SUGGESTIONS FOR PROBING A SOFT MUD BOTTOM

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One of the main problems of hydrography is to define the depth of water in the shallow waters of navigable channels. This measurement is difficult when the bottom is of soft mud. A boat may find itself stuck in muddy water which blocks its propellers or obstructs its pump outlets. This type of muddy bottom is encountered in the approaches to large tropical rivers. There we find intensive life, backed up by a constant deposit of fine mineral matter mixed with much organic material. Bacterial activity produces colloidal suspension of varying consistencies and with features that have as yet been little studied.

Soft sediment materials are difficult to sound with accuracy. The sounding lead penetrates into the soft mud until it reaches a harder layer of mud or until friction stops its descent. Experiments have shown that in such cases the navigable depths cannot be defined in this way. Acoustic sounding is also inadequate for resolving this problem, for the various depth recorders (of various frequencies and powers) give depths which differ : the higher the frequency the more the acoustical waves are absorbed. Moreover the results may vary considerably with the intensity of the wave emitted, the reception circuit gain, the kind of recording paper used and the resolution of the depth recorder.

Japanese and American delegates to several hydrographic conferences [1] have raised the question without arriving at any agreement on a standard procedure.

Finding a publication of the Monaco Oceanographic Museum entitled *Le Mud Penetrator* of interest, Captain LEMIÈRE was eager to reprint it in the International Hydrographic Review. *Le Mud Penetrator* describes an apparatus, its method of use and the tests carried out of continuous profiling in mud which this equipment has made possible. This is a geophysical approach to sedimentological problems. The author has, however, preferred to write a somewhat shorter article for the International Hydrographic Review. Indeed, apart from the fact that it would be superfluous to inflict upon the reader descriptions which are unnecessary to a hydrographer, it appears desirable to publish some more recent information, for in this field techniques are constantly being improved.

(1) See *Int. Hydr. Bull.*, January 1965, page 14.

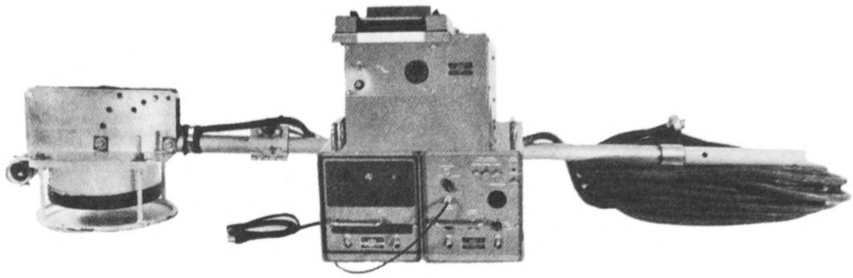

FIG. 1. — *Photograph of the equipment.*

In the centre, the electronic unit and the recorder; the rolled cable to the left is used to feed the current. To the extreme left the transducer is mounted on a " fish " whose balance is shown in the background. This system makes good navigation possible up to a speed of 4 knots with the instrument immersed 1 m. To the extreme right of the balance is the counterweight which acts as a counterpoise to the balance. The electrical cable is used to support the transducer from the ship. This cable is attached to the balance point in water of the equipment. The electrical connection for the cable is situated at the right-hand side of the electronic unit. (Photograph by kind permission of Dr. H. E. EDGERTON).

