BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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1980/84

OPERATIONS MANUAL

FOR MARINE MAGNETIC SURVEYS

ON THE M.V. NELLA DAN, 1980/81

by

L.A. TILBURY, R. WHITWORTH & H.M.J. STAGG

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INTRODUCTION

Every year the M.V. Nella Dan makes a series of voyages to Antarctica to resupply Australia's bases. These trips provide an opportunity to collect many thousands of kilometres of under-way data at low cost and relatively little inconvenience to the supply operations.

During the 1979/80 Antarctic season, BMR began a moderate Antarctic marine geoscience program using the Antarctic supply vessel M.V. Nella Dan. The aim was to collect magnetic data over the Antarctic margin, the plateaus surrounding Australian sub-Antarctic Island Territories, and the southeast Indian Ocean. A basic system was installed to collect magnetic data using a computer-based data acquisition system. Despite teething problems and the fact that experienced BMR personnel were only on two of the four voyages, a total of 32 600 km of magnetic data was collected on the three Antarctic cruises and the cruise to Macquarie Island (see Fig. 5). Although excellent coverage was obtained over the Kerguelen Plateau and the southeast Indian Ocean, only about 1000 km of data was collected over the Antarctic margin because of the sea ice conditions.

Several extensions to the program are now being implemented for the 1980/81 season to maximise the scientific value of the program, to increase the accuracy of the navigational data collected, and to ease the workload for post-processing at BMR. The most significant is the installation of BMR's deep sounding Raytheon echo-sounder to obtain water depths over the deep ocean basins. This will supplement ANARE's echo sounder which obtains depths to only 3000 m and therefore can be usefully employed only on the Antarctic margin and adjacent plateaus, a small fraction of the total traversing.

Navigational data, previously logged manually every 10 minutes or so at best, will this season be collected in digital form every 10 seconds. The TRACOR satellite navigator is being modified by BMR to obtain digital output of the navigational data, viz. time, latitude, longitude, course and speed.

The Nella Dan has been extensively modified for Antarctic Division to carry out its Marine Science program (Biology) during the FIBEX cruise in the 1980/81 season. The ship is now a suitable platform for a more comprehensive marine geoscience program. In particular, there is now a proper instrument laboratory for the computer-based data acquisition equipment, a wet and dry laboratory, and the stern of the ship has been cleared to allow installation of winches, for example a seismic cable winch.

2. AIMS AND SIGNIFICANCE

The extent of present marine geoscientific knowledge in the Antarctic region is irregular and meagre. The average line spacing is about 300 km and, apart from the Nella Dan tracks, almost no lines extend over the Antarctic continental margin. The more detailed coverage is over the southeast Indian Ridge, which has attracted the interest of U.S. scientists. The Kerguelen Plateau has also received some attention, from the French in particular but also from the Americans and Japanese, and it is known that the Russians are contemplating work in that vicinity.

The current program on the Nella Dan has the following aims:

a) a reconnaissance magnetic investigation of the Antarctic continental margin. The estimation of depth to magnetic basement and hence sediment thickness is the dominating interest. Effort will be concentrated in the Prydz Bay region between Davis and Mawson over the offshore extension of the Lambert Glacier/Amery Ice Shelf rift.

b) investigation of plateaus surrounding Australia's sub-Antarctic Island Territories. The Heard Island region in particular requires resolution of its tectonic history and possible economic potential. Studies will be oriented to further defining the structural framework and evolution of these regions using the adjacent magnetic anomaly patterns.

c) to further define the structural elements and 'magnetic' age of the Southeast Indian Ocean region, in order to obtain a better understanding of the evolution of the Australian and Antarctic plates following the break-up of Gondwanaland.

d) secular variation studies over the Southeast Indian Ocean. Further development of an Australian Geomagnetic Reference Field (AGRF) using estimates of secular variations obtained by comparison at intersections with tracks of earlier surveys, particularly those of the Eltanin.

Research objectives and methods

(1) Antarctic continental margin:

From the viewpoint of economic potential, the continental shelf and upper slopes are more interesting than the deep sea floor. The combination of magnetic and bathymetric data across the margin can establish the presence of sedimentary basins and determine their extent and possible thickness to an accuracy of perhaps 25 percent, provided there are suitable intra-basement magnetic sources. The Prydz Bay region is of particular interest as previous work suggests a sedimentary pile of over 5 km, and possibly as much as 10-12 km thickness within the rift zone of the Lambert Glacier (Fedorov & others, in press).

The offshore East Antarctica margin (that area bounding the southeast Indian Ocean) is essentially unknown. Interpretations of seismic reflection and sonobuoy refraction data collected by the Eltanin show up to 4 km of sedimentary section on the outer continental margin with basement deepening landwards (Houtz & Markl, 1972). However, these data extend landward only to the foot of the continental slope. Several reconnaissance lines over the margin would determine the presence of any major sedimentary basins.

(2) Plateaus surrounding Heard Island and Macquarie Island

The Kerguelen-Gaussberg Plateau is a broad topographic high situated in the south-central Indian Ocean. It is about 2000 km in length, extending from 300 km north of Kerguelen to more than 1000 km southeast of Heard Island, i.e. to within 800 km of the Australian Antarctic Territory. Studies by Houtz & others (1977) have shown that much of the plateau appears to be covered by a veneer of sediments up to 1 km thick. However, localised accumulations at least 2-3 km thick have been recognised, which are of potential economic interest. The structural framework and evolution of the plateau requires further study to assist in the definition, correlation, and evaluation of the areas of thicker sedimentary section. In particular the magnetic anomaly patterns adjacent to the plateau margins which would place constraints on its evolution need to be determined, especially to the southwest of the plateau where there is little information.

The Macquarie Ridge is a complex feature which forms a narrow topographic high extending southwards some 1400 km from near the south of New Zealand to about latitude 60°S. A comprehensive study of the Macquarie Ridge complex undertaken by Hayes & Talwani (1972) concluded that it evolved as the consequence of the interaction of the Pacific and Indian plates, and that the predominant motion has been right-lateral strike-slip at about 4-5 cm/yr.

Magnetic and bathymetric data can be collected over this complex feature to add to our knowledge of it, and also over the adjoining Tasman Sea basin where parts of the magnetic anomaly pattern require elucidation. Furthermore, a major tectonic boundary must exist within this portion of the Tasman Sea basin, to separate the predominantly north-trending anomalies of the Tasman Sea basin from the predominantly east-trending anaomalies of the southeast Indian Ocean.

(3) Southeast Indian Ocean

Most of the data from the southeast Indian Ocean were collected on the Eltanin cruises between 1968 and 1972. Weissel & Hayes (1972) have identified the overall magnetic anomaly pattern, outlined the tectonic framework of the region, and discussed the possible evolution of the region from the commencment of seafloor spreading, 55 m.y. ago, to the present. However, the Eltanin data, had a line spacing of about 300 km. This is sufficient for broad definitions of major features but leaves the definition of finer structures in doubt and often in some confusion. An example of the improvement provided by more detailed traversing can be seen in the results of the Project Investigator-1 aeromagnetic survey of the Australian-Antarctic Discordance (Vogt & others, 1979). In that case, the line spacing was about 20 km. The magnetic anomaly pattern and the numerous fracture zones can be identified with confidence. In addition, two oblique sets of fractures not previously apparent are clearly seen to divide the region into a series of wedges.

Similarly, the magnetic pattern adjacent to the Antarctic margin and to the Kerguelen-Gaussberg Plateau is very poorly defined. Its definition is essential to an understanding of the tectonics of the margin and plateaus.

(4) Secular variation studies

As a secondary outcome of magnetic traverses across the southeast Indian Ocean, an estimate of the secular variation in the Earth's magnetic field for this region can be made. This will be determined by comparison at intersections with tracks of earlier surveys, primarily of the Eltanin circa 1970. Because of the rather imprecise navigation used, a statistical comparison using all available intersections will be made.

There are two objectives in this. The first is to study the long-wavelength variations in the magnetic field over the southeast Indian Ocean, their variation with time, correlation with depth, and other parameters (vide Vogt & others, 1979). The second is to provide a refined empirical model of the secular variation in the southeast Indian Ocean. This is required for effective integration of data collected on surveys made over a lengthy span of time (ten years or so). Studies of the International Geomagnetic Reference Field (IGRF) have shown its inadequacies in the Indian Ocean region; data on the Australian Northwest Shelf could not be accurately integrated, even though surveys were only four years apart (Petkovic, 1974).

