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THE ATLAS BOTTOM MAPPING RECORDER FOR GAPLESS SURVEYING OF INSHORE WATERWAYS

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SUMMARY

Depth values are normally recorded by echo sounders as a single sounding profile. This has the disadvantage that no information is available from the space between these sounding profiles.

For obtaining an impression of the depth of the sea bed side scanning can be used; this method is, however, not accurate enough in shallow water, and moreover the results are not true to scale.

The Bottom Mapping Recorder avoids these disadvantages by using a large number of transducers mounted on outriggers or, if the ship is running transverse profiles across a river, mounted along the length of the keel. This Bottom Mapping Recorder combines the advantages of the accurate and true-to-scale information of the echosounder with the area imaging and extended coverage given by side scan. Its applications include both inshore and offshore surveying up to depths of 60 m, especially in rivers, canals and harbours.

INTRODUCTION

Is any surveyor really satisfied with the complete survey cycle beginning with preparations, continuing with the echo soundings at sea and ending with the final chart which must include all the depth data necessary for safe navigation ? Certainly no-one is happy about the gaps between the profiles if the survey is of a shallow water area. The solution to the surveyor's problem would be a system giving complete coverage of the sea bed and a reproducible, on-line, true to scale record. For inshore surveying, and especially for river, canal or harbour surveys, the Bottom Mapping Recorder comes very near to this ideal.

The principle of bottom mapping using a large number of transducers was developed independently in the 1960s by Dr. KIETZ of Krupp Atlas-Elektronik, Bremen, and by Dr. FAHRENTHOLZ [1] of Kiel. The operational principle is very simple : a vessel is fitted with two outriggers, one on each side, in which are installed up to 50 transducers using the relatively high frequency of 210 kHz; alternatively if the vessel is surveying in narrow channels these transducers can be mounted along the length of the ship. Each individual transducer is a combined transmitter/receiver. The time difference between transmitting and receiving induces a certain voltage within the receiving circuit of the electronic system. The depth information from each transducer, in the form of this voltage, is fed into the same number of capacitors. One by one these capacitors convey the voltage to a stylus which thus inscribes a trace on the recording paper in varying graduations of the colour black. During each measurement cycle the depth information is continuously inscribed by the movement of the record paper, resulting in a series of graduations providing a contrasted picture of the bottom, shallow depths being registered as a block of dark dots, and greater depths in a progressively lighter grey.

From this prototype of Bottom Mapping Recorder some 15 instruments (Type BOMA-10) were manufactured and installed in various vessels for use in inland water surveys (notably in the rivers Rhine, Moselle and Danube), but also for the ports of Helsinki and Hamburg and other shipping waterways.

Due to their mechanical design the earlier types of Bottom Mapping Recorder needed rather a lot of maintenance. Using the same principle for measuring and recording, a new type of Bottom Mapping Recorder (BOMA-20 series) has now been developed employing entirely solid state components. For the control unit, instead of mechanical parts with rotating contacts and stylus mechanism, the newly developed Recorder uses a small processing computer; and the chart of the bottom contour is drawn by means of a solid state matrix printer, the paper drive mechanism being its only moving part. This new concept has greatly enlarged the range of the instrument's applications.

THE ELECTRONIC EQUIPMENT

(figure 1)

The standard electronic outfit is housed in a 19-inch module, and a chart plotter is then added as a first extension; other electronic units can be added in their own 19-inch modules. As the space available for equipment installation will differ in the various vessels, individual requirements have to be considered.

The Bottom Mapping Recorder has been designed to operate with up to 50 transducers, generally spaced 1 m apart. For very shallow waters a spacing of 0.5 m would be required, and for areas over 15 m deep a spacing of 2 m. A pulse generator controls each transducer separately, and each has its own receiver matching circuitry which compensates for manufacturing tolerances and for different echo strengths. The processing computer controls the transmission interval and sequence for all 50 transducers.