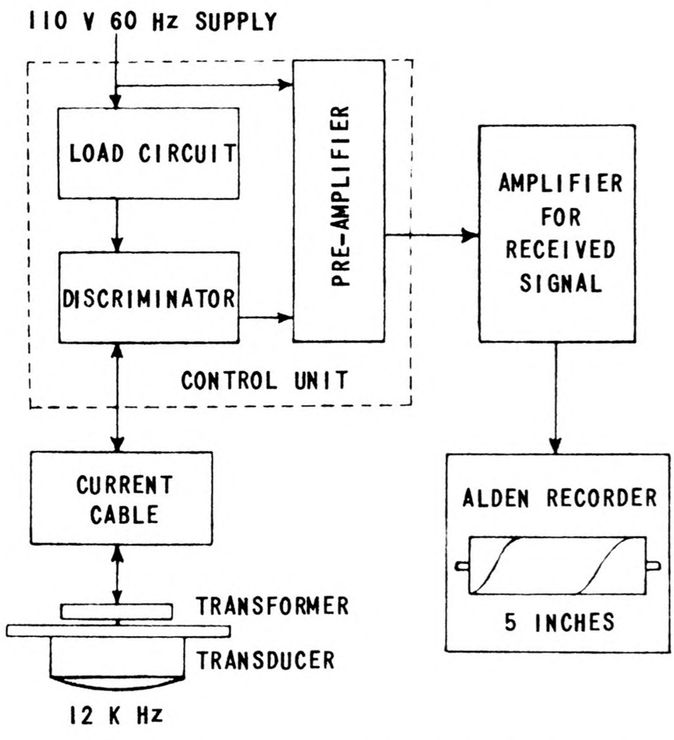

FIG. 2. — *Circuit diagram of the Mud Penetrator.*

Energy is obtained from a conventional 110 V, 50 or 60 Hz, 4 ampere circuit. The voltage, raised to 900 V and rectified, charges an electrical condenser which subsequently discharges through a special trigger tube as commanded by the recorder. The discriminator with back-to-back diodes permits the discharge to be made to the transducer without exceeding a certain level in the receiving circuit, but allows the received signal from the bottom to be recorded. The cable of 30 m or more in length is used for both current and towing. A coupling coil is used with the transducer to increase the voltage to about 4 000 volts. The received signal is directed towards the pre-amplifier by the discriminator and from there to the amplifier and to the recorder. The different dial readings — the recorder's rotating speed, the value of the capacitor in the circuit, the amplification, the paper speed marker — all these are situated on the front panel of the instrument.

Mud probes for resolving problems of sedimentological recognition have been in use for about 10 years, although a few experiments had been made earlier. This equipment has been used for studying such problems as the nature and depth of well-defined sandy or mud layers, the depth of the sub-bottom rock in the exploration of estuaries, and the archeological quest for ancient buried wrecks. At present the equipment which is the most used is manufactured by Edgerton, Germeshausen and Grier, Inc., of Boston, U.S.A.

An EDO sonar transducer with ADP crystals is stimulated by a capacitor discharge which is very short and the acoustic pulse transmitted in the water has a basic frequency of 12 kHz and lasts 100 microseconds, i.e. about three half cycles. The transducer serves as a receiver for the waves reflected by the sea bottom and the sub-bottom. The voltage which the received waves produce at the transducer's terminals is amplified and recorded on an electrolytic paper in the same way as on the usual depth sonar.

The author has used the Mud Penetrator successfully in several areas of interest. Sometimes, however, only poor results were obtained, since the bottom was of pebbles or gravel, or was covered with seaweed. The waves were either diffracted by obstacles of a size little different from the transmitted wave-length or else absorbed by them. Experiments have shown that absorption and diffraction diminish according to the wave-length. 6 kHz transducers, as was expected, gave better penetration in coarser sediment [EDGERTON, 1963-1965; LEENHARDT, 1964*b*].

With a 12 kHz Mud Penetrator in 30 m of water in the Gulf of Fréjus some strange reflection shapes became locally visible. These shapes are related to fine sediment of sand and mud deposited fitfully before the present day. The penetration obtained at the base of the formation is

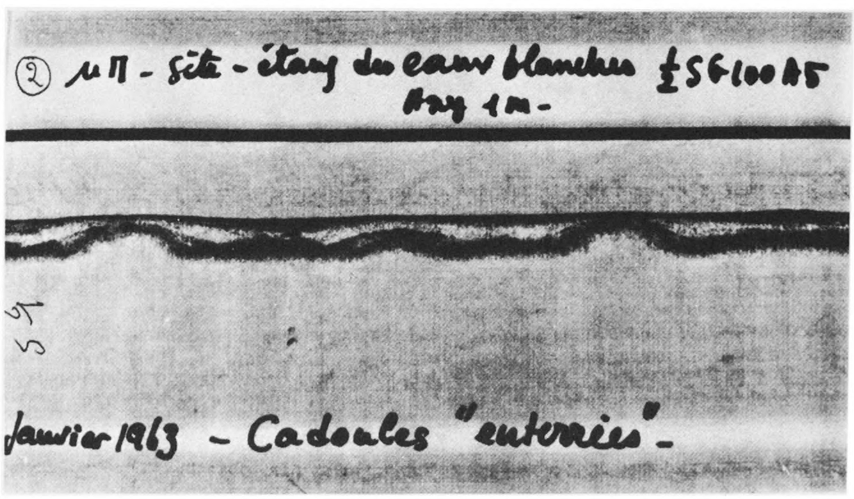

FIG. 3. — *The Etang de Thau.*

Under a flat muddy bottom, a sub-bottom (probably formerly the sea-bottom) presents an irregular shape due to biological activity. These mounds are known as " cadoules ".

