# ECHOGRAM PROFILES AND HOW THEY CAN BE ESTABLISHED

by Dipl. Ing. SCHULER,

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In order to navigate a ship, navigators use the chart. The principal feature of the chart is the information it contains on the depth of the water. The relating of data regarding depth to the geographical position, and the determination of such data, is the objective of national charts and of charting operations; charting provides the work sheets for cartographical preparation and the subsequent production of such charts as are deemed necessary. The work as briefly described above forms part of the tasks of the German Hydrographic Institute of Hamburg.

I should like to report in particular on the determination of depth for charting purposes by the echo sounding method, which forms a part of charting and which will be discussed at this Conference.

Previously, the normal procedure of establishing depths was by employing the sounding pole, the hand-lead, the lead line or the sounding machine. As we know to-day, this method was inconvenient, time-consuming and, frequently, inaccurate. Therefore efforts were made to mechanize the procedure ; the first ideas on echo sounding techniques were conceived 50 years ago. However, sounding equipment sufficiently reliable during operation was not introduced until 30 years ago. I will not bore you with details regarding the history of its development or with the more fundamental problems as regards measuring echo transmission time, but I will rather deal with the present situation.

Although there does not exist a safety regulation in international shipping requiring echo sounding equipment, there is hardly a sea-going vessel that is not furnished with or does not operate an echo sounding device (Fig. 1). The echo sounding equipment is capable of providing the mariner with depth information in the location of measurement ; such information may contain a mean error of $\pm$ 4 per cent due to hydrographic causes, provided the equipment is of the high performance type. This means an error of approximately $\pm$ 20 cm. per 10 metres, or $\pm$ 2 metres per 100 metres of depth. This accuracy is sufficient for all practical purposes. The sound velocity in water is known to be approximately 1500 m./sec., and to be dependent on salinity and temperature. Hydrographic research has revealed that such factors by no means remain constant in a given area, but are subject to continual fluctuations (Fig. 2). Thus one may not expect accurate measuring data. However, a chart should indicate the depth as accurately as possible ; the echo sounding equipment as used in surveying must be so designed that the echo transmission time can be adapted to the actual conditions of the area sounded. For work in limited areas, average values may be used which have been established empirically (Fig. 3). Precise determination of the relevant factors is indispensable for accurate measurement.

As is the case with any other location aids, the sound is also subject to the influence of frequency-dependent absorption, diffraction, variations in reflection, acoustic interference, etc. The higher the sound frequency used, the greater the absorption ; a loss in attainable depth can be compensated to a certain extent by lobe gain or by increasing the output. For reasons of economy, at present echo sounding equipment for smaller depths down to 100 m. operates on a frequency of 50 - 80 kc./s.; for medium depths down to 1000 m., 15 - 20 kc./s.; for greater depths down to 11000 m., 3 - 12 kc./s. Frequencies below 12 kc./s. are not normally used for commercial applications, since an endeavour must be made to avoid the extensive spectrum of interfering frequencies radiated from the ship and its driving gear. Moreover, the dimensions of the oscillator are increased if it is desired to obtain a special directivity. Such a directive effect is desirable for performance reasons and also for the purpose of obtaining a more precise interpretation of the indicated depth information on the recorded echogram.

The area of the sea-bed scanned is large in the case of low directivity and increases with the depth according to the cross-sectional area of the cone of the group of oscillators employed. The depth and local correlation of the elements becomes more difficult, as the echo increases in length and extent.