A preliminary version of an Australian Geomagnetic Reference Field (a modified IGRF) has been developed (Petkovic & Whitworth, 1975; Whitworth & Petkovic, 1977), and is in use by the Marine Geophysics Group of BMR.

3. WORK PROGRAM 1980/81

The most obvious feature that can be seen from any compilation of geophysical work in Antarctic waters is the limited availability of data, with an almost total absence of data over the Antarctic continental margin itself. In the Southern Ocean the major contribution is the work done by the Eltanin, but even that does not extend west of the Kerguelen Ridge. Therefore the main objective of the work proposed is the collection of data on a systematic basis to build up information in Australia's area of interest. This can be achieved with the co-operation of the ship's crew and the ANARE changeover personnel, with only a minor effect upon the operation of the Nella Dan supply voyages.

The Antarctic supply cruises of 1980/81, and in particular the FIBEX cruise, should provide BMR with data over its prime area of interest: the Australian Antarctic margin. The FIBEX traverses as planned (Fig. 5) contain six crossings of the Antarctic margin, together with several traverses parallel to the margin. Further, the deep-water traverses are over the Enderby basin, a deep ocean basin whose age of formation is speculative.

The ship's tracks to and from Antarctica should be designed to complement existing traverses, with a line spacing at a suitable multiple of 20 n. miles. The effect such adjustment to the ship's tracks would have on travelling time is trivial. The great circle path to Mawson would be extended by less than 10 n. miles if it was moved 240 n. miles to one side.

Proposed traverses

One of the objectives of the BMR magnetic work is to obtain a comprehensive network of magnetic observations over the Southern Ocean. In the short term the aim is to reduce the 300 km spacing to about 100 km in a direction oblique to the existing Eltanin tracks. Figure 5 shows the proposed network and the proposed FIBEX traverses. Also shown are existing tracks along which geophysical data have been collected, including the tracks of the 1979/80 Nella Dan surveys.

With the impending movement of Antarctic Division to Hobart, it is important that the northernmost lines of the network be completed this season. These lines will complement the 1979/80 data to produce a band of traverses across the Kerguelen-Gaussberg Ridge and adjacent deep ocean basins. On the Macquarie Island voyage, traverses will be sited to fill the gap in traversing to the northeast of the 1979/80 traverses.

The two return trips from the Antarctic mainland are sited parallel to existing lines from Davis and Mawson. The outward lines should where possible, within the constraints of weather or other factors, follow segments of the proposed network. However, regardless of direction of traversing, data should be collected at every opportune moment as all data are useful; the proposed network is intended to maximise the scientific value of the program.

Watchkeeping:

The BMR geophysicist on board will require assistance from ANARE personnel to ensure continuous monitoring of the data acquisition system, and to deploy and retrieve the magnetometer sensor. It is proposed that watchkeeping will be done on a rotating 4-hour shift basis, 24 hours per day.

Compilation maps of both existing ships' tracks and proposed traverses will be provided to both the bridge and the watchkeepers. Part of the bridge/watchkeepers' duties will be to navigate the ship along the proposed traverse lines by means of the satellite navigator. Positions should be plotted on these maps at least every six hours, and preferably every two hours, to maintain a continuous track plan. This will avoid accidental positioning of traverses along existing lines, will allow quick assessment at changes of traverse plan, and will provide a reasonable track plot for use on succeeding voyages.

This operation manual is intended to give the watchkeepers a basic outline of the navigation, magnetic, bathymetric, and data-acquisition system. The daily routine for each of the systems are given in the Appendixes, and are as much as possible a step-by-step explanation of the things the operator should do. These will be revised as experience dictates.

4. SHIPBOARD MAGNETIC OBSERVATIONS

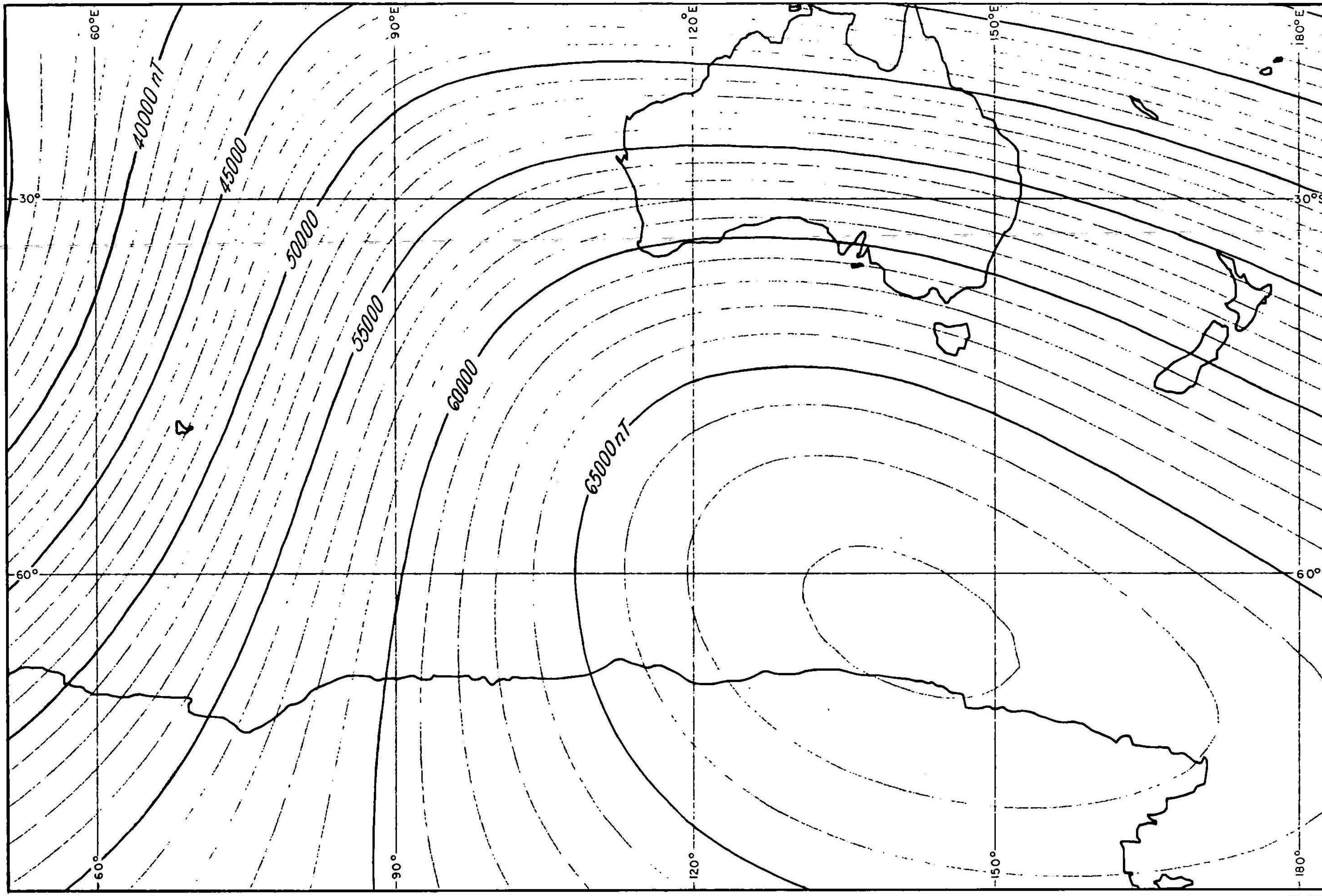
Magnetic data will be obtained with a Geometrics proton-precession magnetometer which measures the total intenstiy of the Earth's magnetic field. The magnetometer sensor is towed about 300 metres behind the ship, at which distance the magnetic effect of the ship's steel hull is negligible. Normally the sensor is towed at speeds over 6 knots, which keeps the sensor within 30 metres of the surface (Fig. 2a). When the ship is travelling more slowly, the sensor must be pulled in to avoid damage to the pressure equalisation diaphragm. A winch at the stern of the ship is used to deploy the magnetometer sensor and to store the cable when not in use.