The recording is made on 5-inch wide paper on the Mud Penetrator where the pulse length is a minimum. The depth of water is about 6 m.

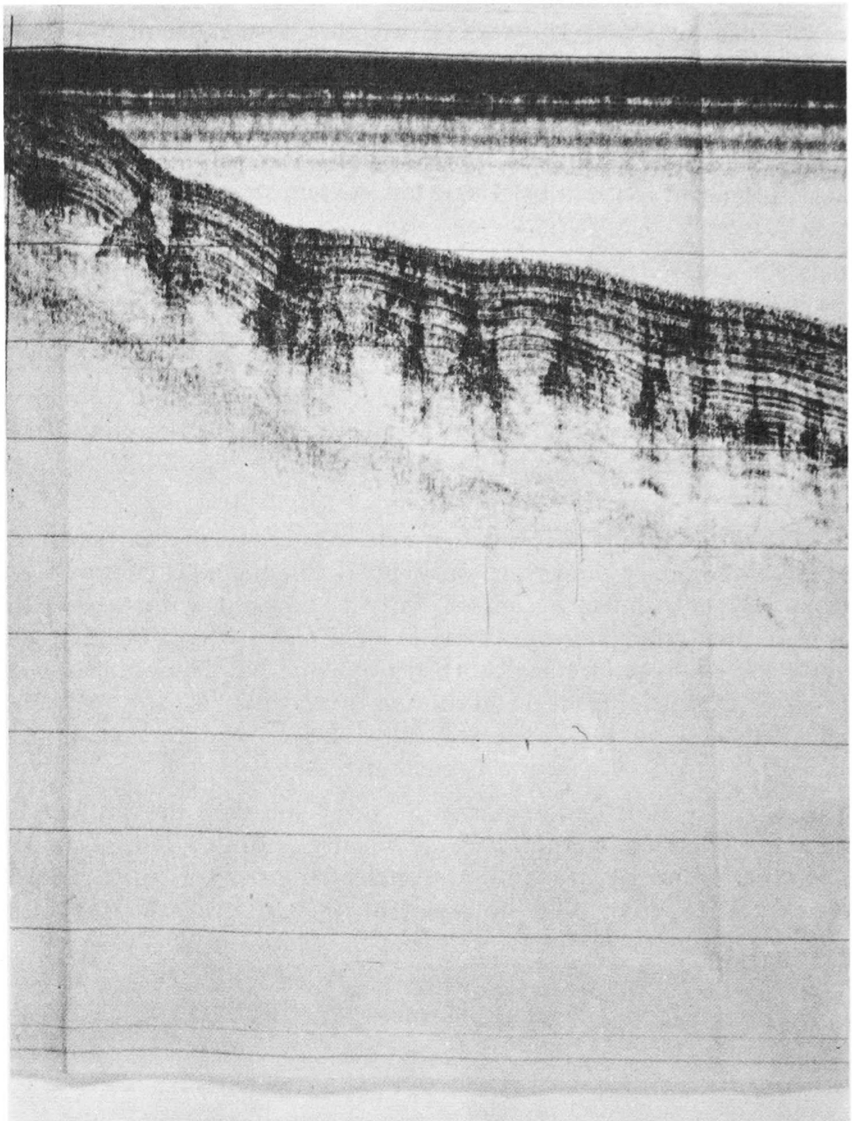

FIG. 4. — *Lac Léman.*

Under bands of mud there appear pagoda-like structures whose origin has not yet been determined.

Here the recorder is an E.G.G. Seismic Recorder, Model 254, with an 11-inch width of paper. Many operating improvements have been designed into the instrument. The bottom echo is registered at the second helix rotation. The distance between the two time calibration lines is 10 ms. The depth of the water is about 80 m.

about 5 m. With a 6 kHz equipment the detail of these shapes is considerably less clear, but the sub-bottom at about 10 m, corresponding to a longer and more homogeneous phase of the geological history of the gulf, is clearly shown on the left of the recording.

With the same device Dr. EDGERTON has been able to record the fresh-salt water interface in Boston harbour.

