International Hydrographic Review, Monaco, LVI (2), July 1979.

AUTOMATION OF HYDROGRAPHIC DATA COLLECTION AND PROCESSING IN DENMARK

by G. MØLLER RASMUSSEN

REVIEW OF THE DEVELOPMENT OF AUTOMATION

In 1969 the Farvandsdirektoratet (the Royal Danish Administration of Navigation and Hydrography) began to take interest in the processing of hydrographic survey data by modern automatic equipment. The method initially utilized and still successfully used is based on the traditional means of data collection employed in surveying ships. After collection, the data is converted to a form suitable for EDP processing. To assist in the conversion, the Farvandsdirektoratet (FRD) obtained a D-Mac Pencil follower on which the positions and soundings are digitized. The fairsheet is drafted on a Norwegian made KONGSBERG plotter (Kingmatic MK III) which was purchased in 1971.

The method itself will not be further described here as it is already well known, and will soon be outdated for there is now a very simple and feasible way to use system software for the processing of data which will be described later on.

For several years it has been apparent that more efficient use must be made of survey data and the associated EDP equipment. Additionally, there was a need to develop a more rational method for conducting measurements along parallel sounding lines, using towed paravanes. In 1972, the Hydrographic Office (at that time called Søkort-Arkivet) requested the Naval Supply System to assist in the solution of these problems.

A datalogger able to collect data from both the mother ship and the paravanes was constructed by the Danish firm Navitronic. Considering the amount of data involved, the intention was that the selection of soundings should be made in the datalogger itself. For various reasons, however, and as a temporary solution, this selection is being handled in the software package, an advantage here being that it allows contouring which was found to require a greater number of soundings than originally planned. The software has been developed in the EDP section of the Hydrographic Office, using a modular system which will enable a complete system to be built up in successive steps.

This paper will report on the system that has been tested and is ready for use, and will then briefly outline the system that is still being developed.

OPERATIONAL SYSTEM

The data acquisition system

The NAVITRONIC ship's system is built of modules designed to fit in standard 19-inch racks. All modules are plug-in units, permitting immediate exchange of a module, or its replacement by those of more advanced design. Figure 1 is a block diagram of the current configuration.

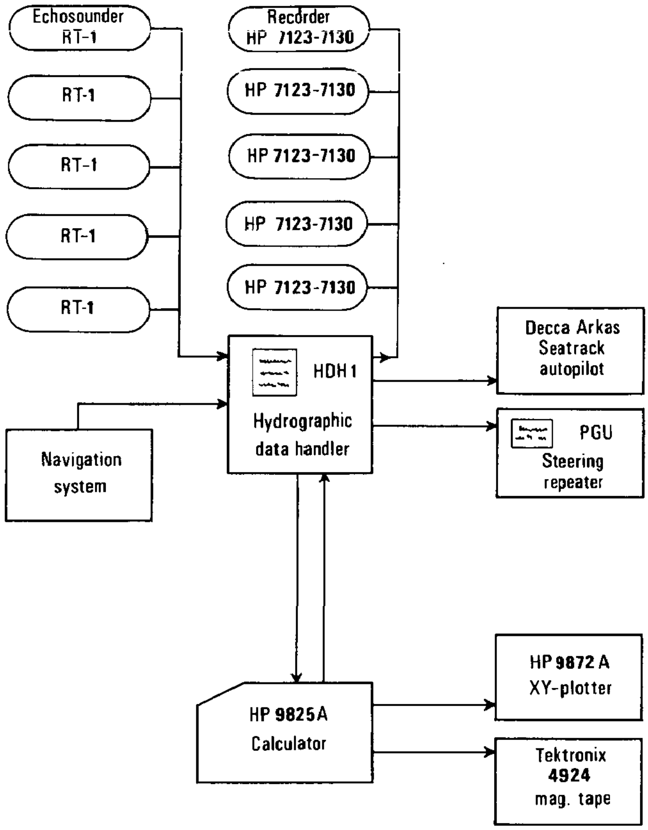

FIG. 1. — Flow diagram of the ship's system.