Magnetic data will be recorded in both digital and analogue form, the prime recording system being the computer-based digital data-acquisition system (DAS). The digital system provides data that can be readily manipulated, displayed, and plotted in map form. However, it is prone to malfunctions which must be speedily detected to avoid lengthy editing procedures. Continuous monitoring of the system is essential if it is to be used to its fullest advantage.

The analogue system permits quality control and display of the data being recorded as well as providing a fail-safe backup. It is important that the strip-chart recording and annotated information are adequate for later recovery of data if the computer or a vital peripheral should fail. All relevant data should be annotated on the strip-chart (and DAS print-out) to avoid extra paperwork. All non-standard events should be clearly marked on the record (and print-out) at the time at which they occur. These would include: instrument problems and modifications, calibrations, changes in tuning, and clock corrections.

Initialisation of magnetometer system

Once the ship has cleared port, or sea ice, the officer on watch is advised and the magnetometer sensor is streamed using the procedure outlined in Appendix 1. The magnetometer unit is turned on and tuned to give maximum signal level (Appendix 2, part 1). When tuned properly, the digital values should change by only a few units each polarisation cycle. This digital value should be cross-checked against the expected field value as determined from Figure 1.



Record No. 1980/84

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MILLER'S MODIFIED MERCATOR PROJECTION

1 : 60 000 000

Fig. 1. Total magnetic field intensity over the Southern Ocean

The strip-chart recorder isturned on and calibrated (Appendix 2, part 2), and used to record the analogue signal directly from the magnetometer. The nominal paper speed of the strip-chart recorder is 15 cm/hour. Two pens are used to record simultaneously at 100 nT and 1000 nT full-scale sensitivity. The 100 nT trace has ten-minute time marks, and the 1000 nT has one-hour time marks, impressed upon them respectively when the NCE clock is in use. The operator must identify the hourly time marks and absolute field levels as part of the normal routine. The calibration tests plus ten-minute time marks allow adequate definition of horizontal and vertical scale for later digitising of the data if needed. Should the GED clock be used, time marks must be applied manually.

Normal operation:

The analogue and digital systems are run in parallel and the daily routine (Appendix 13) should ensure that equipment malfunction or failure is soon detected. In particular, the operator should ensure:

(i) Digital value as recorded by the DAS, and printed on teletype every 10 minutes, is the same as that on the magnetometer.

(ii) Noise level on magnetic trace, as observed on the 100 nT trace, is not excessive. This is generally within 2 nT peak-to-peak, but may rise to 5-10 nT peak-to-peak in heavy seas.

(iii) Analogue strip-chart is adequatelly labelled.

Trouble shooting

When the magnetometer is functioning properly, the noise level is generally within 2 nT peak-to-peak ($\pm$ 1 nT), rising to 5 nT peak-to-peak in heavy rolling seas. Noise of this amplitude is readily observed on the 100 nT trace. Noise levels higher than expected can arise from a variety of causes. It will pay to start checking for the simplest possible causes and work to the more complex. The most useful steps when investigating excessive noise are:

1. Check that the tuning is properly set for the magnetic field being measured, and cross-check against the expected field value shown in Figure 1.

2. Vary the tuning and inspect the result on the oscilloscope (CRO); the amplitude of the precession signal should be at a maximum and should be clearest when the equipment is properly tuned, and the signal should last for a reasonable period of time (about 2 seconds).

3. Check for interference when the ship's radio transmitter is operating and from other noise sources such as other equipment operating from the power supply.

4. Check the oscillator and any other electronic parts easy to get at: fuses, polarisation current, period of polarisation, cycle rate, etc. Check that the console and sensor shield are properly earthed, as described in the manual for the magnetometer.

5. Check all electrical plugs carefully, particularly at the winch and sensor; clean or replace as necessary.

6. Inspect the cable between the console and the winch and the sensor cable for damage such as breaks in wiring, shielding, and earthing.

7. Check the sensor casing for damage such as cracks, gouges, or metallic inclusions.

8. Clean the tuner switch and all circuit board contacts with Freon spray.

9. Replace each circuit card in the console one by one, replacing each original card if there is no improvement.

10. Check the sensor kerosene for water and other contamination by pouring it into a bucket and waiting for impurities to settle. Replace if necessary with clean household kerosene.

Further background information is available in the Geometrics manual.

Sensor offset and depth

The depth of the sensor below the surface is a function of several factors, including tow speed, cable length, drag (type and diameter) of cable, drag (shape) of sensor, and weight of sensor. For a given cable and sensor, the only variable factors are the tow speed and cable length. Occasionally, over rough bottoms such as reefs or when the towing speed is low, the sensor must be towed above a specified depth. Figure 2 shows the sensor depth versus towing speeds for various cable lengths. From this figure, it is obvious that sensor depth increases dramatically for all cable lengths if the towing speed is less than 3 knots.

At low towing speeds, the only option available to decrease the sensor depth (without using flotation aids etc), is to shorten the cable length. However, this introduces a further problem: the sensor will be influenced by the magnetic effect of the ship. This is summarised in Table 1 which shows the magnetic effects of ships of various sizes versus the cable length.

TABLE 1: Approximate Magnetic Effects of Ships, Measured by a towed Magnetometer.

Size of Ship	Length of Towing Cable			
	30 m (100 ft)	100 m (330 ft)	150 m (500 ft)	250 m (830 ft)
25 m (84 ft) 200 tons	200 nT	6 nT	1.6 nT	0.4 nT
50 m (84 ft) 700 tons	700 nT	20 nT	6 nT	1.4 nT
70 m (230 ft) 1700 tons	1700 nT	50 nT	13 nT	3.0 nT
90 m (300 ft) 3300 tons	3300 nT	80 nT	25 nT	6.0 nT

The Nella Dan has a length of 75 m, and a nett tonnage of 1060 tons. (Gross tonnage 2206 tons). It is therefore comparable to the third category of ship size. From the table, it can be seen that with the normal cable length of 300 m, the magnetic effect of the ship is only two or three nanoteslas. Halving the cable length to 150 m will increase the magnetic effect to about 13 nT.

From the above considerations, it appears that the minimum towing speed that can safely be used is about 3 knots. By halving the cable length to 150 m the sensor depth is about 50 m, and the magnetic effect about 13 nT. Both of these effects are acceptable in order to achieve reasonable quality of magnetic data.