These examples draw attention to several technical details which make all the difference between one depth recorder and another, and thus suggest a possible way to approach depth recording in soft mud. In exceptional circumstances it sometimes happens that ordinary depth recorders penetrate the mud and record the sub-bottom [CAPART]. In the case of the Mud Penetrator this performance is common.

It has the following superiorities :

1. Handiness of the equipment.

This has an overall weight of 100 kg. It can be mounted in any boat (for instance a Zodiac Mark III was used for a marsh in La Crau). The equipments with which the first mud studies [SMITH, MAC CLURE] were made are still in use, but they are heavy and cumbersome both in design and execution.

With modern mud-probes the only component which may be heavy is the transducer. Everything being equal in all other respects, reducing the frequency by half will lead to multiplying the weight by eight. However this factor enters only slightly into the problem with which we are concerned; indeed transducers of more than 12 kHz are still light in weight; the directivity and the transmission level (1) (also factors which vary with weight) may remain at moderate values.

2. Quality of the acoustic pulses.

Ordinary depth recorders use either oscillating transmitters or transmitters with resonance-tuned capacity to operate the transducers. As a result all the waves transmitted have considerable length (5 ms for an EDO UQN/1, and usually at least 1 ms for Low Frequency depth recorders). The resolution cannot be less than 50 cm.

Thanks to a damping resistor the Mud Penetrator's transmitter has a shorter pulse duration, and details of about 10 cm are easily discernible (except in general on the bottom itself).

3. Flexibility of the recorder.

a) *Adjustment of the output power* is of importance. It is necessary to bring out in relief the reflections which are produced on the interfaces between mediums with different acoustical characteristics, or in a heterogeneous medium where these characteristics show a gradient. Usually the bottom will record a distinct discontinuity and the strong reflection will saturate the amplifiers and mask the details lying immediately underneath. The output power is varied by changing the capacity in circuit, that is, the energy per pulse.

(1) See for example GUIEYSSE and SABATHÉ.

