SUGGESTIONS FOR DRAWING UP HIGHLY ACCURATE BATHYMETRIC CHARTS

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Present-day sounding methods are ineffective for drawing up very accurate charts of the ocean bed.

This is due to inadequate sounding procedures as well as processing methods. We shall propose improvements regarding the use of directional transducers and also the speeded-up processing of the data gathered which, for establishing accurate charts, must be both fine and numerous.

Until recently, only hydrographic surveys offered the necessary guarantee of accuracy both for depth measurements and for fixing. Unfortunately, these surveys are carried out almost exclusively in shallow areas close to the shore in places where navigation may prove dangerous.

The exact contour of the bottom is all too often still unknown. We have no very clear idea of the general aspect of the sub-marine topography off certain mediterranean countries. The drawing up of accurate bathymetric charts has, however, become a necessity on account of developments in oceanographic research, geology and deep-diving devices such as bathyscapes, diving saucers and naval submarines which can dive more and more deeply.

At present scientific institutions are collecting most interesting data on ocean bathymetry by means of the systematic use of their echo-sounders on every expedition. Fixes are then obtained with radar, with loran, by astronomic sights or by dead reckoning. In this way a first outline of the ocean bed is given. We may cite, for example, the excellent surveys of Jacques BOURCART for his chart of the western Mediterranean, or the large and spectacular charts of B. HEEZEN and M. THARP unfortunately published as physiographic charts and not in depth curves. These studies interest primarily the geologian. We have not, however, reached the point of drawing up charts having the same degree of reliability as current topographic maps.

Recently, thanks to aerial photography, the techniques of terrestrial cartography have made enormous progress. At sea, in the best conditions, photography cannot be carried out below 50 m, and this is obviously inadequate. It is possible to conceive transposing this method, and to take " elastic photographs ", but only low frequency elastic waves ($<$ 15 kHz) propagate sufficiently far. This method is impracticable for it would be necessary to be able to have available a source of sufficiently extended parallel rays, like those of the sun. The technique used on land being physically impossible in oceanography, it is necessary to innovate in order to progress. Sounding methods, however, have not varied in the last 30 years : equipment has been improved, but always in detail only.

The basic instrument remains the sonic sounder (EDO, ATLAS, ELAC, KELVIN HUGHES, etc.) of 10 to 30 kHz frequency. In general these sounders have a relatively wide transmission lobe which means that on a slope of rugged relief it is not possible to determine with accuracy the depth at the measurement point. The recorder is sometimes a sparker instrument (ATLAS, BENDIX, ELAC, KELVIN HUGHES, WESTREX, etc.), less often a wet paper instrument (MUIRHEAD, further developed by ALPINE and in the U.S.S.R., or else the ALDEN which, during the search for the submarine *Thresher* in Spring 1963, gave proof of its superiority) (*).

Positioning on land has made enormous progress, thanks to the use of radiolocating procedures such as Rana, Toran and Decca. However, under ideal conditions, once the surveying work at sea is over a drawing office section must analyse the bands of soundings and slowly draw up the corresponding bathymetric chart.

The track plotter, plotting the ship's track immediately, is a facility that scientific institutions must no longer do without.

The suggested improvements will cover two aspects :

— The accuracy of sounding in areas of rough bottom topography;
— The speeding up of processing work.

1. — Accuracy of topographic sounding

The only method at present envisageable is the reduction in width of the sound beam. This means increasing considerably the size of transducers. ELAC make a 15 kHz sounder whose transmission beam aperture is 2°7. Such achievements are still inadequate. It will be necessary to be able to fix a position to within 10 m, in depths of 2 000 m, in the same way as is done at the surface; that is to have available an angle of 0.005 radian, or $\frac{1}{4}$ of a degree.

Such a beam is technically possible. It is only a question of the cost of the transducer and its stabilization in relation to ship movement and its installation aboard a ship that must necessarily be conceived for this work.

2. — Speeding up of processing work

As the positioning accuracy of Rana, for example, is of about 10 m, this accuracy should as far as possible be retained for the chart.

The series of operations here described may or may not include a narrow beam transducer, although on the Continental Slope only this last can be used.

(*) S. KNOTT, private communication.

It would seem necessary to go beyond the ideas of SMITH and KARO by obtaining no longer one position per square mile, but one position per 100 m^2 — thus 34 000 times more measurements than SMITH thought necessary. If homogeneous and definitive bathymetric charts are to be drawn up, and briefly if we wish to obtain documents of comparable quality to topographic maps, then the digital method is imperative as soon as the information is received.

The average speed of an oceanographic vessel is 10 knots, i.e. a sounding must be taken every two seconds. The suggested scheme for the operation is as follows.

A sounder and a radionavigational system are installed aboard a vessel carrying out systematic bathymetric soundings. The data from both instruments are digitalized and recorded on magnetic or punched tape.

The sounder

The sounder sends out an elastic pulse into the water. This pulse is reflected by the bottom and is received back after a travel time that is a function of depth and of the velocity of sound in water.

If an automatic instrument is used to scan the bottom, confusion may arise between the DSL, noise, or multiple echoes and the bottom properly speaking. To do away with this indetermination it therefore necessary that an operator, with the assistance of a standard control record, should manually fix a time interval during which the automatic instrument records the first echo received and this will be the bottom. Thus a gate framing the bottom will have been determined. As this gate is fairly large, the controls are not continuously manipulated, and in a flat area this will very seldom be necessary; for example one gate corresponds to 200 m of change in level. Travel time may amount to up to ten seconds. In order to obtain the required 1 m accuracy, the record must be to the millisecond : 4 figures per position will suffice (no ambiguity respecting the tens of seconds).