Five echo sounders are employed, one in the mother ship, and one in each of the four paravanes. The digitized sounding from the echo sounder is considered as the starting point. Frequency and length of pulse are selected according to the needs of the assignment. The echo sounder is free from interference from other acoustic sources, since false signals do not have the same pulse lengths, repetition rates or amplitudes and thus are not registered. Additionally, all soundings are checked to ensure continuity in regard to indicated depth and length of the returned pulse.

The desired speed of sound can be selected from within the interval from 1,200-1,599 m/sec.

For parallel sounding, mine-sweeping paravanes of fibreglass are utilized. The paravanes are equipped with Atlas SW-56 transducers, at a frequency of 30 kHz. Conventional mine-sweeping equipment is used in the employment of the paravanes. The towed system has been described by H.S.T. BECH [1].

The paravane cable is produced by the Swedish firm of HABIA and consists of 4 leads around a Terylene core, with Tefzel insulation. The cable is enclosed in a half-inch steel wire casing manufactured by the Danish firm A/S Randers Reb. Tensile strength is 12,000 pounds. The maximum tension under normal employment has been measured as 4,000 pounds.

When the final tests were undertaken, a special unit based on the doppler system was added to allow compensation for heave.

Processing of the field data

A primary task of the Hydrographic Office is to assemble the sounding and positioning data collected aboard ship and to process these within the Office in order to achieve the highest degree of accuracy in the horizontal and vertical planes.

Raw data is collected by the ship (see Fig. 2) at a rate of 3 soundings per second, over a time interval of one minute. This interval is then screened for the minimum and maximum depths and their corresponding navigational fixes, which are then stored on magnetic tape.

Temporary UTM coordinates are used by the ship for plotting the actual survey lines run. These coordinates are also used to compute directions (at 3 pulses per second) to the automated steering system, in order to maintain the vessel as closely as possible on the predetermined survey track.

The shipboard computer provides a real-time display for the hydrographer aboard which includes: UTM coordinates of each fix, soundings, distance to predetermined survey tracks, lane distance, distance to end-point, course, suspect soundings, etc.

The Data Processing System

The Office computer software used to read and check the survey data is named the HYPOTIC (*HY*perbolic *PO*sition and *TI*dal *C*orrection) Program. It converts the hyperbolic or Rho-Rho Fix coordinates and paravane positions into geographic latitude and longitude, makes tidal corrections to depths, and selects data for further processing (e.g. plotting of all or part of the available data), etc.

The HYPOTIC Program is written in the Algol 6 language for use in the RC 4000 computer of the Danish Geodetic Institute. Memory capacity is 96 K. Figure 3 is a block diagram of the data processing system.