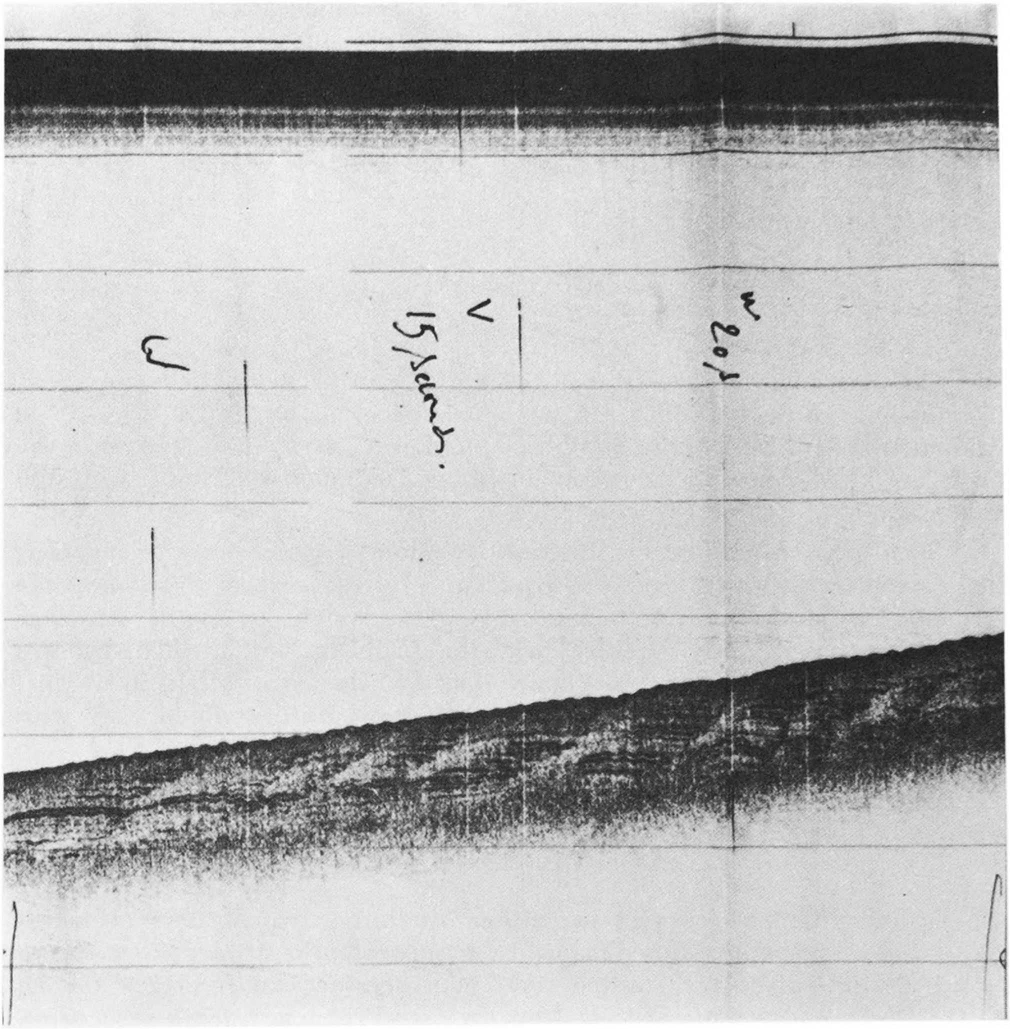

FIG. 5 (12 kHz)

FIGS. 5 and 6 — *Comparison between a 12 kHz and a 6 kHz recording.*

These two recordings were made in succession and at approximately the same place in the Gulf of Fréjus, between Le But and the mouth of the river Argens. The interval between the two scale lines is 10 ms. It can be seen that the mean depth is 40 m.

On the 12 kHz recording the reflections have a greatly increased resolution and show more details than on the 6 kHz recording. On the latter the amplification is stronger, and a deep sub-bottom level can also be seen.

The formations here observed are now being studied from the geologic point of view.

b) *Specific properties of Alfax paper.* Spark paper (the Teledelto system), which is at present used, is either effective or not at all, and a considerable proportion of the information received is lost. With Alfax paper the ratio between the power of a signal that is hardly recorded and that of a very dark signal is over 20. The half tints are particularly well portrayed. This is due to the fact that the registration is in the colour-tones to which the eye is most responsive, and also to the quality of the

