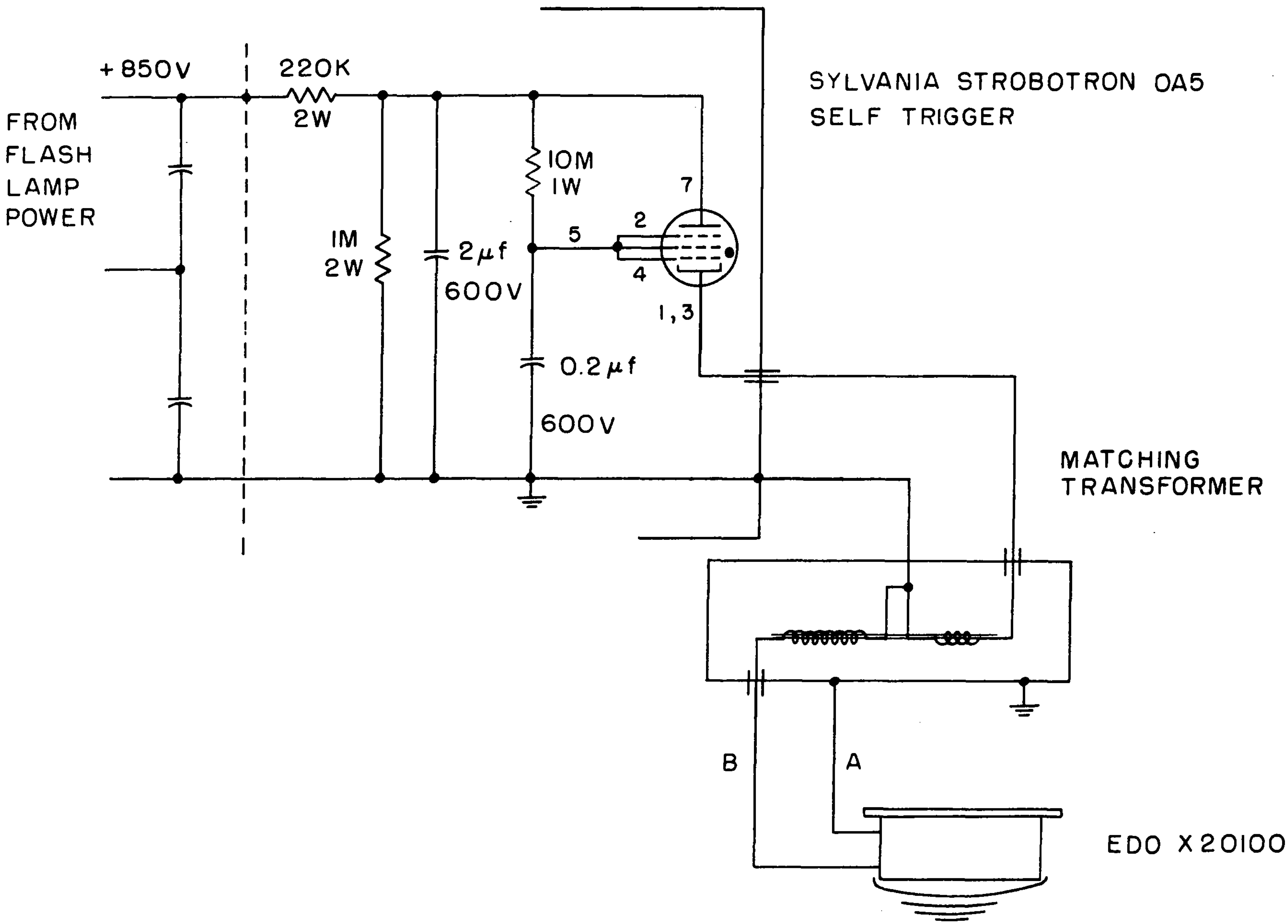
Figure 6 Oscillogram of voltage across the ADP crystal transducer. The frequency is about 12 kc and the peak voltage about 5 kv.

Figure 7 Sonar signals received from an "up" pulse and a "down" pulse reflected by a wooden floor in air. The frequency is 12 kc.

Figure 8 Camera and Edo transducer as used by Dr. John Graham on a W. H. O. I. cruise in the Indian Ocean in 1958 during which 2,433 stereo pairs of photographs were made at seven locations.