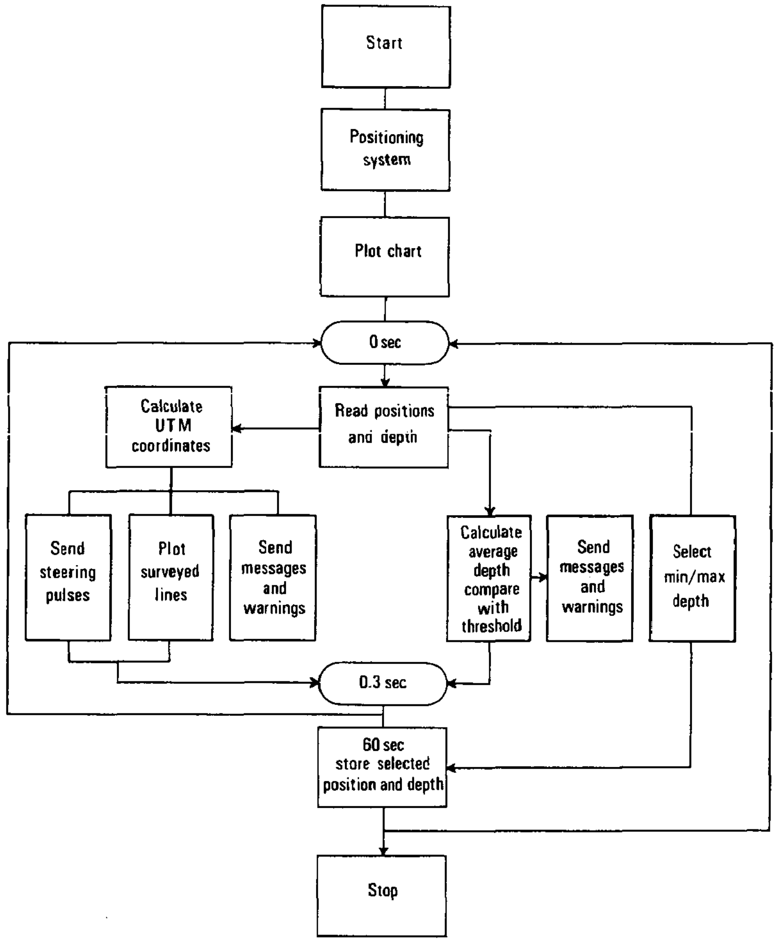

FIG. 2. — Flow diagram of the field data processing.

Input consists of the hydrographic data mentioned under the section on the Acquisition System. A brief description of the syntax (see figure 4) follows:

A record consists of a line of figures in sections with the following significance.

1 character for the length of the record;
1 character for the selector;
1 character for the number of the echo sounder;
4 characters for the depth in decimetres;
4 characters for the time in hours and minutes;

and a variable number of characters (between 17 and 39) for the hyperbolic coordinates in centilanes. (Figure 5 is a sample readout.)

In order to execute the program, the following parameters are required:

— The navigation system utilized (this may be any hyperbolic or range-range system or a combination of these systems).

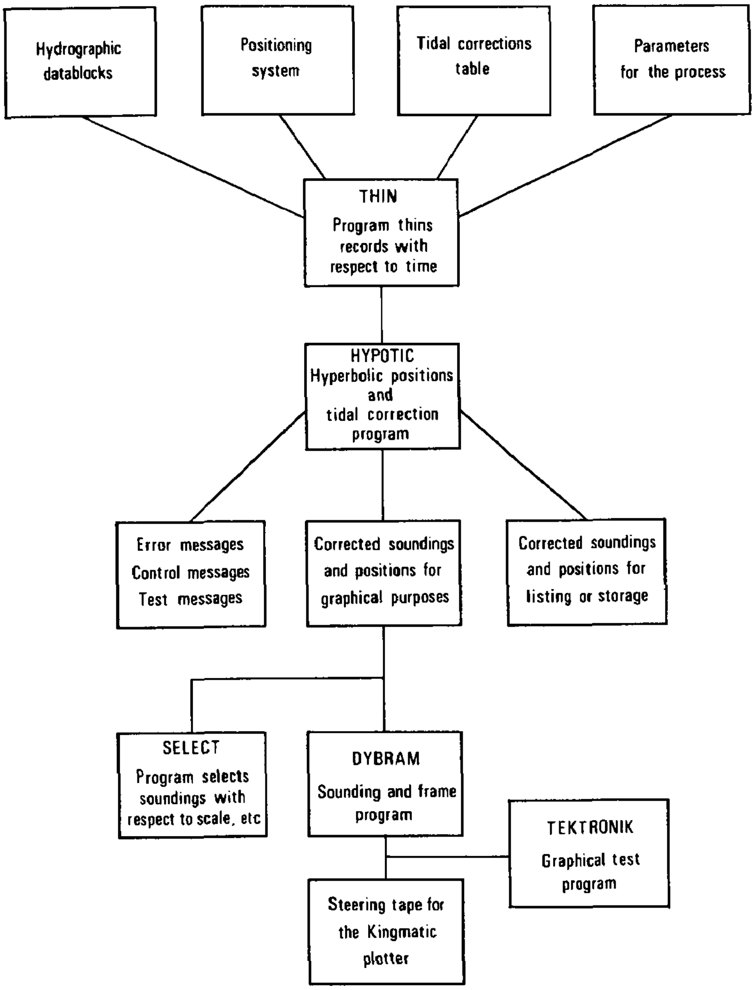

FIG. 3. — Block diagram of the data processing system.