A frequent repetition of the measurements is highly desirable in order to obtain precise and permanent data and in order to obtain control information on changes in the depth ; range of measurement and pulse frequency are interdependent, and the maximum range is thus finally divided into 4 main range sections. Range groups are provided with specialized equipment. Automatic controls provide reliable constancy; in surveying equipment, frequency pointer instruments for the time-measuring equipment are provided with manual control. The oscillator is required to be a rugged unit that must be able to function for a prolonged period without maintenance in spite of the influences of the sea water and of other stresses ; it must not constitute a weak spot in the hull of the ship. This requirement (Fig. 4) is met by the magnetostriction oscillator which is capable of converting A.C. into sound pressure (when used as a transmitter) and sound pressure into A.C. (when used as a receiver). In order to meet the requirements of continuous operation, the individual components must be of rugged construction, and the overall weight must be low. With the present equipment it is possible to sound depths down to 1000 metres with a transmitter output of approximately 100 W., under normal conditions of bottom reflection; for penetrating into greater depths, the output required is substantially greater. Not only is more energy required, but wider pulses are needed, as in the case of radar technique. With pulse widths of 1 millisecond, the ground echo shows a very good discrimination of small echo reflectors at small depths, but nothing can be seen at greater depths. The detection at small depths of the layers and of fish is very good. For greater depths, wider pulses are required.

About 20 years after the echo sounding system was introduced into shipping, and after the advantage of noiseless operation of the system was appreciated, the conventional reception methods of acoustic perception or the indication by spots of light produced by means of thyratron arranged before a circular scale could be supplemented by a cathode-ray tube and by recording on specially prepared paper. Both methods, no doubt, brought about a very substantial extension of the application of echo sounding technique. They have a rather low threshold and are capable of analyzing the echoes. The content of the echo undulations is expanded in time by an indicator moving at a uniform rate : in the case of the cathode-ray tube by an electronic beam on the fluorescent layer, and in the case of the recorder (Fig. 5)

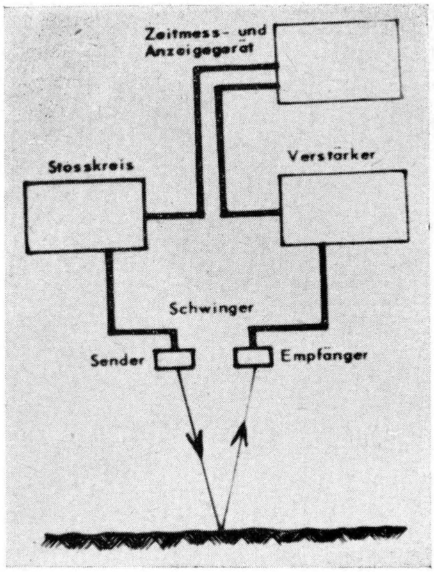


*Fig.* 1.

Fundamental arrangement of an echo sounding instrument.

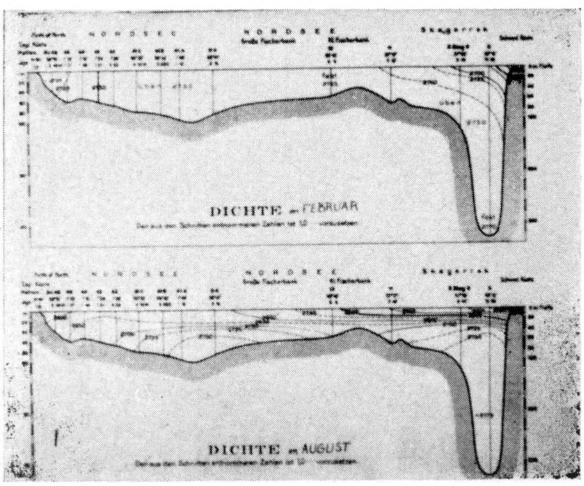


*Fig.* 2.

Density distribution of sea-water over a special North Sea profile during winter and summer.