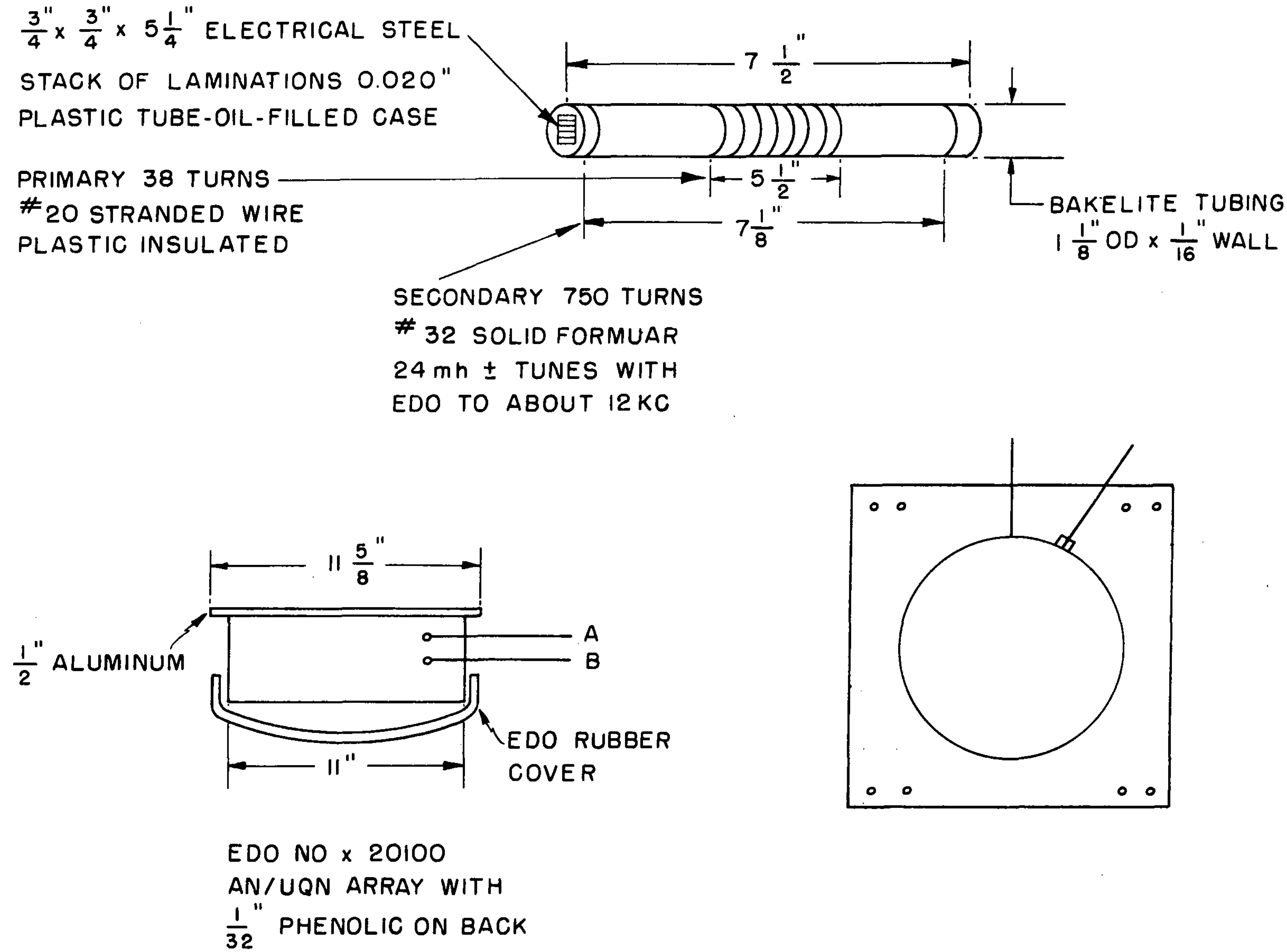
A bottom signaling sonar which emits pings at one-second intervals until the bottom switch shorts out the pulses.



An Edo type X20100 transducer driven by a self-triggered strobotron circuit through a matching transformer at 12 kc with a 1/2 millisecond pulse length.