— The positions of shore stations, frequencies, velocities, coding delay (in the case of Loran), and any fixed error (if present) of the navigation system.
— Tidal corrections in tabular form.
— Choice of computer file to be used during the operation.
— Ellipsoid chosen (if not the standard).
— Selected initial point.
— Exclusion of unwanted sounding lines, etc.

Figure 6 is a sample readout.

Control System Checks during Loading

The computer omits data 'blocks' if they do not correspond with the syntax, and prints out the type of error encountered.

The program sections containing the soundings, times, and positions are handled separately, as the datalogger has special conventions for determining if individual values should be replaced by zero. This would be required if there were echo-sounder, chronometer, or navigational equipment errors.

For the case of errors which result in such omission of data, the program may still be utilized by deducing the missing parameters as follows:

(a) Time can be re-established from the average speed of the ship.
(b) Depth is not re-established.
(c) Positions can be calculated if two or more correct positions have already been digitized. Positions of zero are excluded.
(d) If only one position has been digitized, depth positions can be calculated from the time and average speed.

The Determination of Position

This depends, of course, on whether the data block is derived from the mother ship or one of the four paravanes.

The hyperbolic coordinates are converted into differences of distance in metres. The determination of position is an iterative one, as the actual geodetic differences of distance are calculated from an initial point. These distances are calculated with an error of less than 1 metre, and azimuth error is less than 0″.035. Calculation of errors is based on formulae developed by P.D. THOMAS [2]. Utilization of these formulae, with a non-iterative cycle, results in geodetic accuracies that meet the requirements of hydrography, and permits rapid repetition of the procedure. The formula for iterative solution corresponds almost completely with the theories of Wolfgang HELBLE [3]. Slight alteration of the formula will give faster congruity, resulting in a final solution after the very first cycle.

The accuracy of the iterance is as follows:

— At ranges of less than 22 nautical miles = 2 metres
— Between 200 and 1,200 nautical miles = 15 metres
— More than 1,200 nautical miles = 30 metres.

The calculations of the range-range coordinates are based on the same mathematics.

The position of the paravanes is determined from the position of the mother ship and the azimuth. The error in determination can be considered negligible.

As previously mentioned, the recorded soundings are corrected for tide before they are copied.

Output Data

This is of two types:

1. Corrected soundings and positions in a form usable for further program processing with a view to automated cartography/hydrography.

```
|a|b|c|d|,e,|,f,|,,,,,,,,,,,,,g,,,,,,,,,,,,,,,---------,,

   pos.a:               start  CR-EOB
   pos.b:               length of record.
   pos.c:               selection of soundings between positions.
                        (not used for the moment).
   pos.d:               transducernumber.
   pos.e:               sounding in decimeter.
   pos.f:               time in hours and minutes.
   pos.g:               position(s) with chars according to
                        pos.b.

   Exemples:
        mothership alone  -  Toran-position.

CR|4|0|0|0134|1034|596200345963

        mothership + 4 paravanes - Seafixposition.

CR|3|0|0|0171|1037|5430097654
CR|1|0|1|0176
CR|1|0|2|0166
CR|1|0|3|0172
CR|1|0|4|0161

        mothership + 2 paravanes - Seafix- and Deccapositions.

CR|7|0|0|0171|1410|5432897800123456789012345
CR|1|0|1|0161
CR|1|0|2|0184
```