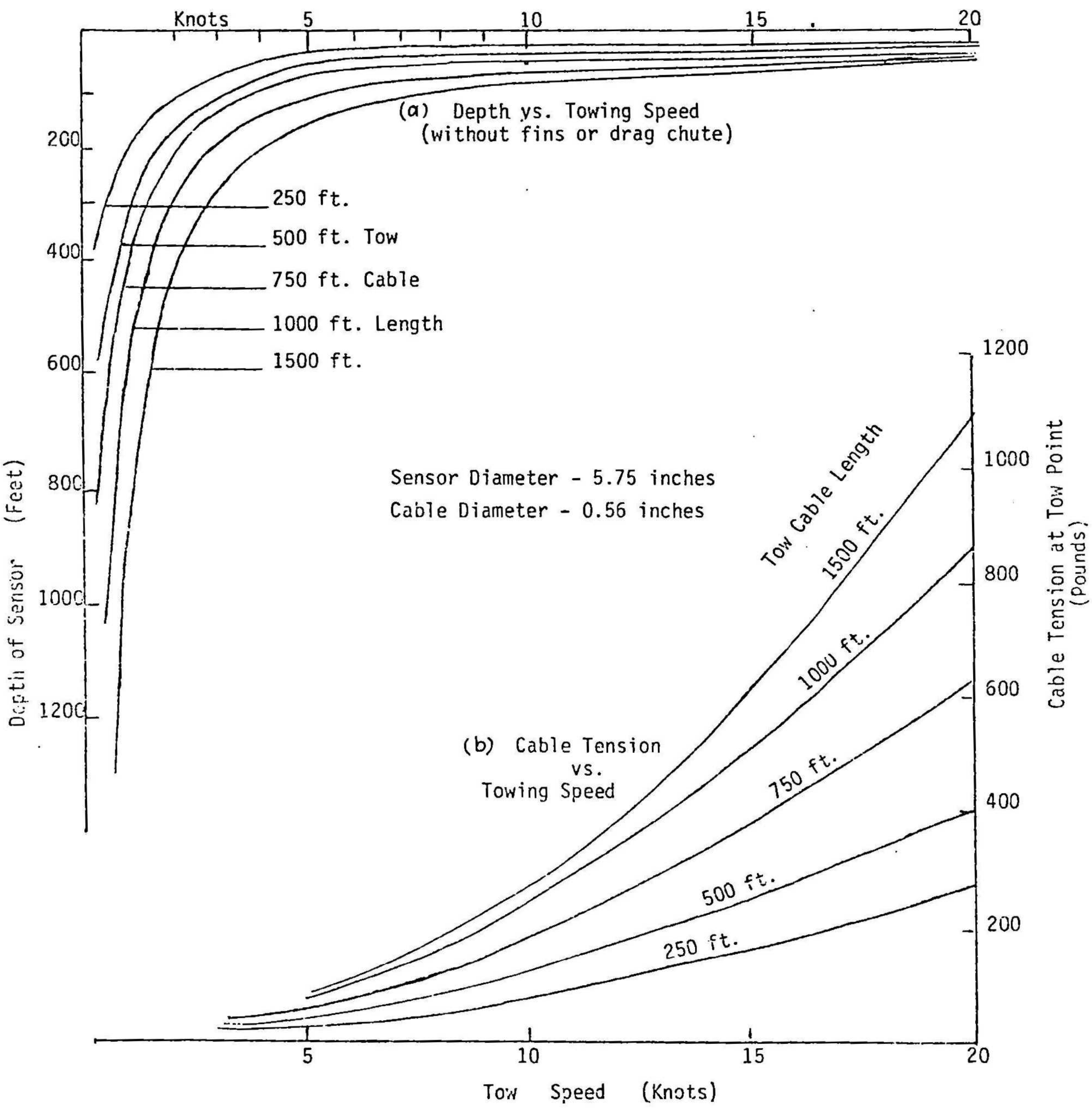


Fig. 2. (a) Depth of sensor v's Tow Speed
(b) Cable Tension v's Tow Speed

5. SHIPBOARD BATHYMETRIC OBSERVATIONS

Several bathymetric systems are available on the M.V. Nella Dan. These include an Atlas fathometer used by the ship's officers, two Simrad high-resolution echo-sounders used by Antarctic Division as 'fish-finders', and a deep-sounding Raytheon bathymetric system used by BMR to obtain depths over the deep ocean basins. The Atlas is located on the bridge, and the others are located in the electronics laboratory.

Bathymetric data will be recorded in both digital and analogue from. Two of the available bathymetric systems, the Atlas and Raytheon systems, have been integrated with the BMR data acquisition system (DAS). The Atlas is primarily an analogue device having its own chart record, while the Raytheon output is displayed on an EPC graphics recorder. The EPC recorder is run in continuous sweep mode at large scale, with 1 cm equivalen to about 15 m. At this scale, the output record is equivalent to those produced by normal precision depth recorders.

A Digitrak digitising unit has been coupled to the Atlas to provide digital water depths; the Raytheon has its own digital output. Both systems require regular operator attention to ensure that the tracking mechanism is in fact tracking water bottom.

Raytheon bathymetric system

The Raytheon echo-sounder is a special purpose system that transmits a 'chirp' signal using an array of up to 8 transducers mounted inside the ship's hull. This method avoids having to cut large numbers of holes in the bottom plates. The return echo is correlated and compressed by a 'black box' into a normal signal.

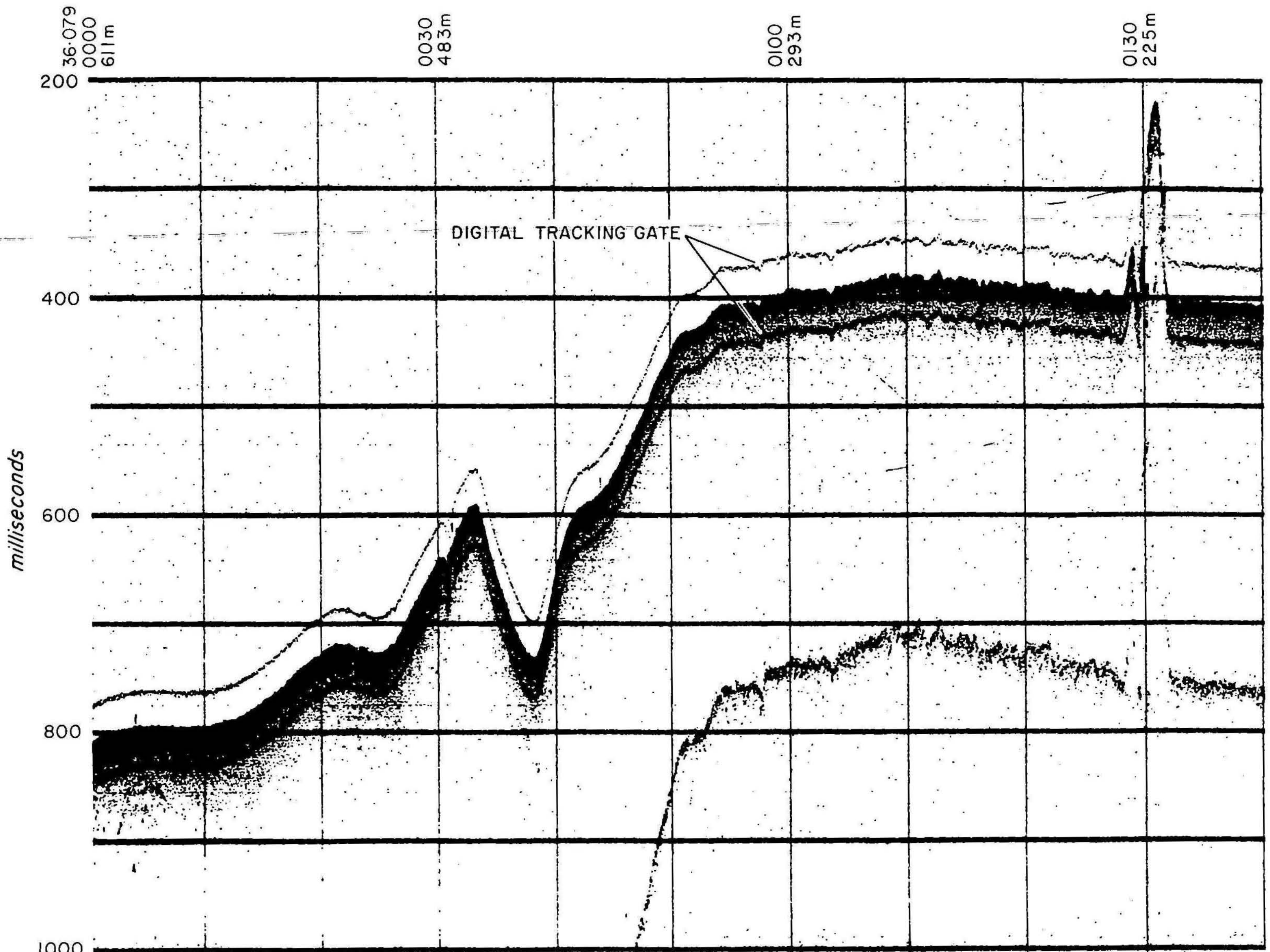
The signal is displayed on a graphic recorder and under optimum conditions a sub-bottom penetration of a hundred metres or so can be seen in deep water. The system is a deep-sounding echo-sounder designed to reach abyssal depths greater than 5000 metres.

The installation on the Nella Dan involves the transmission through a thick (25 mm) hull plate which involves a two-way transmission loss of about 9 dB. This loss is acceptable under good operating conditions as the deep ocean floor can still be reached. However, it will probably be excessive in rough weather, especially when the ship is rolling heavily. Owing to the large transmission loss, it is envisaged that the system will be run on full power (o dB) at all times.

As the system has a high power output (over 2 kW), the transducers require a pressure head to prevent them from cavitating. To provide this pressure head a standpipe about 8 m high has been installed. During operation, it is essential that this standpipe is checked regularly to ensure it is full of water. This can be checked visually using the sight glass at the top of the standpipe. If the water is not visible, the standpipe must be topped up with fresh water.

Initialisation of Raytheon. The key, or trigger, for the Raytheon system is supplied by the EPC graphics recorder. Thus the EPC recorder must be set in normal operating mode (See Appendix 2, part 9). Following this the components of the RAytheon: the CESP (Correlation Echo Sounder Processor), the PDD (Precision Depth Digitiser), and the PTR (Transceiver), are turned on and set to normal operating mode (See Appendix 2, part 10).

