MULTIPLE ECHOES OBSERVED IN SONIC SOUNDING ON A SOFT BOTTOM

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The phenomenon of multiple echoes, in sounding over a soft bottom by means of high-frequency sonic oscillations, has been observed not only in the Surveying Ship *Meteor*, but also in many fishing vessels equipped with Debeg "Radiolots" (1). It shows, in a purely empirical fashion, the correlation between the appearance of multiple echoes and the bottom of the sea when this has a stratified structure.

To elucidate the question of the production of these multiple echoes, let us first describe briefly the manner of operating the "Radiolot" with which the observations were made.

The sound emitter is a three-ply block on the *piezo-electric principle* constituted as follows. A piezo-electric quartz disc (2) is cemented between two steel plates. Owing to its relatively large diameter, about 25 cms. (10 ins.), the quartz disc is not in one single piece but is formed by a mosaic of 50 to 100 fragments of rock crystal. This 'sandwich' oscillates as a whole at its proper longitudinal frequency, determined by its transversal dimension and the resultant of the velocities of sound in steel and quartz; this frequency is about 37,500 Hertz. As the piezo-electric effect is reversible, the emitter is at the same time an ideal receiver. The ratio between the dimensions of the radiating surface and the wavelength is so great that strongly directional emissions are produced; the angle of spread is about 13°. The three-ply block is excited by a damped high-frequency impulse of about a thousandth of a second duration and of a maximum intensity of some 6,000 volts. The tension set up by the incoming echoes is amplified and led to a chronomicrometer with an indicator consisting of a scale over which discharges of light take place.

In discussing whether the multiple echoes can be provoked by periodic disturbances of any kind coinciding occasionally with changes in the nature of the bottom, here is the picture we obtain.

Exterior electrical disturbances which may arise from insufficient insulation of the conductor leading to the sound emitter, through the functioning of transmitters or interfering machinery, give false indications at all possible positions of the scale of the "Echolot", and are, for this reason, recognisable without ambiguity.

Acoustic interference is unlikely, owing to the high frequency of the "Radiolot". The three-ply block, as a resonant receiver, constitutes a very bad microphone for all frequencies outside this resonance. One can naturally conceive of the existence of the frequency of resonances as a fundamental or harmonic oscillation in the noise of the ship. If this case were to occur, false reading would appear at every possible position of the scale, as in the case of electrical perturbations, and they would thus be easily recognised.

We also examined whether, by emitting an echo impulse, it were possible that sensitising of the amplifier could be produced up to the point of auto-excitation or generation of oscillations of relaxation. The unequivocal result was that the signal entering the amplifier returns without alteration of shape on leaving it.

Hitherto, with acoustic sounders working at low frequencies (3), a difference of echo according to the nature of the bottom had not been noticed. We are thus led to seek the explanation in the difference of frequency. According to RAYLEIGH (4), however, the degree of reflection at the limiting layer of two mediums depends on the ratio of acoustic penetration of the two mediums and not on the frequency. Consequently it must

(1) *Made by the Deutsche Betriebsgesellschaft für drahtlose Telegraphie m.b.H., Hardenbergstrasse* 43, *Berlin.*

(2) Prof. LANGEVIN, *International Hydrographic Bureau Sp. Publication No.* 3, *Monaco* 1924.

(3) *E.g. the Atlaswerke membrane sonic sounder at* 1050 *Hertz.*

(4) Lord RAYLEIGH, *Theory of Sound II*, 1896.

also be possible to obtain a picture of the layers lying on the sea bed with low frequency sound waves, all the more so in that the absorption by friction in the medium, which according to STOKES (1) increases as the square of the frequency, is much less than with high frequency sound waves (2). It seems rather that it is a high sensitivity of the receiver and the nature and method of use of the chronomicrometer which determine an individual echo indication.

The chronomicrometer of the "Radiolot" is constructed as follows. A strip of light screened in such a way as to leave only a slit 25 mm. long by 2.5 mm. wide (1 × 0.1 in.) turns at a speed of 10 revolutions per second behind a scale. Thus, 10 soundings are taken per second. In this way, a practicable reading of the echo and a high accuracy of measurement are obtained.

The metre divisions of the scale are at intervals of 1.2 cm. (1/2 in.) along the arc. At the instant of arrival of the echo the strip of light appears, its intensity and duration depending on the intensity and damping of the echo. Echo impulses following one another at an interval of some 3.10^{-4} secs. are well recorded. This naturally presupposes that at least the first impulse has a duration less than 3.10^{-4} secs. It will be seen from this that as a first postulate for the measurement of thin sedimentary layers of the sea bottom, the indicating element of the chronomicrometer must, so to speak, possess a high damping power.

Another essential condition for the production of multiple reflections on crowded boundary layers is, as will be guessed, a small angular opening of the emitted sound impulse, and a sufficiently short duration of impulsion.

If the angle of spread is large, the lag between the arrival of the wave front at the different points attains values which exceed the duration of travel due to the distance to be measured between two boundary layers.

The minimum difference of measurable depth is determined independently of the lag caused by the angle of spread, by the magnitude of the duration of impulsion. Values lower than this minimum can only be obtained as a result of damping of the reflected impulse ; i.e. the receiver only reaches the maximum amplitude of the train of exponentially dying oscillations, on reflection on a boundary layer of great permeability.

The prior condition in these questions is a frequency of functioning of a magnitude such that the wavelength be always less than the smallest thickness of layer recorded.

DISCUSSION OF THE INDICATOR IMAGES.

Figures I, II, III and IV represent soundings taken over different natures of bottom. The information concerning the nature of the bottom has been taken from the official charts.