FIG. 4. — Program syntax printout.

```
thumbwheelrecord. 0750701101009
mainrecord....... 4000195095448820250091 5
                 {1010000
paravanerecords..{1020194
                 {10 30196
                 {1040196
                  4000196095448820150091 2
                  1010000
                  1020194
                  1030196
                  1040196
                  4000196095448820150090 8
                  1010000
                  1020195
                  1030196
                  1040195
                  4000196095448820050090 5
                  1010000
                  1020194
                  10 30197
                  1040195
                  4000196095448819950090 1
                  1010000
                  1020195
                  10 30198
                  1040195
                  4000196095448819150085 8
                  1010000
                  1020194
                  1030196
                  1040195
                  4000197095548817150075 4
                  1010000
                  1020195
                  10 30198
                  1040196
                  4000198095548815550064 8
                  1010000
                  1020195
                  1030198
                  1040196
                  400019909564881 3950054 3
                  1010000
                  1020197
                  10 30199
                  1040197
                  40001990956488123004 37
                  1010000
                  1020198
                  1030198
                  1040198
                  40001990957488106500 3 32
                  1010000
                  1020197
                  10 30199
                  1040200
```

FIG. 5. — Program syntax readout.

2. Corrected soundings and geographic positions ready for use in a program to produce the fair sheet on the drafting machine.

At the time the program is processed, the following transcript is copied by the terminals.

1. Continuous recording (immediate transcription) of blocks selected according to the input data.
2. Recording of errors, with precise identification (see figure 7).
3. Possible test recordings with special reference to program maintenance.

The HYPOTIC program involves approximately 91,000 bytes.

ACHIEVEMENTS TO DATE

To what extent is this Data Processing System already operational? The development plans show that certain portions of the handling phase are still largely experimental. At the moment it is the developmental phase which is the most advanced and also the dominant area in data processing, but Denmark's development strategy has been planned in such a way that it is difficult to differentiate between the developmental and production phases. The modular construction of the system, together with the necessity for intermediate solutions (with future production in mind), tend to result in constant improvements to the system. As a result, the extent to which our hydrographic surveys are being automated is continuously increasing. Though it is impossible to provide exact figures it is estimated that for surveys in 1978 approximately 80 % of all the fairsheet work has been accomplished through automation. Figures 8-11 illustrate both graphic and textual outputs of the system.

DEVELOPMENT PROCESS

A few words on the procedures followed in the development of the capability might be useful for others considering similar efforts.

A Working Group consisting of hydrographers, engineers and EDP experts was formed in 1972 by the Søkort-Arkiv and the Naval Supply System in order to examine the possibilities of improving surveying efficiency. The requirements, almost identical with the capabilities as now achieved in the operational system, were formulated by Captain K. Kaergård, the Hydrographer of the Danish Navy.

The construction of the data logger was carried out in liaison with the Navy Supply System by Navitronic A/S, and the software for the control and steering functions by Decca Arkas A/S in liaison with hydrographers, in particular the EDP section of the Hydrographic Office where the data handling software is generated.

```
list
  10 job fs 1 6001 time 0 20 0 size 60000
  20 hypotic in,dyb1,dyb2 preselect,yes ,
  30         min,no zero,yes
  40 toran
  50 m 55 36 10.298 n    10 22 13.533 e
  60 s 55 54 40.597 n    10 14 51.887 e
  70 s 55 36 48.132 n    10 37 15.966 e
  80 2030.75 khz
  90 299650 kmsek
 100 /
 110 55 46 12.163 n   10 33 4.684 e
 120 s
 130 scope login drawer
 140 blip
 150 finis
 160
run
finis       fs0 at 15 26


***hypotic    warning
   zero soundings
   area   101   line   5

   transducer no. 2       1  sounding  of zero

***hypotic    warning
   zero soundings
   area   101   line   6

   transducer no. 3       2  soundings of zero

***hypotic    warning
   zero soundings
   area   101   line   7

   transducer no. 1       1  sounding  of zero
   transducer no. 4       1  sounding  of zero

***hypotic    warning
   zero soundings
   area   101   line   13

   transducer no. 1      94  soundings of zero
   transducer no. 2       1  sounding  of zero

no of visible records (mains) produced      5934    (1286)
out of a total of                           6430 records

Max  40704 characters =   103 m tape in temp entry drawer
end    126

end     10

end  215 sec   job fs0  log wk  date 1976.05.19   15.09.50

>>
```