Normal Operation. Once the initialisation procedures are completed, the major function of the user is to ensure that an adequate analogue record is produced on the EPC and that the digitiser is tracking the water bottom.



Record No. 1980/84

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Fig. 3. Raytheon Bathymetric system – example of good digital tracking.

The PDD digitiser places a digital tracking gate on the analogue record which allows the user to ascertain the quality of the digital values. An example of good digital tracking has been taken from the 1980 Heard Island Expedition (Tilbury, in prep) and is show in Figure 3.

When the digitiser loses track, the alarm light comes on and remains on until a valid echo is received. The gate width remains constant, in our case 100 m, until the number of missed echos is equivalent to the ALARM number, usually set at 8. At this time, the alarm light starts flashing, and the digitiser reverts to search mode, where the width of the gate doubles on each consecutive missed echo until a valid echo is received. The system is then automatically reset in normal tracking mode.

With the automatic search procedure, the Raytheon system usually locks on to bottom track fairly rapidly, with minimal loss of digital data. Occasionally, however, especially in regions of rough topography or in rough weather where the signal-to-noise ratio is low, the Raytheon will lose track and will not regain bottom track. At these times, it will be tracking either noise or possibly the trailing edge of the transmission pulse. If this occurs, the digital tracking must be reset manually (see Appendix 2, part 10).

In extremely bad weather, or at times of excessive rolling or pitching of the boat, the digital output of the Raytheon will be suspect, and it will be almost impossible to keep the tracking mechanism locked onto the water bottom. However, as the CESP correlator produces a white 'halo effect' above the water bottom, is is still possible to produce an acceptable analogue record which can be manually digitised later.

Atlas/Digitrak system

The Atlas is primarily used as a shallow water echo-sounder. Although it has a maximum range to about 1800 fathoms (3300 m), the resultant chart record is so exaggerated at this depth as to preclude a precise depth reading. It is acceptable for depths less than about 1000 metres, and it is in areas of these depths, particularly on the shelf, where this system will be used.

Initialisation of Atlas system. The Atlas echo-sounder is turned on and an appropriate depth scale chosen. The Digitrak is turned on and the tracking mechanism is set manually at the approximate depth (See Appendix 2, part 11).

Normal operation. Once initialised, the major function of the user is again to ensure that an adequate analogue record is obtained on the Atlas, and that the digitiser is tracking the water bottom.

Several shortcomings exist with this system:

(i) The Atlas chart record has no automatic time marks. To obtain a useful analogue record for back-up purposes, time marks should be inserted manually using the MARK switch at least every hour.

(ii) As the Atlas recorder is on the bridge, and the Digitrak system in the electronics laboratory, it is difficult to ensure that the digital system is tracking the water bottom correctly. Consistent depth over several cycles usually indicates correct tracking. The depths will vary by a few tenths of a metre, even when tracking well.

(iii) The Digitrak system is prone to malfunctions at the bottom of its scale ranges, and requires operator attention to reset scale and tracking mechanism. For example, scale one is 0-80 metres, and thus if the system is tracking a deepening water bottom, the tracking mechanism will remain at 80 metres until the operator resets it to the 0-300 metre scale, and locks the tracking mechanism onto the water bottom. For that reason, it is preferable to use the 0-300 metre scale as long as the system will track reliably.

THE NAVIGATION SYSTEM AND HOW TO USE IT

The navigation system on the M.V. Nella Dan is centred on a Tracor navigator which uses the U.S. Navy TRANSIT satellite system. The Tracor is a single-channel long-count receiver which provides position fixes with an accuracy of about 0.5 n mile, on average about every 2 hours. The satellite navigator is coupled to an Anshutz gyrocompass and ship's pressure log to provide intermediate dead-reackoned positions. With a reasonable allowance for propagation of error in the dead-reckoning mode, intermediate positions determined at sea should be good to 1 to 2 n. miles. On this basis it should be possible to navigate the ship within 5 n. miles of a specified traverse line, and to maintain an acceptable profile separation at a line spacing of 20 n. miles.

For the 1980/81 Antarctic season, Antarctic Division has provided a new Tracor Mark II satnavigator with much improved user functions, but with digital output that is slow for a data logger system. BMR has therefore modified the electronics of the existing Tracor to enable the BMR data acquisition system to access the navigation data display at 10 second intervals. The two satellite navigators run independently, with the new model currently installed on the bridge, and the old model in the electronics laboratory.

Initialisation of Tracor satellite navigator

At the start of the survey, and following any power failures, the Tracor satellite navigator must be initialised. To do this, an approximate starting position (latitude and longitude), time (GMT), and antenna height must be entered using the MODE (function key on the Tracor. The ship's log and gyro-compass inputs used in the dead-reckoning must also be calibrated.

The ship's pressure log provides an output in the form of a contact closure every 10 metres, i.e. about 180 'clicks' per n.mile. This figure is input to the Tracor to convert the number of 'clicks' received into distance travelled.

The gyrocompass is a stepping motor which results in only the fractional degree indications being transmitted to the Tracor. Therefore, it is necessary to synchronise the heading manually, before normal operation in automatic mode. The synchronising of the gyro heading with the Tracor is the most difficult part of the initialisation procedure. Two people are required: one to enter parameters into the Tracor and the other to call headings from the bridge via the intercom.

Firstly, the person on the bridge observes the "whole degree" heading value from the gyro (or gyro-repeater) which most closely approaches the ship's actual course. This value is called to the laboratory to allow the operator to insert it manually into the Tracor. Secondly, as the heading next approaches the chosen value, the bridge warns the operator, and then calls 'MARK' as the heading reaches the chosen value. The operator then initiates automatic mode. Thirdly, a series of headings are called to the laboratory to confirm the adequate synchronisation of headings in the Tracor (to within 0.5 degrees). Because of the time lags involved, it is important to synchronise the gyro input when the ship is travelling on a steady course with little yawing.

A summary of the Tracor initialisation, together with the required function numbers to enter the parameters, is given in Appendix 11.

Initialisation of the acquisition system

After loading the program into the computer (see Appendix 3), the user must answer a series of questions to configure the system to his requirements. As the system is based upon general-purpose software designed to give flexibility of operation, somewhat greater effort is required on the part of the user than might otherwise be the case. Users will be coached by the BMR representative in the early stages. With the mnemonic prompts provided to aid the user, little difficulty is anticipated.

The data inputs must be specified, and the channels within the output buffer where they will be saved must be identified (see Appendix 8). The first two channels are automatically assigned to the day, and GMT time. Following these are the five channels of Tracor data, viz. Tracor time, latitude, longitude, course, and speed.

At present, course and speed are values averaged over the sail line listing interval, rather than the instantaneous value. And lastly the four channels of geophysical data: water depth 1, water depth 2, magnetics, and magnetic anomaly value.

Next the values the computer will see when the Tracor is turned off or has failed must be provided. These are used to suppress the otherwise lengthy and continuing BCD error messages that would result. The Tracor time, latitude, and longitude are double-word digital inputs of 6 characters each. The values that must be provided to operator program FAIL are explained in greater detail in Chapter "Digital Input."

Up to this point the information has been quite general, and the computer has no idea what the numbers represent. Now it is necessary to independently provide specific information that will allow the navigation data to be converted and utilised. The user must identify the channel where the positional data starts, i.e. the output channel containing the latitude. Similar questions are asked concerning the geophysical data. An estimate of the ship's position, course, and speed must also be supplied to allow computation of initial values of parameters in the DAS.

Way points and sail line navigation may be provided immediately the system starts up. It is usually more convenient to leave this until later.

Finally the various terminal listing frequencies must be defined. These are all given in seconds, and must be in multiples of the acquisition period of 10 seconds. It is convenient for tabulating the hard copy on the system teletype to choose 600 seconds for both current data and table frequencies. For the bridge teletype providing sail line information, it is convenient to choose 600 seconds for the sail line data, and 3600 seconds for the header.

Normal operation

Once the initialisation procedures are completed, only occasional updates to the system operating parameters will be required. The more obvious requirements will be:

(i) To navigate the ship along a specified line, the user must first supply the way points to be used in operator program WAY. Only nine way points are allowed, and line labels must be six characters in length. Way points are given in degrees and minutes for both latitude and longitude. A series of way points may be built up in advance of actual requirements.