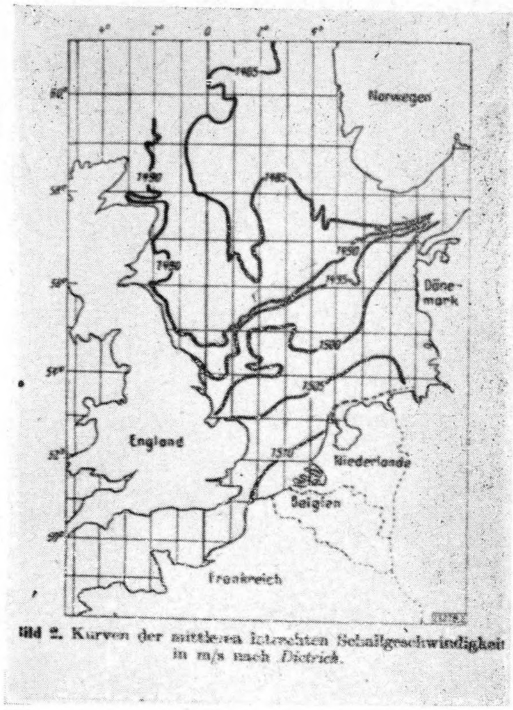


*Fig.* 3.

Average monthly value of vertical distribution of velocity of sounds in North Sea, computed by Dietrich from temperature and salinity.

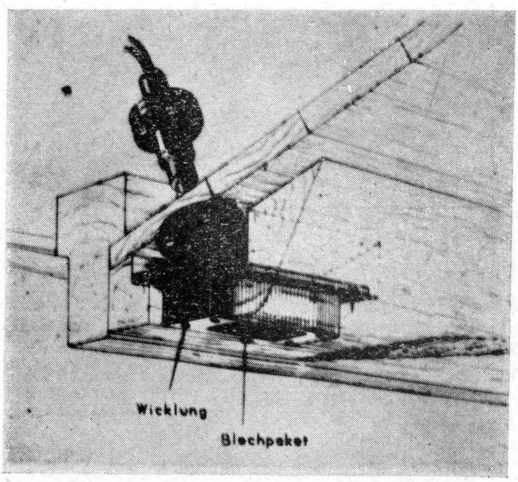


*Fig.* 4.

Magnetostrictive oscillator in an all-wooden hull.

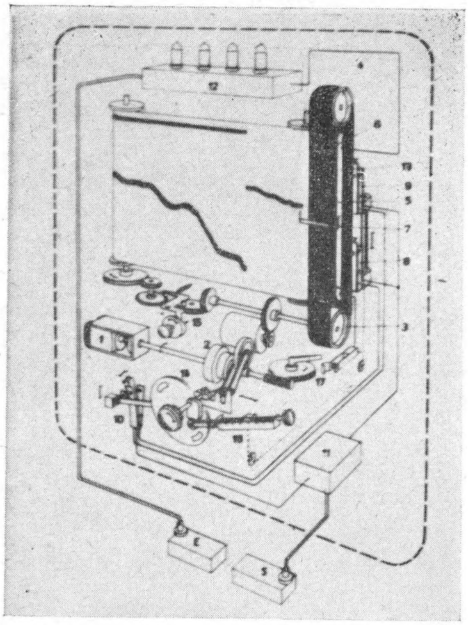

*Fig.* 5.

Echograph with table, styles and gear.

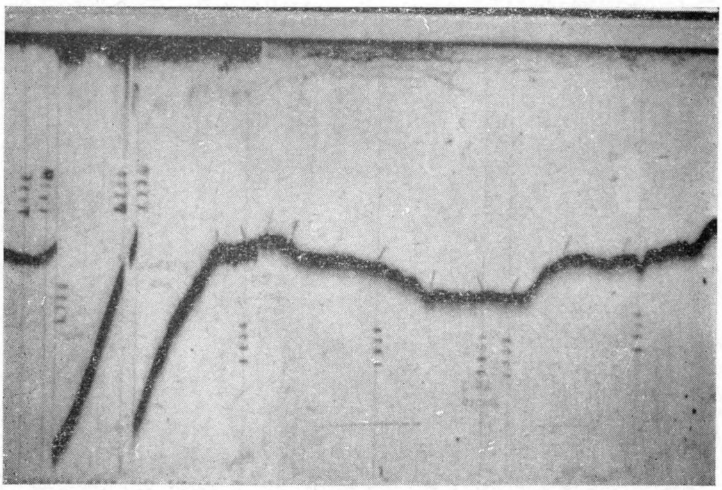

*Fig.* 6.