FIG. 6. — Readout of input parameters.

```
  syntax illegal length field
  area    2   segment no.   5   record no.    5
  document dyb11   bossline  550

***hy   record error
  syntax no leading new line
  area    2   segment no.  14   record no.   20
  document dyb12   bossline  2410

***hy   record error
   digits missing
   area    2   segment no.  14   record no.    3
   document dyb15   bossline  3650

***hy   record error  record lost
   last records in preceding segment not positioned
   area    2   segment no.  17   record no.    0
   document dyb15   bossline  4410

***hy   record error
   digits missing
   area    2   segment no.  13   record no.   16
   document dyb18   bossline  1020

***hy   record error
   selector not zero
   area    2   segment no.  16   record no.    9
   document dyb18   bossline  1420

***hy   record error
   syntax no leading new line
   area    2   segment no.  17   record no.   15
   document dyb18   bossline  1630

Max   3840 characters =     10 m tape in login entry logrslt
Max  52992 characters =    135 m tape in login entry drawer
end  16465

end job    fs0 626 sec   log ch   date 1975.10.07   14.58.09

>>
get dyb11
list 540 560
 540 30001921812000000000
 550 00019718130750020064
 560 30001951817000000000
```

FIG. 7. — Printout of record errors.

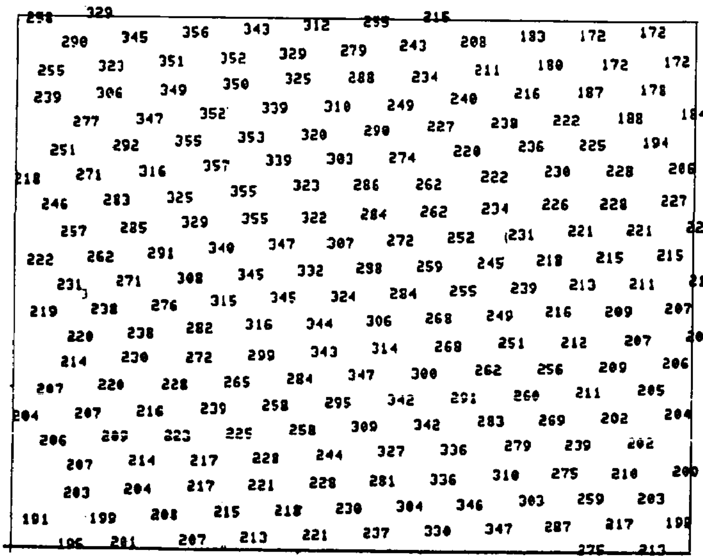

FIG. 8. — Portion of a fair sheet drawn by a Tektronix 4014.

SURVEY TECHNIQUES

Vessel

Any kind of survey ship can be used, but if parallel sounding lines using paravanes are desired then a minesweeper of the "Sund" class is preferred. A ship of this class has two screws, a displacement of 375 tons and a surveying speed of 9 knots. One of these vessels has been specially equipped with a survey control room installed next to the chart room.

Positioning systems

The Datalogger as delivered is ready for use with any kind of navigational equipment, and permits simultaneous operation of two hyperbolic systems—Toran (2 × 6 characters) and Decca (3 × 5 characters)—and one range-range system, Motorola (2 × 6 characters), for example.

Whatever navigational system or systems are chosen, the software employed selects the most favourable range values for use in the calculations. Both Toran and Motorola are currently used in Denmark. Since these systems are well known there is no need to describe them in this article.