Then using operator program LINES, the user must ask for the next line. The first two way points are taken and used in computing the sail-line information, i.e. cross-course error, distance to start and end of line, etc., to be printed on the teletype on the bridge. The way-point list is pushed down to eliminate the point(s) used. Note that if every way point has a normal label, only the first point is eliminated; if the second way point has the label ****************, both points are eliminated.

(ii) As the navigation data saved are displayed on the TRACOR screen, extra information can be saved by using the MODE key on the TRACOR. In particular, the last valid satellite fix can be displayed by using MODE 20, and quality of fix by MODE 21. In practice, these keys should be manually set every 30 minutes or so to save the satellite fix information. Note that at least 30 seconds should elapse between using MODE 20 and 21, to allow acquisition of correct navigational data between the two sets of extra data.

(iii) The user may wish to vary the terminal listing frequencies from time to time using any of the operator programs CURNT, TABLE, SAIL, or force a listing using FCURNT, FTABLE, and FSAIL at a non-regular time.

(iv) The strip-chart recorder is provided as the major quality control system. It is anticipated that latitude, longitude, course, and speed and two geophysical data channels will be plotted. The calibration of the recorders can be checked using operator program STAIR, and adjusted using INDAC. Variation in channel allocations is made using operator program CHART.

(v) When operations cease, the user may still wish to continue navigating using the system but does not require the data to be saved on magnetic tape. Recording can be closed down using operator program CLOSE, and restarted later using OPEN. The other facility that should be used is EJECT when inserting a new cassette; this ejects the old cassette under program control. The eject button on the cassette drive should be used only in emergencies.

(vi) There are several other miscellaneous routines likely to be used only rarely. These are summarised in the appendixes on "Operator Programs" (Appendixes 6 and 7).

7. THE DIGITAL DATA ACQUISITION SYSTEM

General description

BMR has provided a data acquisition system (DAS) built around a Hewlett-Packard HP 2108 or 2113 computer. This system acquires time, navigation, bathymetric, and magnetic data every ten seconds and saves the information on cassette tape in blocks spanning two minutes. The DAS acquires the data as 4-bit BCD characters, checks for valid character transmission, and converts to internal Hewlett-Packard floating-point word format before saving it on tape. To appreciate the advantages and limitations of the DAS, it is necessary to understand how the system works. There are three effectively independent programs within the system which communicate to some degree.

The acquisition program ACQ

This program is written in assembly language and is driven by the clock. Every ten seconds on a multiple of ten seconds (i.e., 10, 20, 30, 40, 50) the clock time, geophysical data, and navigation data are acquired as raw data and placed in the input buffer; the input pointer is incremented. When the input buffer is full the pointer jumps back to the first line and the buffer is filled all over again. This continues blindly regardless of whether or not the data are extracted, processed, and saved.

The present software has an input buffer that will last for one hour. Hence it takes almost one hour before the acquisition over-runs the processing. Should that occur, the output pointer is forcibly incremented to prevent overwriting, and only the latest one hour of data is retained.

The processing program DAN80

This program maintains an output pointer marking the last data sample that has been extracted from the input buffer and processed. As long as input and output pointers differ it knows there are data to process and makes one pass through the processing loop. The cycle is repeated until the pointers agree; then it idles until the next acquisition cycle bumps the input pointer again.

Within the processing loop, a sequence of steps is executed, from extracting the data from the input buffer to storing it in the output buffer. First the data are extracted and converted from 4-bit BCD code to internal

Hewlett-Packard word format. At this point a check is made to see if each character is valid in an effort to detect transmission errors or possible equipment malfunction. If an error is detected, a warning message is printed on the teletype. Should the erroneous value detected correspond to that seen by the computer when the particular device is switched off, the message is suppressed.

A check is made for jumps in time between consecutive samples to aid in detecting clock faults. A warning message is given at such times. As there is only one clock in this system, the program then proceeds on the assumption that the clock is showing the correct time. It is up to the operator to decide whether or not there is a clock malfunction. If the jump in time is negative, or positive and long enough to create an empty output block, the current output block is padded with 'unknowns' (10^{10}) and immediately written to cassette. A new output block is started and the current record is inserted in the correct slot within it.

An output block spans a regular period of two minutes, i.e. 0000 to 0150, 0200 to 0350, 0400 to 0550, etc. The program ensures that each record is inserted in the correct slot to maintain this regularity. Should any slots be skipped because of time jumps, they are filled with unknowns. Whenever an output block is filled, it is output to the cassette drive and an informative message is printed on the teletype. The next record is then inserted in the appropriate slot in the output block.

At an operator-selected frequency (usually 10 minutes) the time, position, course, speed, magnetic, AGRF-corrected magnetic, and bathymetric values are printed on the teletype. These are provided both as a simple digital back-up in case the cassette drive breaks down and to enable on-line plotting of navigation and geophysical data. The magnetic and bathymetric values should also be checked from time to time against the digital display on the magnetometer, Raytheon, and Digitrak. This is important as a bit drop-out cannot be detected by any other method, in contrast with a bit lock-on, which will eventually result in a BCD error.

Also at an operator-selected frequency, information on the ship's position relative to a derived sail line is printed on a teletype on the bridge. The information printed on this teletype includes the cross-course error and the distance to start and end of line. This information is printed to enable the ship's officers to keep the Nella Dan on line.

The operator system CHAOS

Once every processing cycle, or at any time when the computer is not processing, the operator has the opportunity to intervene and modify key parameters. Most of the time the DAS is waiting for another acquisition cycle to occur, which will then be followed by a brief processing cycle. Therefore the operator will in general be able to intervene in the operation of the system within a fraction of a second. He does this by setting SWITCH bit 0 (zero) manually or by touching a key on the teletype, and at the appropriate time enters the mnemonic of the CHAOS operator program he wishes to execute.

The CHAOS system is effectively a third level of program to which the operator can rapidly gain access when required but which is otherwise dormant. When the operator has initiated a CHAOS program, there is usually a series of questions he must answer. In general, termination of the operator program causes the request to be implemented. The operator should then preferably quite the CHAOS system by asking for program EXIT. Should the operator neglect to exit from CHAOS, it terminates itself after about 20 seconds.

It is most important to realise that if an operator program is not properly completed, e.g. by his not answering a question, then the DAS cannot return to the processing program. The acqusition program meanwhile is continuing to acquire data, and should the delay extend to one hour will cause overwriting of the input buffer data that have not yet been extracted and processed. It is therefore imperative for the operator to exit properly from the CHAOS system at all times.

8. INPUT OF DIGITAL DATA

The policy has been adopted that all digital data are input in standard 4-bit BCD format, i.e. four digits are packed into a single 16-bit word. The only exception to this is the clock input, which is not treated as a data channel. Two methods are used to input such data. One employs the BMR digital multiplexer which provides 16 input slots of 16 bits each; the other is by special purpose techniques. Wherever possible the multiplexer is used. In this case, two forms of input are allowed:

(i) 4 character input, using one slot in the multiplexer.

(ii) 7 character input, using two slots in the multiplexer.

NB. Two slot input is restricted to 7 characters (or significant figures) as this is the largest number that can be represented in floating point format within the Hewlett-Packard computer.

The user must identify the multiplexer slots through which the input data will be supplied. This is done in operator program REFER, by providing output channel number, and two multiplexer slot numbers (see Appendix 8). Single-slot input is identified by giving slot 1 as zero.

e.g. 10, 15, 16
12, 0, 2

identifies output channel 10 as using slots 15 and 16 of the multiplexer so it can have up to 7 characters input, while channel 12 uses only slot 2 with a maximum of 4 characters input.

With special-purpose equipment such as the Hifix, Trisponder or Tracor navigation systems, a variation on this approach is used. In each case data input must be done using a specially written computer sub-program which reorganises the data to make them look as if they had been input via the multiplexer. Conversion can then proceed exactly as for normal input.

In such cases the information given in operator program REFER must flag that the data are provided from a special source, and whether they are the equivalent of one or two slots in the multiplexer. This is done by giving the first slot as slot 99 and the second slot as 0 or 1 for single (4 character) or double (7 character) word input respectively.

e.g. 6, 99, 0
7, 99, 1

identifies channel 6 as special input the equivalent of single slot input, while channel 7 is the equivalent of double slot input.