Echogram, 3 phasings, left long pulse, right short pulse.

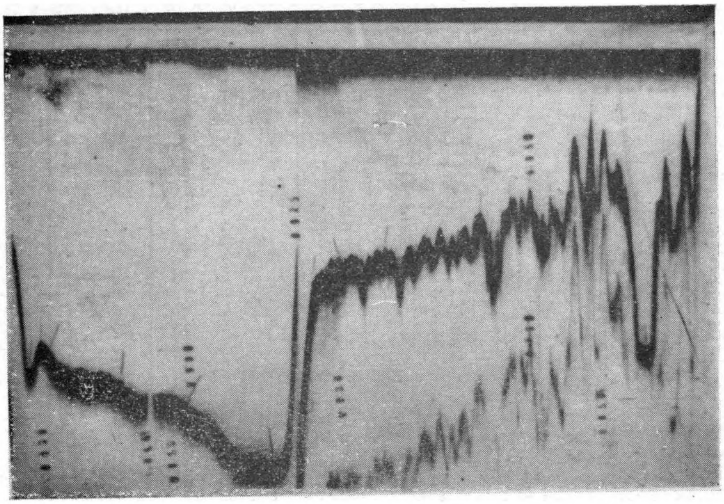

*Fig.* 7.

Echogram from east coast of Greenland.
Left : slow speed of paper ; right : high speed.

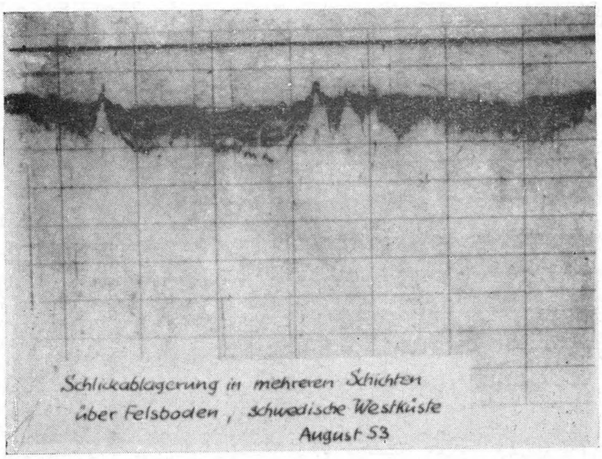


*Fig.* 8.

Mud over rocky bottom off the west
coast of Sweden.

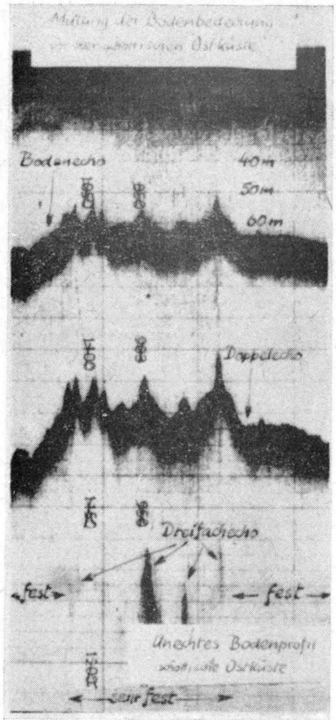


*Fig. 9*

Bottom profile with different factors of reflection.