Sounding profiles

The introduction of the datalogger has not radically changed the conventional method of running sounding lines. However, modifications to methods always need to be made with new instruments.

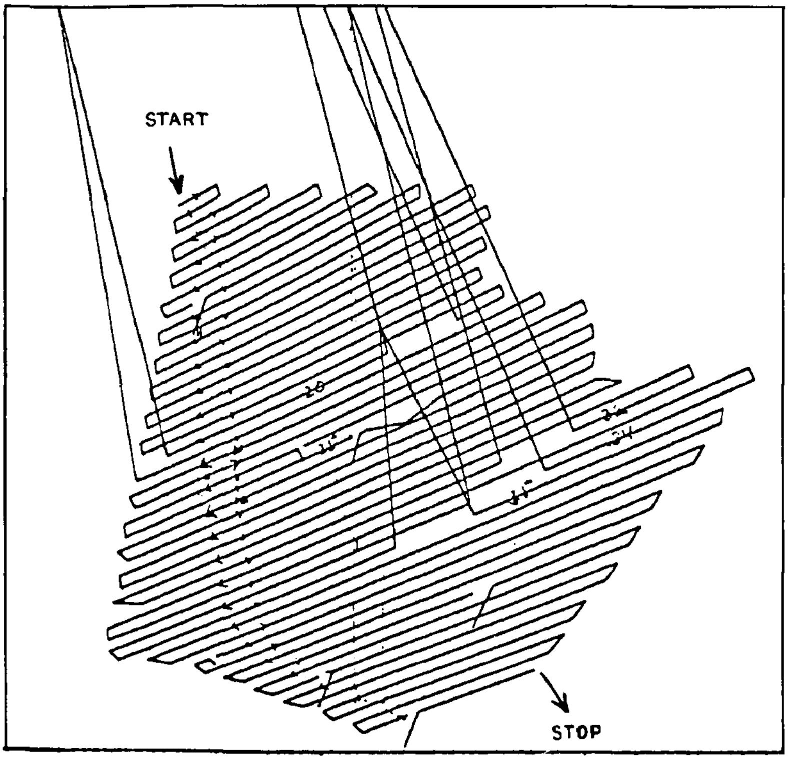

FIG. 9. — Portion of a smooth track automated plot.

Toran configuration is based on the "V-mode" and consequently the two ranges have a common station.

The radionavigational system can be used in either the hyperbolic mode or in the range-range mode, or in a combination of these modes. The power supply can come from either normal public sources, or from a thermo-generator driven by propane gas.

Tidal observations are measured by gauges placed as close as possible to the survey area. In order to ensure the best possible data the number of gauges established is varied according to the size of the area and the expected fluctuations of water level.

The line density and the length of the towing chains for the paravanes are determined by the nature of the survey area. The normal distance is 100 metres to the outer paravanes and 50 metres to the inner paravanes, from each side of the ship.

Experiments have showed very small divergence from the given angle when sounding in this way. The observed divergences give smaller errors than those arising from the electronic positioning system or the steering equipment.

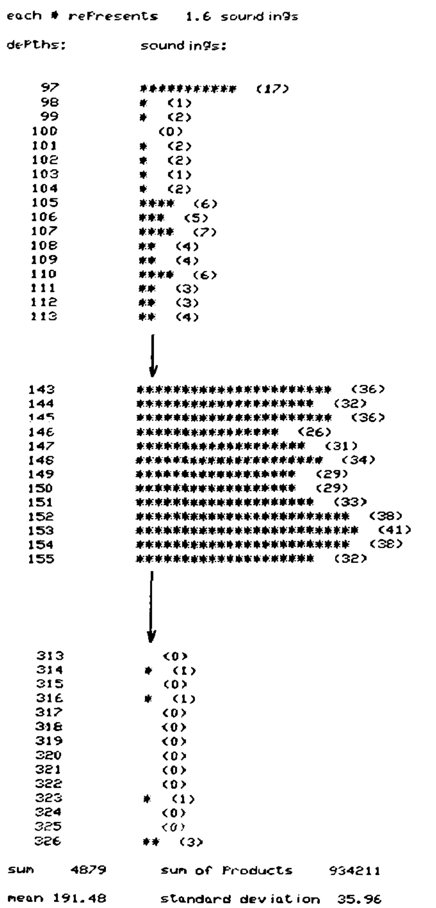

FIG. 10. Histogram of all soundings versus depths.