Fig. 1. — The standard electronic equipment.

The input signals of each transducer are first electronically verified, then digitized, rechecked and fed into the processing computer's store. The logical commands of the computer are distributed to the various transmitter and receiver circuits by means of an interface. Satisfactory functioning of the transmitter and receiver stages can be checked later on the monitor.

The transducers are electronically combined in five groups of ten each. The measurement cycle begins with the first transducer from each of the five groups, and then the second, third, and so on; thus after 10 measurements the total spread has been covered. The actual duration of each measurement depends on the depth below the transducers. For example — assuming a ship's speed of 2 m per second, an average depth of 15 m and sound velocity of 1 500 m/s the transmission requires 1/100th of a second to reach the bottom and 2/100^{ths} for two-way travel. For ten transducers the theoretical time cycle will therefore be 20/100^{ths} of a second.

The electronic control system permits the sounding to be repeated if any transducer registers faultily. Let us assume that this is the case for five out of ten transducers, and that 15 soundings have to be registered entailing a theoretical time consumption of 30/100^{ths} of a second : this period, plus the necessary switching time means that 50/100^{ths} of a second (i.e. half a second) will therefore be required for each measurement cycle. Thus each half second the Bottom Mapping Recorder will provide full information for its sweep width, say 50 m, and if the vessel is moving at 2 m per second, a measurement cycle will be completed for every metre travelled. Since the transducers each have a beamwidth of approximately 8°, total ground coverage is provided. This example can naturally be adapted to various ship speeds and depths.

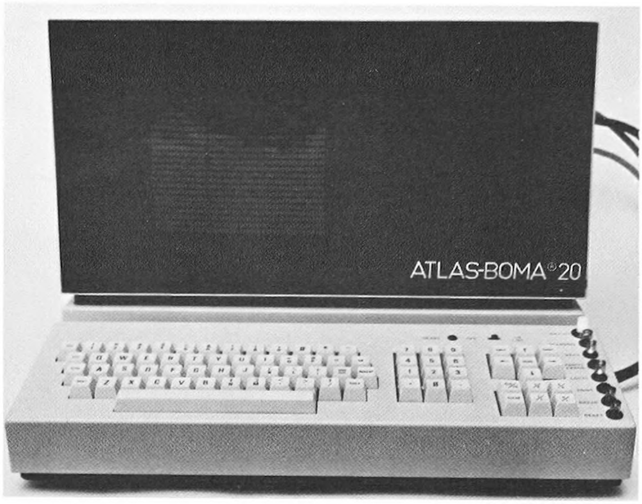

FIG. 2

Monitor (figure 2)

The Bottom Mapping Recorder's monitor is the most important part of the output equipment, and has two functions :

1. Together with the control keyboard, the monitor serves as an interactive communication system between operator and processing computer, not only during input of parameters (speed of sound through water, tidal range, reference depth, danger depth, etc.) but also for input of other data, such as for system checks (figure 3).

FIG. 3. — The monitor screen showing input parameters. (See explanation of parameters later).

2. To present a real-time bottom profile beneath the line of transducers. Thus, independently of other output units the monitor provides instant and continuous depth checking over the whole area covered (figure 4).