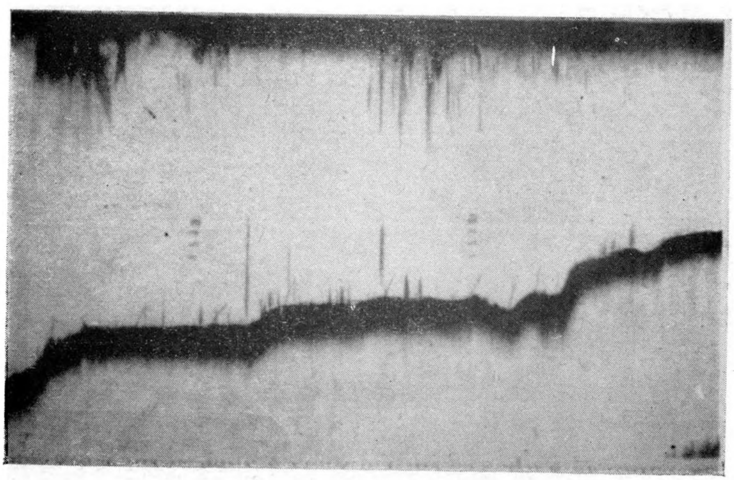

*Fig. 10.*

Fishes down to 100 m. and above the bottom.

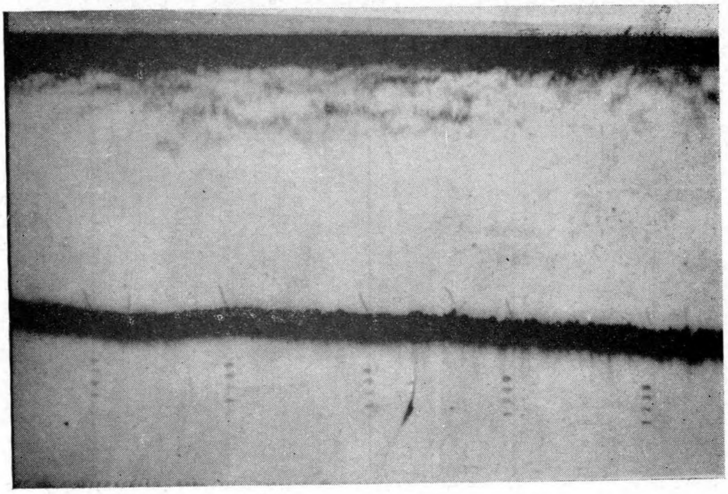

*Fig.* 11.
Density stratification in waters of Greenland Sea (Denmark Strait).

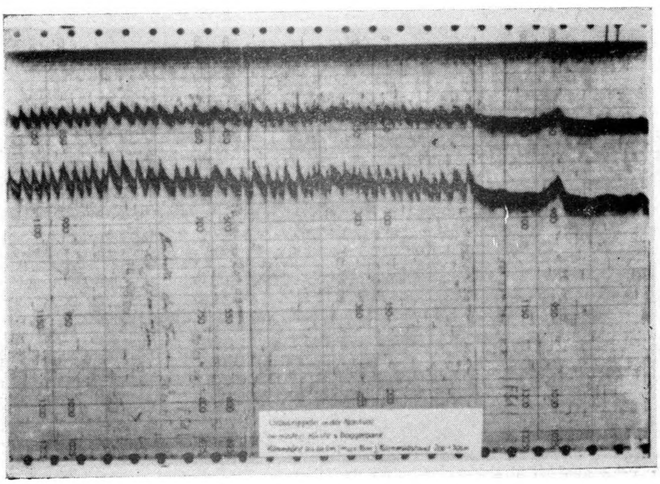

*Fig.* 12.
Sand-dunes in North Sea off Netherlands coast.

by a fine stylus, which is connected to the A.C. produced by the echo, on prepared paper. In the beginning, the echo sounding recorder used electrolysis on iodized moist paper, and at a later stage, burning into dry graphite paper. I need say nothing about oscillograms, of which you are already well informed. The oscillograph presents a temporary picture and provides quantitative data ; the recorder supplies a document containing true depth information, but the echo analysis can be used qualitatively only. Graph recording on paper is the only method suitable for surveying. For scientific purposes, a combination of both methods is used, which supplies additional material by means of photographs taken of the screen display and evaluation of the photographs like an actual echogram. Fig. 5 shows a modern recorder whose individual units, i.e. cabinet with recorder and drive, are the same in any design. The beginning of an echogram may also be seen ; further photographs from true recordings will follow.