Radionavigational system

The digitalizing of data from a radiolocating chain (coding of the polyphasemeter rotation) does not pose insurmountable problems. Twelve figures per position are required. Five other figures denote the time, but are only recorded every minute.

These digitally converted data must be stored in a form directly capable of being used for processing the information; i.e. on punched tape, punched cards or on magnetic tape. Two important considerations in the choice of means are :

— the bulk of data (congestion);
— the rate at which the data are received.

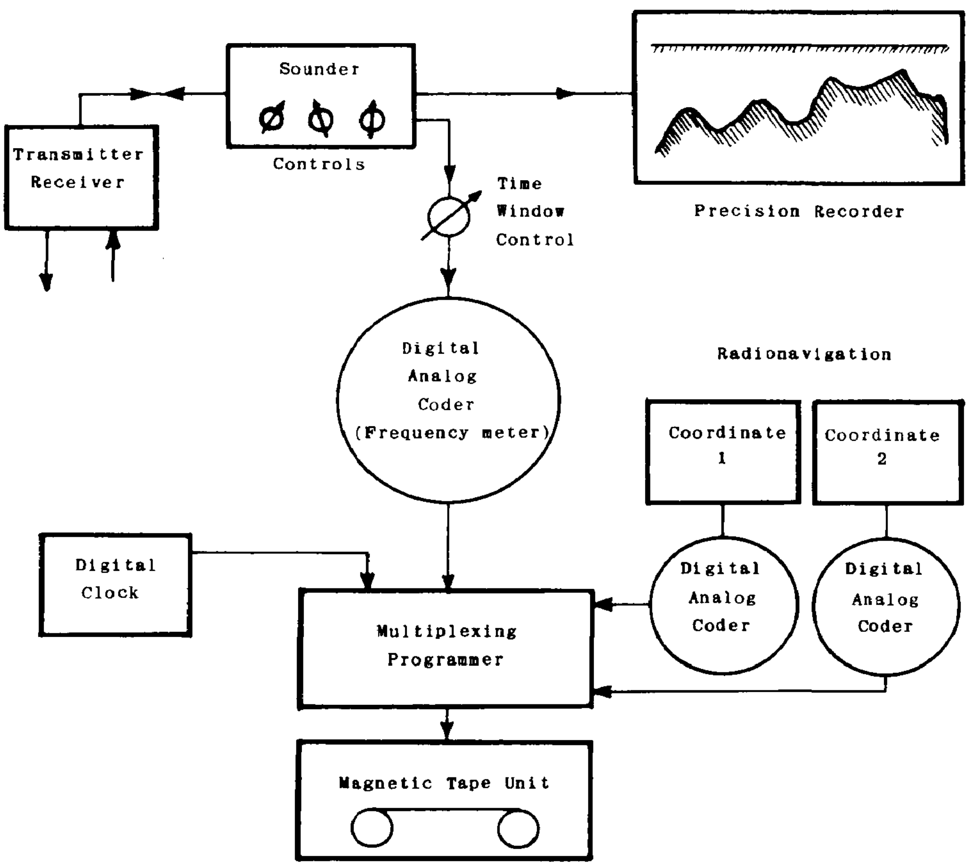
The bulk of data

The system described must operate at the rate of one position per second (20 knots), i.e. it must be able to record at every second 4 figures for the sounder and 12 figures for the position. Moreover it must allow for 5 figures per minute for time, i.e. a total of about 1.5 million digits have to be stored each day.

This represents :

— 17 500 punched cards, i.e. 80 dm^3;
— 10 punched tape rolls, each of 380 m;
— *70 m of magnetic tape (1/10th of a roll).*

BLOCK DIAGRAM OF THE SYSTEM



The digital clock may also be used as the sounder's time coder. Likewise, by means of a switch, one coder may be used for both radionavigation coordinates.

Speed

A system accepting 30 characters per second will be sufficient. It would be preferable to choose 50 characters per second to provide for all contingencies, e.g. an increase in the sounding vessel's speed.

These factors lead to magnetic tape being preferred. The manual processing of such a bulk of information necessitating at least 200 times the period taken to obtain it.

At a second step, the data are introduced into a digital electronic computer.

The data processing programme calls for :

— the conversion into depth of millisecond travel time in water, either by recalculating the local velocity of sound in water for groups of *n* points by means of general equations and *in situ* measurements, or else by storing in memory tables giving this velocity in function of the various parameters (coordinates of the position, season, etc.);

— the conversion of the coordinates of the radiopositioning system into UTM coordinates (rectangular or geographic coordinates).

The processing programme will determine the coordinates of the various bathymetric contour lines. The computation will be by four-step interpolation between the various measurement positions.

At the output three documents will be obtained :

1) Coordinates and depths, both corrected, on magnetic tape;
2) Coordinates of contour lines, on magnetic tape;
3) Chart of the bottom, at the desired scale, on the track plotter.

The computer programme can only give interesting results if it is prepared with the closest collaboration between the oceanographer, the cartographer and the programmer.

In this way, the work of drawing up an accurate chart, excluding work at sea, will become as, if not more, speedy than terrestrial cartographic work.

Such a degree of accuracy will not be immediately necessary over the whole ocean expanse. Two or three cooperatively equipped ships throughout the world would suffice for detailed charts of the most rugged areas to be drawn up with but fairly little delay.

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