FIG. 2

FIG. 2

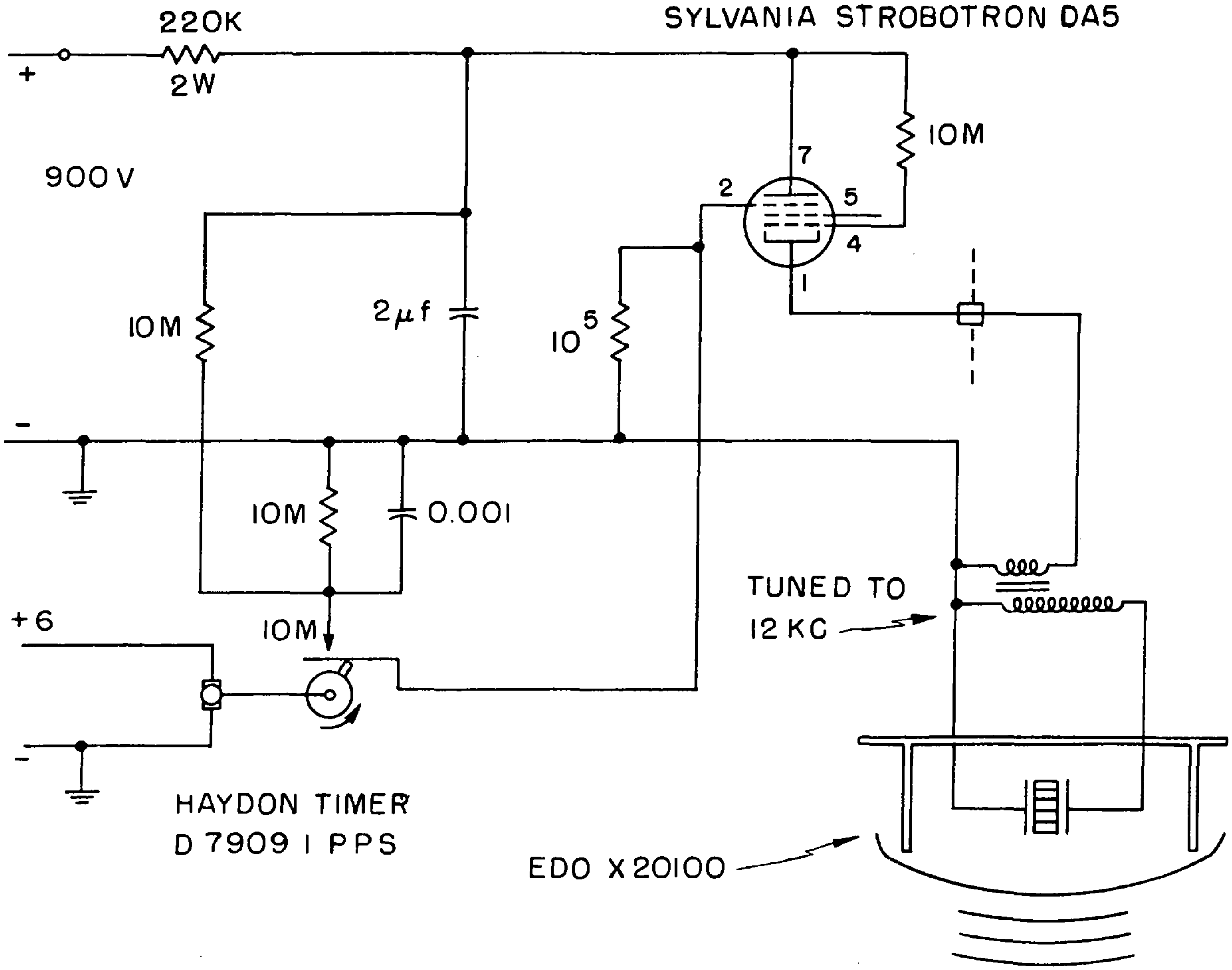


Details of a matching transformer for the pulse operation of the Edo X20100 transducer from a 900 volt strobotron circuit.

FIG. 3

FIG. 3

FIG.4



A deep-sea sonar transducer driver similar to that of figure 2, except with precise timing for recording.