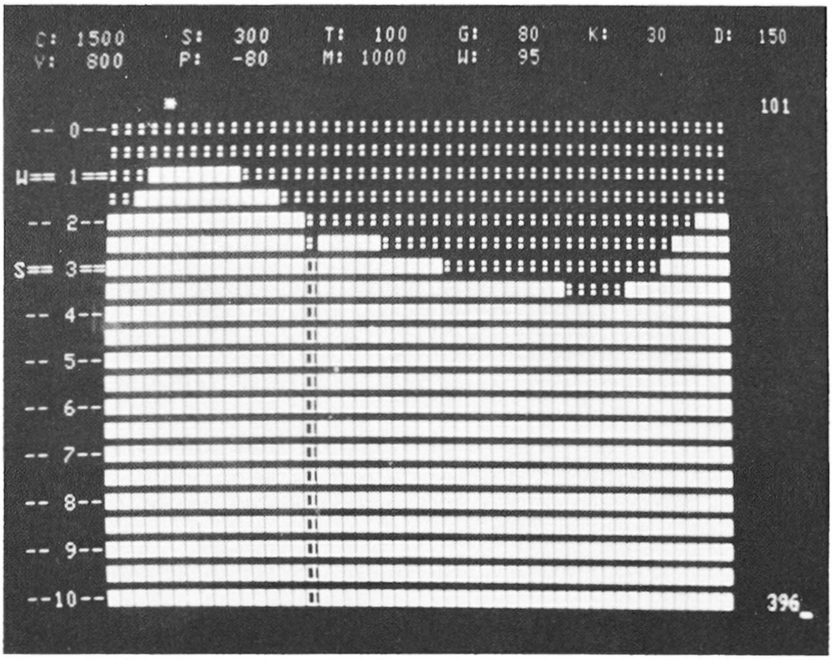

FIG. 4. — The screen showing survey parameters above, with the real-time profile below.

Figure 3 shows the monitor screen before input of new survey parameters. It is seen that all parameters currently held by the computer are displayed first. It is only necessary to feed in changes where the old parameters are no longer valid, or if the output is needed in a different form.

Figure 4 shows the monitor screen during the running of a profile, with the parameters repeated at the top of the display, and the real-time profile of the ground beneath the transducers displayed below. The transducer beams are here shown registered horizontally from port to starboard, with, vertically, 11 different depth steps. A danger depth (W) and a reference depth (S) are specifically marked. An asterisk is shown above any parts of the profile where the depth registered is less than this danger depth.

The Chart Plotter

The chart of the bottom is traced by the chart plotter which apart from the paper feed is designed without moving parts. Thus, in contrast to recorders of other echosounders, it is almost dust-free and not liable to mechanical wear, and its working principle is very simple. A bottom chart plotted at a scale of 1/500 is shown in figure 5. All the depth values *greater* than a pre-set reference depth are shown on the left, and all depths *shoaler* than this reference depth are recorded on the right. The depth recorded by each transducer is shown as one of five graduations of shading: white (deeper), light grey, grey, dark grey or black (shallower). These graduations are produced by an 8 × 8 dot matrix for each transducer, each shade having its own matrix code visible with the aid of a magnifying glass. At the head of each record the survey parameters are repeated; e.g.

C	1 500	Velocity of sound in water (m/s)
S	300	Reference depth (3 m)
T	100	Transducer depth (1 m)
G	80	*Below* the reference depth each shade represents a depth difference of *80* cm.
K	30	*Above* the reference depth each shade represents a depth difference of *30* cm.
D	150	The verification logic accepts a difference of 1.5 m between successive soundings from each transducer. Differences of more than the set figure from one sounding to the next will not be accepted and an error sign will be plotted.
V	800	Ship's speed, here *8* m per second. Manual input of this speed is only necessary if the Plotter is being operated without an additional device for measuring ship's speed.
P	000	The tide level is here set at *zero*. The value may of course vary during the course of the survey due to tidal influences, but it can be fed in without interrupting the survey programme: in this case it will appear in the blank column between the left and right hand traces.

To the right of each trace (figure 5) is printed a "Repetition indicator"; in the example shown it appears on the extreme right of the record showing depths shoaler than the reference depth, and the number *1* is here being displayed. This number tells the surveyor that all depth values shoaler than the reference depth fall within the range of one single shade cycle. The depth range for each cycle is determined by the pre-set depth difference (*K* above) for each shade. For depths shoaler than the reference depth, where K is at 30, five shades each representing a 30 cm depth difference yield a shade range of 1.5 m. For a depth of 2 m (i.e. between 1.80 and 2.10 m) shoaler than the reference depth, then the "repetition indicator" will show the number 2, and the shade recorded for this transducer would be light grey (i.e. the second shade in the second cycle). This principle allows a recording of absolute depth values, and so long as the ship steers a straight course at an exactly known speed the chart will be true-to-scale.