Echo sounding equipment is used primarily in navigation and in surveying when the determination of the depth is desired ; here you will see such an echogram. Fig. 6 shows various ranges of measurement of a profile off the Greenland east coat ; time of advance 0.5 cm./min. ; vertical scale ratio about 1 :2000 ; time recorded every 5 min.; time advance of the paper variable according to the horizontal scale ratio desired or required for the profile (Fig. 7). Level ground requires a low paper speed whereas a rugged bottom does not. Many more things can be accomplished with the recorder; however, the degree of hardness of the bottom can be estimated, such as in longitudinal profile from the North Sea shown in Fig. 8. It is possible to penetrate into and record a mud bottom up to 16 metres thick ; these data were confirmed by simultaneously taking samples by bottom or core-samplers (Fig. 9). The number of multiple echoes returned from the sea bottom shows whether the bottom is hard, i.e. rocky, or whether it is firm, i.e. sandy ; according to the reflection factor formula, the returned sound pressure increases with the difference of sound-impedances for water and bottom; the greater the sound pressure, the greater the opportunity for the shock wave to travel back and forth between the ship or the water surface and the bottom ; in such cases, multiple echoes will be recorded. This is, of course, a question of gain control ; once the data of the amplifier are known for a certain setting and are kept constant, the number of the multiple echoes received give an indication of the nature of the bottom, i.e. hard, firm or soft. Such information in addition to that of the depth are of great importance for fishing charts, since it is believed that the type of the ground influences the massing together and behaviour of fish. Such an echogram is particularly remarkable if different hardnesses of the bottom alternate. To-day, one can record fish, which provides skippers of fishing vessels with an idea of the quantity of fish in a certain area ; one can also study the behaviour of fish, e.g. their dependence upon daylight; according to such information the prospects of the fishing operation can be estimated, and from the type of arrangement and the extent of the recordings, the species of fish and the quantity that will probably be caught can be determined. It is no longer difficult to distinguish herring, mackerel or tunny, as is shown by British investigations (Fig. 10). But hydrographers and navigators are more interested in the ability of modern echo sounding equipment to record the thermoclines which contain plancton that provide food for the fish (Fig. 11). Although this is both a physical and a biological effect which is related to the density of the water, it shows clearly the fact that sea water is by no means homogeneous, but consists of a considerable number of locally different media divided into a hydrosphere, similar to the atmosphere and the ionosphere.

There are yet other features showing the dynamical behaviour of water that are of interest to the navigator. Fig. 12 shows a systematic arrangement of irregularities of the bottom, consisting of sand-dunes produced by the influence of a flow vector capable of transporting fine sand grains, which then form dunes. Where such pictures are obtained, there is considerable current, and a sandy bottom. Large areas of the entrance to the English Channel would produce such patterns, but so do also our estuaries, narrow waterways and rivers. Such dunes may be as much as 16 m. high, and the interval between their crests several hundred metres.

Fig. 13 shows that the thermocline — here off the east coast of Greenland, before which hundreds of icebergs were floating or were stranded owing to their great depth — is relatively clear and thin over deep water, but that it then follows the shelf-boundary, i.e. becomes turbulent and expands, so that faster currents in shallow water may be expected due to a decrease in cross-section. Fig. 14 shows no eddying over deep water, but there is stronger and deeper eddying over shallow water.

Finally, Fig. 15 shows that it is possible to obtain recordings of well differentiated layers likewise containing fish, by using wide pulses of about 8 milliseconds, from greater depths also (maximum about 700 m.).

The interpretation of echograms is still in its early stages, yet allows us to hope that this technique will be in a position to assist us substantially in our endeavours to increase the safety of navigation, and in promoting further hydrographic studies.