FIG.4

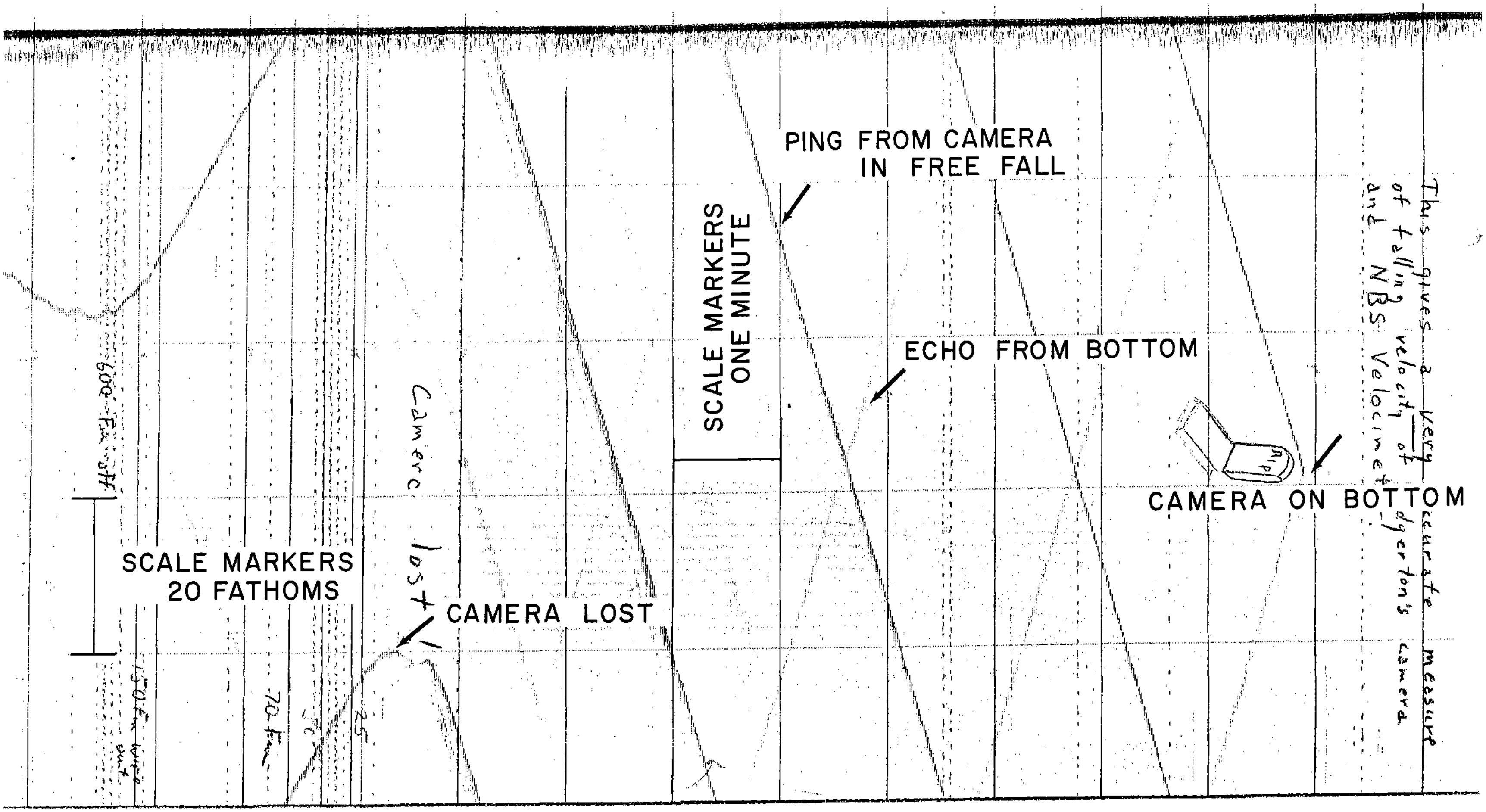


Chart from USNS YAMACRAW (WHOI) showing the free fall descent of a camera after a cable break. The velocity of the camera is 4.5 ft/sec.

FIG. 5

FIG. 5

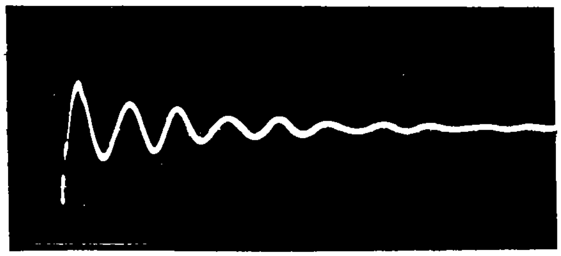


FIG. 6

Oscillogram of voltage across the ADP crystal transducer. The frequency is about 12 kc and the peak voltage about 5 kv.