Automatic scale control

In order to surmount the difficulties of running at a known and constant speed, the Bottom Mapping Recorder has an automatic paper feed

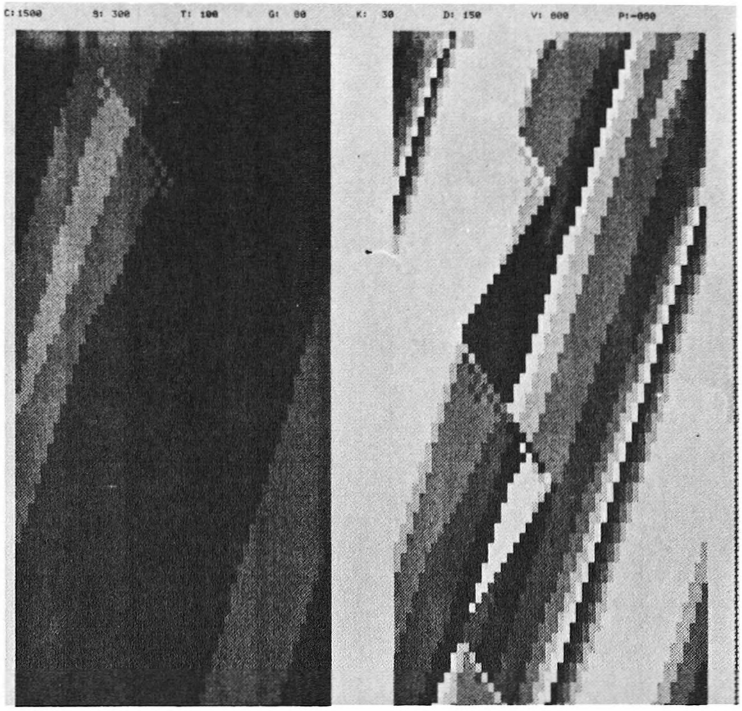

FIG. 5. — A typical bottom chart at 1/500.
Left : depths *below* the reference depth; Right : depths *above* the reference depth.
Note on the right the Repetition Indicator, here *1*.

speed control which can be fed from a Doppler Log System measuring the ship's speed over the ground. Doppler logs can give an accuracy of 0.2%, with output both in pulses and in digital BCD form for feeding to the processing computer. The paper speed will depend on the scale selected but will then follow any alteration in the vessel's speed.

For surveying transversally in rivers or channels a Radiolog — a phase-difference device for taking continuous measurements of the distance between a shore station and the ship's antenna and thus computing the vessel's speed of traversing — can also be connected.

Transverse profile recorder (figure 6)

A further output unit for use with the Bottom Mapping Recorder is a Transverse Profile Recorder which records the bottom profile immediately below the line of transducers at a particular instant. This profile will be at a much larger scale than the one on the monitor and with finer resolution, but it takes longer to plot. A record can be registered every 10 or 20 metres travelled depending on ship's speed and the depths being sounded. This provides a check profile when abnormal bottom conditions show up on the monitor or when incorrect measurements are suspected. If both Profile Recorder and Chart Plotter are in use a mark will be inscribed on the bottom chart at each point where a transverse profile is taken.