Digit	Binary	Octal	ASC II
0	0000	0B	0
1	0001	1B	1
2	0010	2B	2
3	0011	3B	3
4	0100	4B	4
5	0101	5B	5
6	0110	6B	6
7	0111	7B	7
8	1000	10B	8
9	1001	11B	9

However if spurious transmission takes place, more bits than are numerically "legal" can be on. For example if the 8-bit locks on and the digit 7 is transmitted, the result is the "digit" 15. These are recorded within the computer as:

10	1010	12B	:
11	1011	13B	;
12	1100	14B	<
13	1101	15B	=
14	1110	16B	>
15	1111	17B	?

When the computer detects an illegal "digit", it prints a warning message giving both the number containing the false digit plus a marker to indicate which digit it believes to be in error,

e.g. correct number 3027400

faulty transmission 3027<00 8-bit locked on

nnnn↑nn

where n represents a blank, ↑ marks erroneous digit.

Attempting to automatically correct data errors can have disastrous consequences. Therefore regardless of errors on input, the input characters are converted to a floating point number within the computer.

The number $C_7C_6C_5C_4C_3C_2C_1$ is converted as:

$$VALUE = C_7 \times 10^6 + C_6 \times 10^5 + C_5 \times 10^4 + C_4 \times 10^3 + C_3 \times 10^2 + C_2 \times 10^1 + C_1$$

and similarly for a four-digit number. In the example given above, the number recorded would be 3028200. This approach permits later rectification of the error.

When an instrument fails (or is turned off), all its output lines gradually float upwards to become one-bits, ie. a 4-character input becomes ???? which converts to 16665 while a 7-character input becomes ??????? which becomes 16666665. This assumes that the instrument can and does supply all bits.

Some instruments do not have this capability and therefore the undefined bits within the 4 or 7-character number must be set to zero by grounding the necessary pins on the input plugs to the multiplexer. Note that all special purpose inputs are made to look the same, ie. unused characters are set to zero, and are treated in an identical fashion. At the present time, the numbers seen by the computer for the following instruments are:

Digitrak echo sounder	166665 (5 chars)
Magnetometer	166665 (5 chars)
Raytheon echo sounder	766665 (5+ chars)
TRACOR satnav	1666665 (6 chars)
MINIRANGER navigation	3666665 (6+ chars)
TRISPONDER navigation	16666665 (7 chars)
HIFIX navigation	16666665 (7 chars)

To avoid continually warning the user that the instrument is turned off (or has failed), the user supplies in operator program FAIL the number the computer will see when the device is off. If the observed value agrees with the Failure Table entry the value is set to UNKNOWN (1.0E10) and all the BCD error flags cancelled before the program lists the input errors. That is, no BCD error message will be printed on the teletype when the instrument is turned off.

9. THE CLOCK AND TIMING CONTROL

A crystal-controlled clock provides the basic timing for the data acquisition system and magnetometer recorder. It may be a GED or NCE model but both have identical characteristics as far as timing control is concerned. The setting of this clock must be initiated and checked by reference to the Australian Post Office time signals on radio station VNG, or equivalent overseas stations such as WWVH in Hawaii. Time signals generated by the APO standard are accurate to about 100 microseconds, but the received signal may jitter by say 1 millisecond owing to ionospheric effects.

The clock has a one-second reading precision and can be set to within one second of the radio time signal by the simple technique of carrying the time from the radio to the clock using an intermediary clock or stop watch. The specified drift rate for the clock is better than 1 in 10^7, or the equivalent of one second in four months. Clock error should not therefore be significant during a cruise, and time-signal error is negligible by comparison.

The magnetometer is read every 10 seconds, and a drift in the clock of up to even half of this would not greatly affect the accuracy of the data. (This would correspond to a positional error of about 25 metres at 10 knots). Under normal conditions a timing error of 5 seconds would be excessively high considering the drift rate mentioned previously, and would most probably indicate abnormal operation requiring close attention. However on the Nella Dan, a more flexible approach is considered appropriate.

After synchronisation of the clock with VNG, the drift should be determined and logged on a regular daily basis. As long as the drift rate is fairly steady and close to linear, no adjustment should be made until the clock error exceeds five seconds. At that point the clock should be resynchronised with VNG and the adjustment logged. The operator should watch for abnormal clock behaviour indicated by erratic or abrupt changes in drift. Such events should be checked promptly, and if necessary clock drift should be monitored closely until the problem is resolved.

The navigation data are derived from the TRACOR system, which has independent timing control. Keeping the BMR clock within 5 seconds of Universal Time will maintain equivalent positional errors at a trivial level considering the navigational precision of 0.1 n. mile.

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APPENDIX 1: STREAMING AND RETRIEVING THE MAGNETOMETER

A. STREAMING

1. Advise the watch officer on the bridge that you are about to stream the magnetometer.

2. Check that D.C. power to the winch is connected and turned on.

3. At the winch:

   (a) Unlash the cover and the sensor.

   (b) Unplug the deck leader and make sure the plug on the side of the drum cannot foul the winch frame.

   (c) Apply the brake and lift the sensor over the side.

   (d) Release the brake and press the bottom switch to unwind the cable.

   (e) Periodically release the switch to see if there is sufficient drag on the sensor to unwind the cable. When this can be done, use the brake to prevent the winch racing.

   (f) When the innermost layer of the cable is completely exposed, pull the brake hard on to check that it works.

   (g) Release the brake and continue running out the cable until the marker just leaves the drum (one-third of the innermost layer should remain on the drum), then pull the brake on with the drum in such a position that the sensor cable can be reconnected without strain.

   (h) Thread the chain through the holes in the drum and around the winch frame, and shackle it; release the brake.

   (i) Spray both plugs thoroughly with Freon, then plug-in the deck leader and seal the plug join with plastic and insulating tape.

   (j) Replace the canvas cover.

   (k) Advise the bridge that the magnetometer has been streamed.

4. Winch maintenance.

(a) Keep the cover on the winch whenever the winch is not being operated.

(b) Keep the sensor cable connection greased with a non-conducting grease such as silicone.

(c) Keep the sensor head securely lashed when it is stowed.

B. <u>RETRIEVING</u>

1. Advise the bridge that you are about to retrieve the magnetometer, and ask them to slow the ship to about 5 knots.

2. Check that the D.C. power to the winch is connected and turned on.

3. At the winch:

(a) Unplug the deck leader and make sure the plug on the side of the drum cannot foul the winch frame.

(b) Turn the drum enough to take the strain off the chain and apply the brake.

(c) Unshackle the chain.

(d) Release the brake and press the top switch to wind in the cable. The cable should be directed onto the drum by an assistant.

(e) When the section of yellow insulating tape appears, the assistant should go to the snatch block to indicate to the operator when to stop the winch.

(f) Lift the sensor over the rail and secure it.

(g) Release the brake and reconnect and re-tape the deck leader.

(h) Adivse the bridge that the magnetometer is on board.

APPENDIX 2: TURNING THE EQUIPMENT ON

1. Magnetometer

(a) turn D.C. power supply on; adjust output to 28 volts

(b) check all magnetometer switch settings (see Geometrics manual, page 3-2). (NOTE: set INT/EXT switch to EXT with NCE clock; or to INT with GED clock and polarise rate of 6 seconds).

(c) check that MODE switch is on STANDBY.

(d) turn-on power switch on magnetometer.

(e) monitor internal voltages, +12V, -12V, +5V using METER.

(f) turn MODE switch from STANDBY to NORM (Note: MODE switch must be turned to STANDBY before turning magnetometer off).

(g) turn MONITOR switch to POLARISE and check that the polarisation current drawn by the D.C. power supply is about 6 amps.

(h) turn MONITOR switch to SIGNAL and adjust coarse and fine TUNING to give maximum signal level on METER/CRO (use Fig. 1 as guide).

2. Strip-chart recorders

(a) check that the paper supply is adequate for 24 hours' operation; change if necessary.

(b) check the switch settings (see appropriate Recorder manual).

(c) turn-on power and paper drive switches.

(d) lower styli onto paper.

(e) carry out zero and calibration adjustments for those channels connected directly to the recorder.