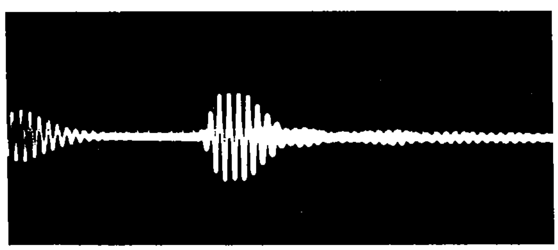
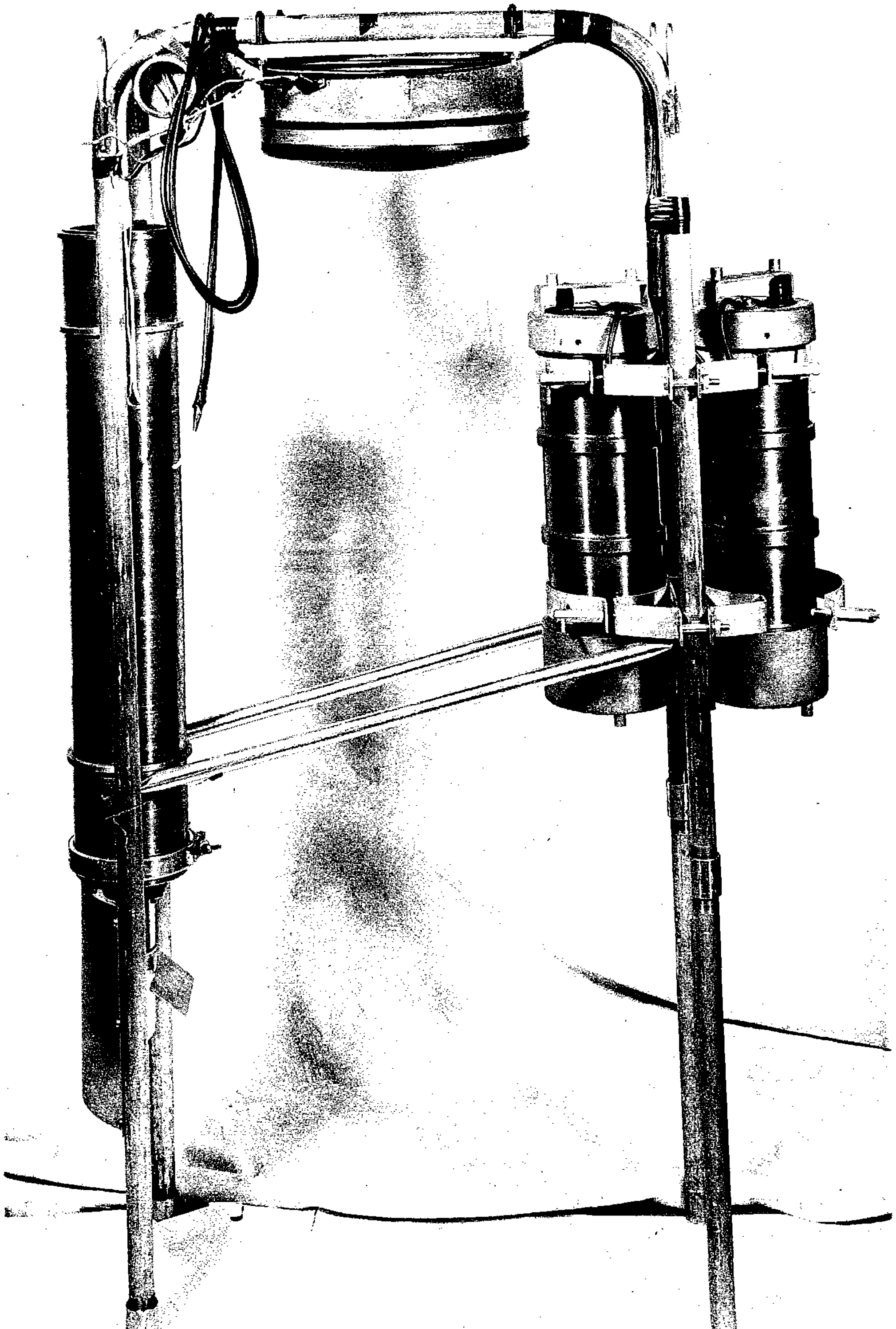


FIG. 7

Sonar signals received from an "up" pulse and a "down" pulse reflected by a wooden floor in air. The frequency is 12 kc.

FIG.8



Camera and Edo transducer as used by Dr. John Graham on a WHOI cruise in the Indian Ocean in 1958 during which 2, 433 stereo pairs of photographs were made at seven locations.

FIG. 8

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