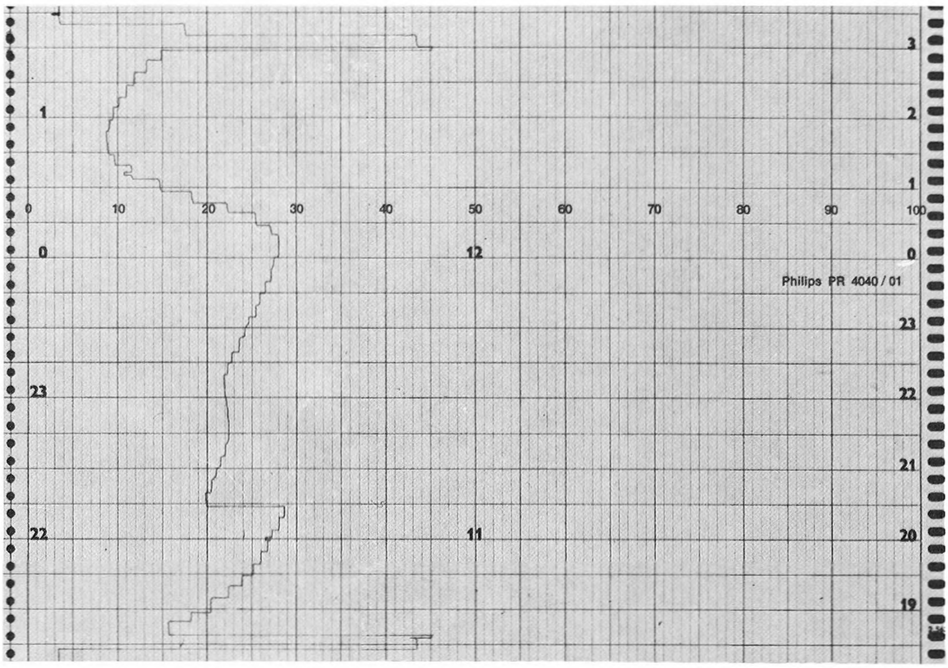

FIG. 6. — The transverse profile recorder trace.

Control Console

With the exception of the initial programming through the punch tape reader, all inputs to the central computer are commanded from the control keyboard. These inputs together with the computer's responses are displayed simultaneously on the monitor, and can only be effected on instruction from the computer as shown on the monitor. Intervention in the running programme of the Bottom Mapping Recorder can be made at any time via this control console, especially for resetting the tide level value during the course of the survey.

Processing computer with tape perforator, tape reader and interface units

The central control for all operations is a digital processing computer programmable via a tape reader to facilitate variation of the program. Alternatively, if only a fixed program is required, without facility for alteration by the surveyor, then a Programmable Read-Only Memory (PROM) can be incorporated and the tape reader will not be necessary. A tape perforator can also be connected to the control computer, and may be used either to punch out duplicate programs or else, by special program, to punch out selected depth values. If a tape reader is provided for program inputs there should also be a perforator for program duplication and for outputting newly established programs.

Interface units are provided between the control computer and input or output equipment where special matching is required. An acoustic interface serves to distribute the control computer's signals to and from each transducer or group of transducers; the depth information from each transducer is collected here and then fed to the computer. A recorder interface serves the transverse profile recorder and/or the chart plotter, and has selector switches and a setting potentiometer for the transverse profile recorder on its front panel. Additional interface units are required if the system is extended by the addition of, for example, a Doppler Log or Radiolog to provide scale control for the chart of the bottom.

Data recording

For maximum extension of the system a magnetic tape unit with interface can be connected as standard. The choice of magnetic tape depends on the purpose of the operation as well as on the amount and type of data expected. The manufacturer, operator and computer centre must also decide on the output format (e.g. 8-track, 9-track, IBM compatible). If magnetic tape output is required the depth information from each transducer has to be combined with the ship's position and heading. A Doppler Navigator System [2] giving position with an accuracy of 0.2 % of the distance run, independently of any shore station, is recommended. Accuracy is also improved by use of the Radiolog electromagnetic distance updating system described above. The processing computer contains an internal software clock system from which real time can be derived. Thus time, position, ship's head and depth values form a "data block" for each survey sequence.

These are registered on the magnetic tape preceded by the "block" of manually input parameters. The tide level value, however, which may be altered during the survey, is repeated at intervals.