Fig. I represents a sounding on a hard bottom giving a good reflection. The sound impulse emitted, extinguishing itself exponentially, is reproduced by the echo which is roughly conformable with it. Figs. II, III and IV represent soundings on a soft bottom. The echoes are of different intensities, and arise, consequently, from boundary layers with different factors of acoustic refraction. In Fig. II, the first echo is weaker and narrower than the second ; the ooze probably forms a soft mushy layer of passage through to the solid bottom. In Fig. III, the reverse holds good. The layer of sediment is hard and of relatively slight permeability. Fig. IV shows between the first and last echoes several intermediate echoes, which infer the existence of intermediate surfaces *a* and *b* in the bottom layers.

The question of knowing whether the last echo comes from a hard bottom (sand, stone) or a boundary layer, e.g. between two kinds of clay of very different densities, can only be truly solved by checking with a driver tube or by borings. The qualitative and especially the quantitative representation of the sedimentary layers is a function of the amplitude striking the reflecting medium (3), of the degrees of permeability and the thicknesses of the different mediums (4). It is thus a condition for taking such measure-

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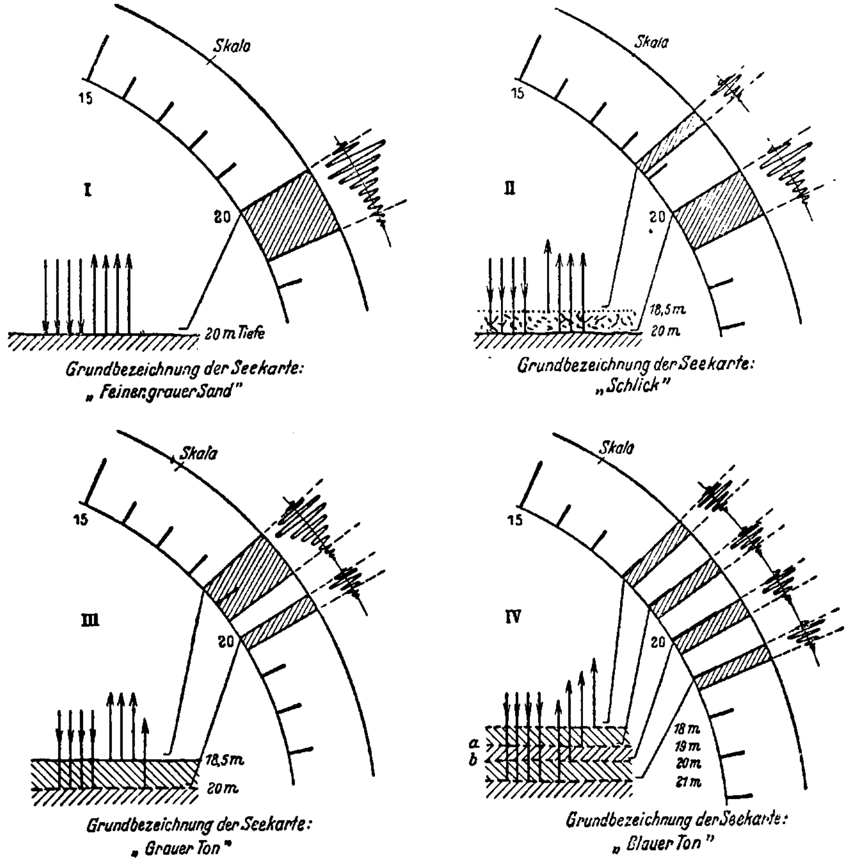
(1) G. STOKES, Mathematical and Phys. Papers, *Cambridge*, 1880.

(2) *But in the "Radiolot" emitter, the greatest absorption caused by the high frequency is amply compensated for by the directional emission.*

(3) *Which in turn depends on the absolute depth.*

(4) *So long as no change of position of the emitter-receiver has taken place.*



I
Nature of bottom plotted
on the chart:
"Fine grey sand"

II
Nature of bottom plotted
on the chart:
"Ooze"

III
Nature of bottom plotted
on the chart:
"Grey clay"

IV
Nature of bottom plotted
on the chart:
"Blue clay"

FIGS. I-IV

Examples of indications of echo of the "Radiolot" in the presence of sea bottoms of different natures.

ments that a greater amplitude should be chosen than that barely necessary. If several measurements made at the same place with different energies of emission give the same result, it may be admitted without fear that the profile indicated is correct.

It is thus, for example, that in the Elbe, in an absolute depth of 13 metres, the same indication was obtained three times with emission energies in the ratio of 1 : 2 : 3. On the other hand, in measurements taken near Bornholm, in an absolute depth of 112 metres, a different picture was obtained with energy 1 as compared with energies of 2 and 3.

The thicknesses of the layers shown on the scale are naturally only relative values, which must be corrected in conformity with the speed of propagation of the sound in the sediment concerned.

SUMMARY.

The question concerns the production of multiple reflections in sonic soundings with high-frequency sound waves, in the presence of soft bottoms. Electrical or acoustic disturbances as a cause of the phenomenon may be eliminated, for on account of their lack of systematic character they can easily be recognised. The high frequency of functioning cannot be incriminated as the source of these multiple echoes, for the degree of reflection is independent of the frequency. The qualitative and quantitative appreciation of different natures of bottom will be all the better as one uses a sensitive emitter-receiver without inertia, with extreme directional action, such as is constituted by a three-ply piezo-electric block, and an indicating element with which can be read intervals, without inertia, down to 10^{-4} seconds roughly. The impulse radiated must be of sufficiently short duration. The different echo indications obtained when sounding bottoms of various natures are discussed.