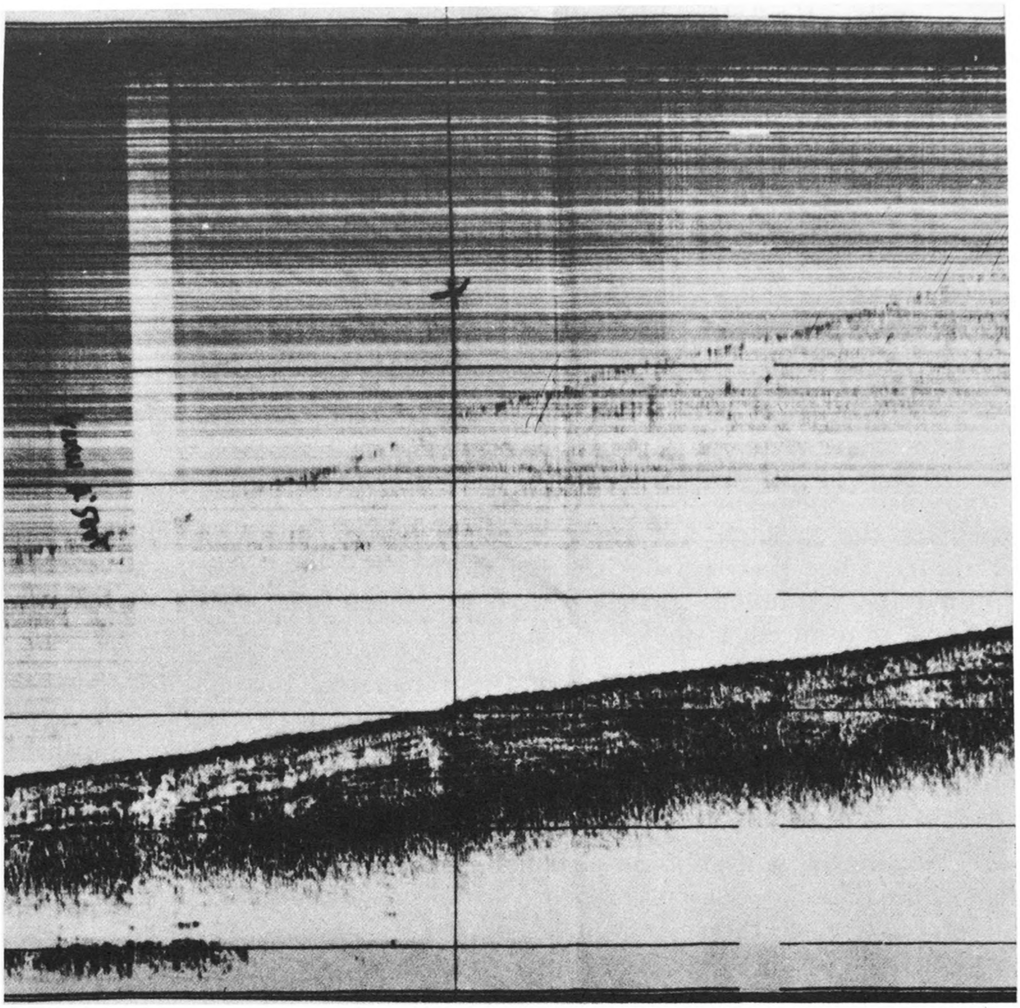

FIG. 6 (6 kHz)

recording system itself, i.e. the mechanical flexibility of the wire on an acoustic holder and the chemical qualities of ferric ions which have been incorporated in the paper [ALDEN and FARRINGTON]. The operator will always obtain a better result if he takes care to regulate the recording gain very carefully.

c) *Very good resolution.* Spark-paper recorders can operate at very high speeds, but as we have seen they lack sufficient sensitivity. Other recorders, such as the Muirhead, employ a similar electro-chemical reaction. The mechanical arrangement of the components is different [cf. LEENHARDT, 1966] and with this technique a speed of more than 500 rev. p. min. will not be possible, whereas with an Alden recorder a speed of 1 800 rev. p. min. is easily attained. Graphic resolution to the problem is thus at least as suitable as the acoustic resolution.

These various points of detail explain the success of the Mud Penetrator. They outline the necessary precautions for obtaining good recordings.

What method should be followed in the case of soft mud ? Japanese trials (*Int. Hydr. Review,* July 1963) open up interesting prospects. The simultaneous use of several frequencies allows the determination of different figurative " bottoms " — at the surface of liquid mud, at navigable depth, and at the base of the layer of mud. This makes the simultaneous use of three transducers necessary.

In practice the spacing out should be of the order of 15 - 40 - 70 kHz (to be accurately determined after tests so as to avoid the secondary resonance peak of a transducer of lower frequency being of the same value as the basic frequency of a transducer of higher frequency). This should permit a satisfactory survey. The equipment is in the form of a triple transducer with an transmission level of about 100 dB (ref 1 barye at 1 m). The directivity is relatively unimportant if secondary lobes are avoided.

At the command of the recorder three transmitters, each tuned to a transducer, send out in turn an acoustic pulse. Each transducer thus receives the pulse it has transmitted at every third revolution of the recorder, since the receiving circuits of the other transducers are locked during the revolution. Interference between the signals received by the various transducers is thus avoided (fig. 7).

The signal received by each of the transducers is amplified and sent out on a single-way Alden recorder. The various reflections will be registered side by side and it is easy to distinguish from which transducer they come — by manually putting one of the transducers out of circuit, for example.

Not having had previous personal experience of a sea-bottom of fluid mud, the author has been compelled to make assumptions in the detailed interpretation of these recordings. However, an idea on how we may expect the recordings will appear is here given *a priori.* The high frequency transducer is only likely to receive one "bottom" — the top of the liquid mud. This "bottom" will also be found again at the medium frequency. However several other deeper reflections will appear at this frequency. Thanks to Low Frequency the deepest of the mud reflections shown up by the Medium Frequency will probably be the first recorded, but others even deeper, right down to bedrock, will also be shown (fig. 8).

It would be vain to hope that one of these "bottoms" represents navigable depth correctly; but knowledge of local conditions from the oceanographic, meteorologic and geologic point of view, together with information concerning the bedrock supplied by the recording, will make it possible to interpolate.

The cost of manufacturing such an instrument should not rise above $ 12 000 (excluding research costs) according to the place and the method used.

Subsequent tests will allow us to develop a simplified device, which could be used under routine conditions by interested harbour authorities.

I thank Dr. H. E. EDGERTON for his advice during the writing of this paper and for his constant help.