SURVEY VESSELS AND INSTALLATION FACILITIES

On account of its special characteristics the Bottom Mapping Recorder can only be installed in suitable vessels. A minimum length of 20 m and draught of 1 m are, for instance, a necessity. The maximum speed using outriggers is 3-4 m/sec (5-7 knots), allowing a bottom chart at a scale of up to 1/250 to be drawn. The installation spacing between transducers (usually 1 m) was discussed earlier.

The Bottom Mapping Recorder can be used in two different arrangements.

(a) Type A ships : with the transducers installed lengthwise either along the keel or on special fittings along the side of the ship (figure 7a, 7b). For surveying the ship traverses sideways across a river, and the width covered will naturally be dependent on the length available for positioning the transducers. This fore-and-aft installation is only possible on vessels whose underwater design produces no bubbles or turbulence which would cause the transducers to register interference. Thus underwater hull protuberances and sharp angles must be avoided. Type A vessels moving sideways for cross-river surveys are normally propelled by two or three Voith-Schneider motors, one bow mounted and one or two in the stern. During surveying care must be taken that the wash from the motors does not impinge on the transducer area.

(b) Type B ships are those with the transducers mounted on outriggers (figure 7c) usually 8-15 m long, though longer or shorter lengths can be considered if indicated by the ship's width or the planned survey area. With these outriggers the profile covered can be between about 20 and 50 m, depending on the beam of the vessel.

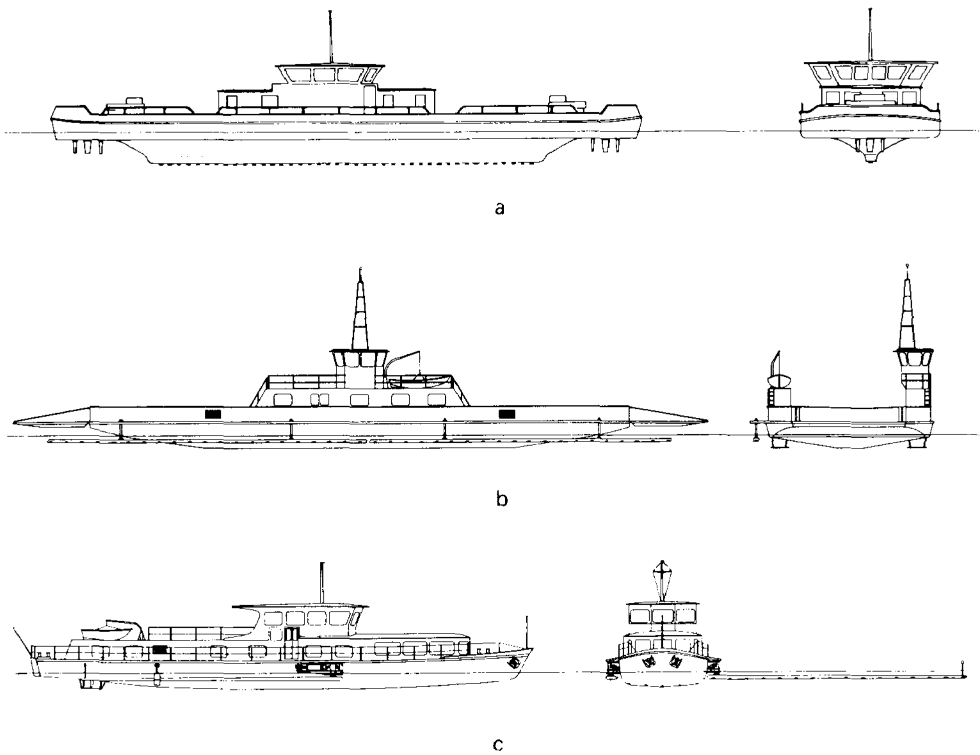

FIG. 7. — Type A ships (a), (b), advance sideways; transducers are installed lengthwise. Type B ships, (c), have retractable outriggers.