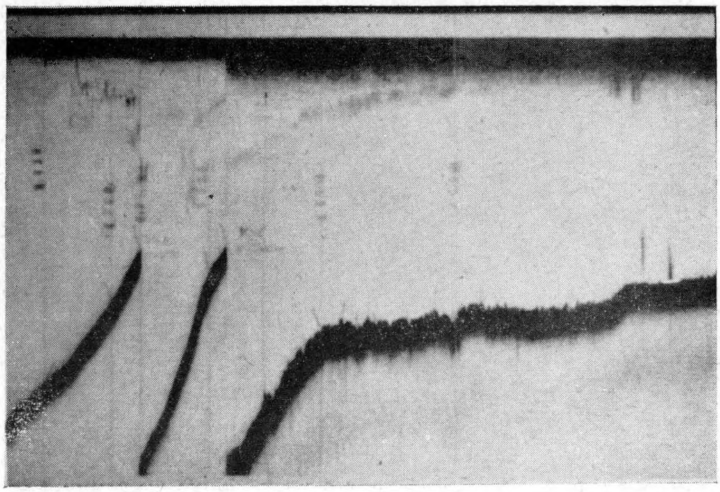

*Fig.* 13.
Density stratification due to depth
and recording of fish.

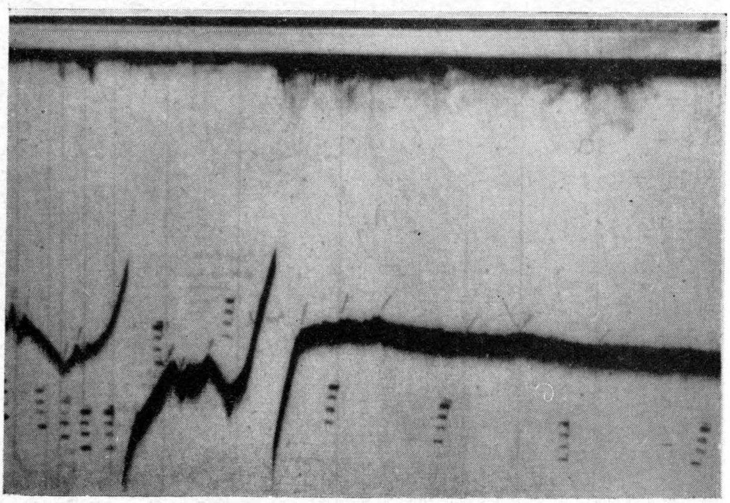

*Fig.* 14.
Eddy of density stratification
due to cross-section contraction.

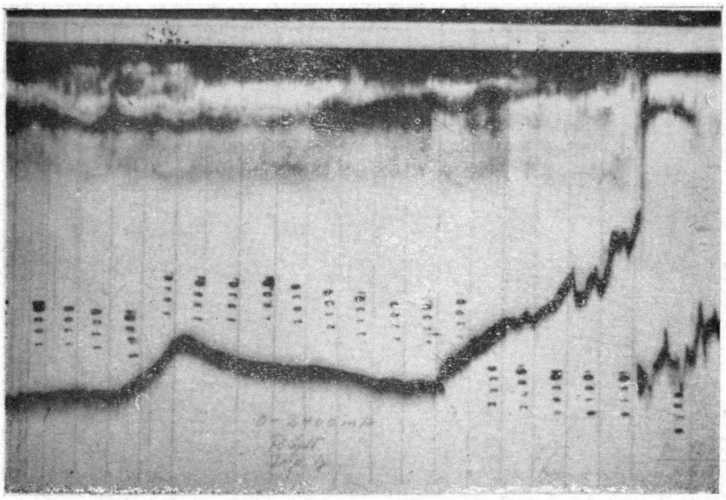

*Fig.* 15.

Record of stratification in medium depths (long pulse-duration).