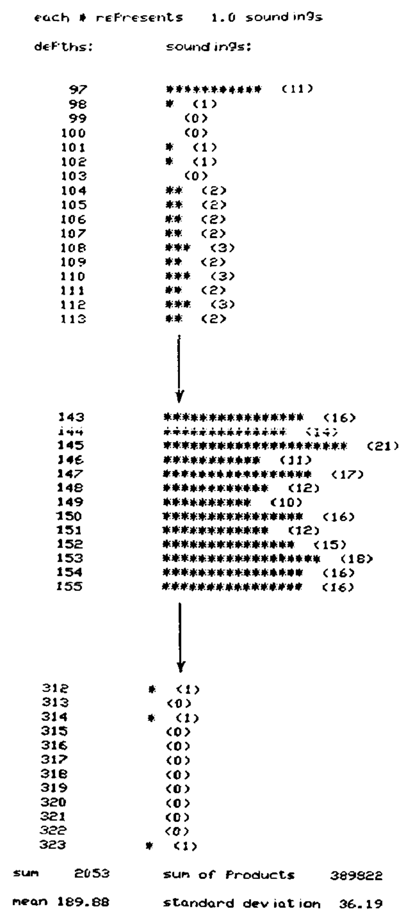

FIG. 11. Histogram of soundings versus depths, after selection.

Navigational Accuracy

In order to acquire the most accurate information from the survey area, the ship's steering system is connected to the radionavigational equipment (for example, Toran) which thus commands the autopilot through a Seatrack module.

A predetermined lane is followed during surveying operations. Stated in terms of lane width, the Seatrack system gives very reasonable steering accuracy, with maximum deviations of the order of 0.02 lane width under normal conditions. Since in the Toran system a lane width can be up to 80 metres, the deviations using that system will not exceed ± 2 metres.

Data may be recorded at intervals varying from 1 second to 20 minutes.

Observations of time, position and depth are manually recorded on the echogram itself as a check on system accuracy, with the marking of the echogram 'fixes' initiated by the navigational equipment to ensure that all records are synchronized in time.

CONCLUSION

The change-over to automation in both the hardware and the software fields is being developed by deliberate steps. This approach was adopted as most appropriate in view of Denmark's limited resources as a small country, and because of a natural cautiousness in regard to embarking on immense, costly experimental projects. The step by step procedure, along with a modular build up of both hardware and software has permitted immediate utilization of the system while at the same time allowing for long-term improvement.

Future plans include the development of hardware for a wave compensator now under construction as well as the consideration of the idea of using the Swedish Radio Transmission System for the transfer of data from the side boats to the onboard datalogger when side launches are employed instead of the towed paravanes. Also under consideration in 1979 is the development of a software program for the automatic drawing of contour lines.

We consider it extremely important to be able to solve the immediate problems to meet survey requirements while leaving the door open for the ultimate goal—a chart drawn by completely automatic processes.

REFERENCES

[1] BECH H.S.T. : Towed echosounders for parallel sounding. *Inter. Hydrog. Review*, January 1979, pp. 13-19.

[2] THOMAS Paul D. : Spheroidal Geodetics, Reference Systems and Local Geometry. SP 138. U.S. Naval Oceanographic Office, January 1970.

[3] HELBE Wolfgang : Ortsbestimmung nach Hyperbelkoordinaten. Deutsche Geodätische Kommission, Reihe C : Dissertationen, Heft 176. München, 1972.