The advantages of the outrigger installation are higher speeds, and greater manoeuvrability in congested waterways. The outriggers also provide extra stabilization in disturbed water. The vertical movement at the extremities of 15 m outriggers on a vessel carrying out a river survey has been recorded as ± 10 cm maximum for waves of 1 metre (crest to trough). Supplementary water ballast tanks can be installed in smaller vessels to provide greater draught during survey operations, thus reducing acoustic interference from aerated water (quenching). These ballast tanks are filled only in the survey area and emptied for passage, thus permitting higher deployment speeds.

CONCLUSION

The Bottom Mapping Recorder, fitted to inshore survey vessels equipped with hydraulic outriggers, provides full gapless coverage over a width of approximately 50 m, thus fulfilling three basic functions :

1. It provides instant and continuous depth checking over the entire area being surveyed.

2. It plots a true-to-scale bottom chart with the depth values presented as graduated tones of black. The record allows direct readouts of isobathic lines.

3. It stores in magnetic or punched tape form — for later processing ashore — all the depth values, or alternatively certain preselected values only, together with time, position, heading and administrative data (if a positioning system is incorporated).

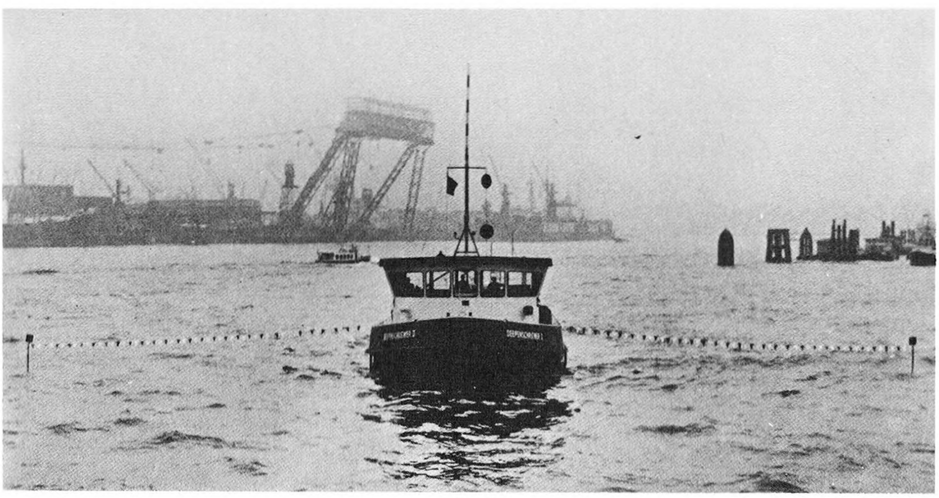

FIG. 8. — The *Deepenschriewer II* surveying in Hamburg harbour.

There is no problem in transferring the information from the plotted bottom chart to the survey sheet using optical magnifying instruments, by a method developed by the Hamburg River and Harbour Construction Authority.

The BOMA-20 has been tested for over a year on board the survey vessel *Deepenschriewer II* in Hamburg Harbour and the River Elbe. It is now being used for both hydrographic surveying and depth checking, allowing the production of harbour maps with isobathic lines within 24 hours of finishing the survey work.

The Bottom Mapping Recorder has greatly improved the accuracy and economics of surveying. The combination of a Bottom Mapping Recorder with a Doppler Log represents considerable progress in saving of time and in the gapless cover of large areas.

REFERENCES

[1] S. Fahrentholz : Profile and area echograph for surveying and location of obstacles in waterways. *Int. Hyd. Rev.* Vol. XL, No. 1, January 1963, pp. 23-37.

[2] W. Stedtnitz and H. Helms : The Atlas Doppler Navigator System. *Int. Hyd. Rev.* Vol. LI, No. 1, January 1974, pp. 95-123.

(Manuscript submitted in English)