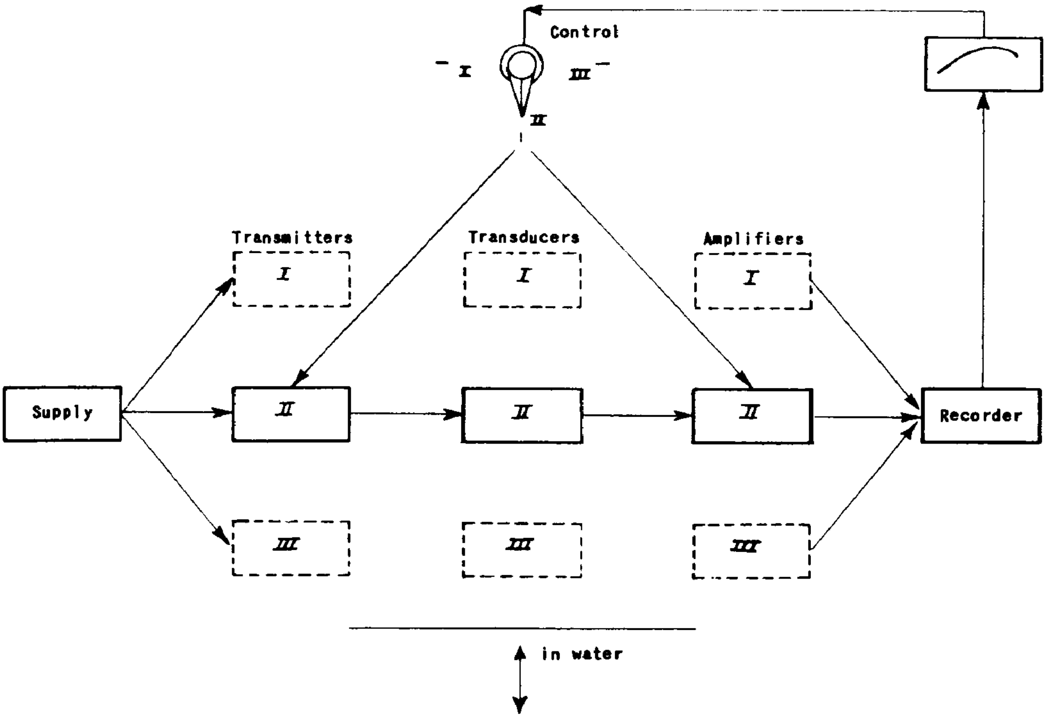

FIG. 7. — *Diagram of proposed equipment.*
This circuit is shown at the time the MF transducer is operating.
(Description given in the text).

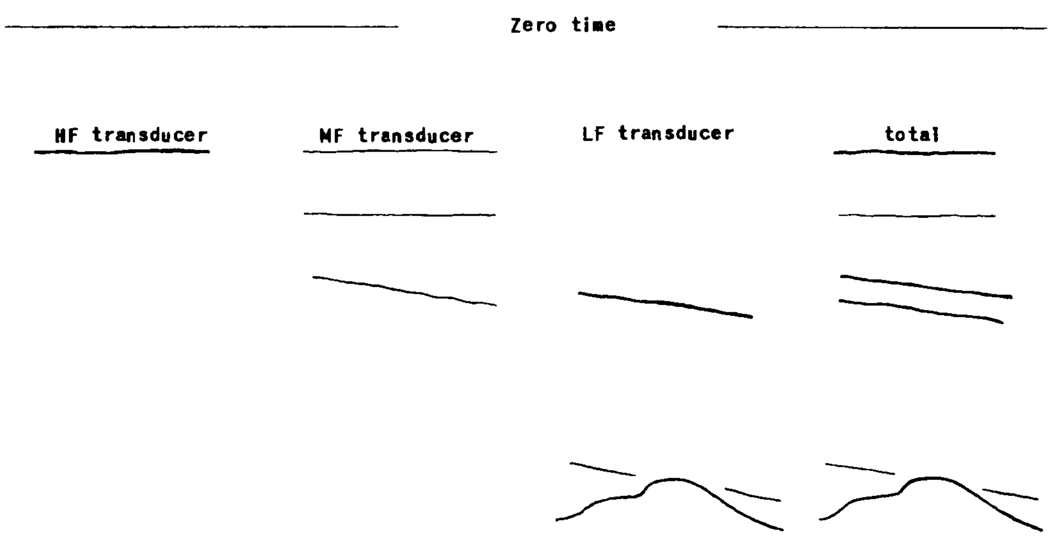

FIG. 8. — *Theoretic example of a recording.*
Diagram of theoretical recording.
(Description given in the text).

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