(f) for those channels connected via the computer, the calibration adjustments are carried out using operator program STAIR, but the zero is set on the recorder.

3. <u>Data acquisition system computer</u>

(a) turn-on power switch on back of computer

(b) make sure both internal fans come on; if not, check fuses etc.

(c) turn key on front of computer ¼ turn anti-clockwise for one second (STANDBY to R), then ½ turn clockwise (R to OPERATE) for HP 2108 computer.

(d) the computer should then carry out a short self-test program and end on HALT with T-register displayed on front switches.

4. <u>NCE digital clock</u>

(a) plugging-in the clock turns-on the internal fan

(b) turn-on CLOCK POWER switch

(c) set 100 kHz oscillator switch to EXT

(d) set clock face to the Julian day number and GMT time slightly in advance of the correct time.

(e) carry the correct time from a radio time signal such as VNG

(f) start the clock when the correct time and clock face agree by flicking the 100 kHz oscillator switch to INT.

(g) plug 10-second time-mark output into magnetometer EXTERNAL polarisation pulse BNC.

(h) connect 10-minute and 1-hour time-mark outputs to magnetometer 100 and 1000 nT analog outputs to strip-chart respectively.

5. <u>GED digital clock</u> (alternative to NCE clock)

(a) plugging the clock into a power source will light up the display panel.

(b) open the front panel and set the Julian day number using the switches on the left. Set the hours and minutes slightly in advance of the correct time using the thumbwheels and switch beneath.

(c) carry the correct time from a radio time signal.

(d) start the clock when the correct time and clock face agree, by flicking the start switch.

(e) make sure magnetometer is switched to INTERNAL polarisation.

6. Digital multiplexer

(a) turn the power switch on the front panel ON. The yellow indicator light should come on.
(b) plug the two digital outputs from each instrument into the slots at the rear of the multiplexer. Place the higher-order bits plug into the lowest available slot, and the lower-order bits plug into the adjacent slot.
(c) note the slot arrangement for each instrument for use in the DAS program initialisation.

7. KSR 43 Teletype

(a) turn-on power switch at back of teletype

(b) the following front switches should be set

(i) PARITY-down (no parity checking)

(ii) DUPLEX-down (full duplex transmission)

(iii) CPS-up (30 cps transmission)

(c) open teletype top, pull back print head from paper using lever

(d) insert paper, making sure sprocket holes line up on both sides

(e) move print head forward, ensuring ribbon is correctly positioned

(f) close lid, make sure ALARM is off, press LOCAL

(g) check that teletype is printing properly by holding down PRINTER TEST for several seconds

(h) press TERM READY, when DATA should come on and all others should go out; the teletype is now connected to the computer

8. Facit cassette tape recorder

(a) turn power switch on fron panel ON

(b) press EJECT and cassette panel should spring open

(c) insert timing test cassette, close panel and wait for cassette to load

(d) press READ and time how long it takes to read test tape; this should be 180 $\pm$ 5 seconds

(e) eject cassette; the recorder is now ready for use.

9. <u>EPC graphics recorder</u>

(a) check that paper supply is adequate

(b) plug-in key pulse to Raytheon system using BNC connector to KEY PULSE (+5V)

(c) plug-in Raytheon output signal using BNC connector to SIGNAL INPUT

(d) turn-on power switch in top left-hand corner

(e) CHART and SCALE LINES

(i) set paper speed rate, usually 4 (30 cm/hr)

(ii) set scale lines switch to 100 MSEC, adjust INTENSITY switch to give clear timing lines

(iii) turn-on TAKE-UP switch

(f) AUTO-EVENT MARK

(i) set time marks to 5 minutes

(ii) synchronise time marks by pressing SYNC button at 5 minute time on DAS clock (NOTE: EPC clock need <u>NOT</u> be correct)

(g) SWEEP CONTROLS

(i) set SPEED knob to 1 second, or as appropriate

(ii) set TRIGGER switch to INT

(iii) set SINGLE SWEEP switch to OFF

(h) AMPLIFIERS

(i) set SPREADING/LINEAR switch to LINEAR

(ii) set PRINT switch to + ve

(iii) set THRESHOLD knob to minimum

(iv) set CONTRAST knob to about 30-50% of full range

(v) set GAIN knob to about 400, but may require adjustment depending on state of stylus, marking amplifier etc.

(i) KEY and GATE

(i) set KEY length knob to 30-50%

(ii) set POSITION switch to CTR/EDGE as appropriate

(iii) set SWEEPS knob to 3 (or as necessary)

(iv) set key switch 1 to KEY (but see (v) below)

(v) set key switch, 1, 2, or 3 to PRINT as appropriate, depending upon depth of water to keep bottom reflection roughly centred on the record

1C. RAYTHEON bathymetric system

(a) Interconnecting wires and internal switches are set at the start of the survey according to the Raytheon manuals.

(b) Ensure standpipe providing pressure head for tranducers is full of water. This can be checked visually using the sight glass at the top of standpipe.

(c) Ensure EPC recorder is on and is supplying key pulse to the Raytheon system.

(d) Set CESP controls on front panel
   (i) turn on power switch
   (ii) adjust THRESHOLD to 5

(e) Set PDD controls on front panel
   (i) turn on power switch
   (ii) set MARK INT to about 5
   (iii) set ALARM to 8
   (iv) set THRESHOLD to 2-3
   (v) set GATE WIDTH to 100

(f) Set PTR controls on front panel
   (i) check POWER OUTPUT is set to -30 dB
   (ii) turn POWER switch to STANDBY for 5 seconds, then to ON
   (iii) check that no warning lights come on, i.e. the excess voltage, load mismatch or excess duty lights.
   (iv) increase POWER OUTPUT slowly, checking whether any warning lights come on.

   NOTE: In deep water, system will require full power (0 dB).

(g) Set digital tracking of PDD by:
   (i) set AUTO/MANUAL switch to MANUAL
   (ii) key in depth on thumb wheel display to the approximate depth; wait until digital tracking locks onto water bottom.
   (iii) set AUTO/MANUAL switch to AUTO

(h) Check display on EPC recorder
   (i) adjust THRESHOLD on PDD so that digitiser does NOT trigger on spurious noise. ECHO light should flicker intermittently, not continuously.
   (ii) adjust THRESHOLD on CESP if required, but only between about 4 and 7 otherwise echo is either obliterated with noise, or truncated completely.

(i) If PDD loses track, establish water depth from EPC display and reset digital tracking using (f).

11. DIGITRAK digitising unit

(a) Ensure that Bridge Atlas fathometer is on and operating in correct depth range

(b) Press power switch ON

(c) Set DEPTH RANGE to appropriate scale, i.e. 80, 300, 1800 metres

(d) Set GATE WIDTH appropriately, usually MEDIUM.

(e) Set tracking gate to approximate depth using SLEW switch, checking depth on meter. (NOTE: True depth is shallower than reading on indicator).

(f) Set TIME CONSTANT appropriately (long, medium, direct), usually MEDIUM.

(g) Set PROGRAM SELECTOR to transmitter/recorder

(h) Press RESET, and press AUDIO off.

(i) Adjust DETECTOR SENSITIVITY gradually from minimum until the bottom echo gives a clear pulse on the neon ECHO indicator.

(j) Adjust DETECTOR SENSITIVITY frequently, DEPTH RANGE less often, and GATE WIDTH rarely to maintain good tracking by the DIGITRAK.

12. TRACOR satellite navigator

(a) Ensure gyro and speed log outputs are plugged into rear of TRACOR.

(b) Ensure interface plug to BMR computer is plugged into top of TRACOR.

(c) Turn power switch at rear ON.

(d) Initialise time, latitude, longitude, course, speed, antenna height, and contact closures per mile using Appendix 11.

APPENDIX 3: DATA ACQUISITION SYSTEM START-UP

1. Insert cassette tape containing binary absolute copy of the DAS into the cassette recorder and close the door. Check that after about two seconds' delay, the tape moves forward to load point and then halts.

2. Make sure the OPERATE/LOCK switch is in the OPERATE position. With the computer on HALT, use the register select switch to select the S-register, set the contents to 141000B then -

   press STORE
   PRESET
   IBL
   RUN

   The program will now be loaded into memory from the cassette - this is accompanied by distinct clicks from the recorder at about one-quarter second intervals, and will take about 7 minutes to complete.

3. If the program loads successfully, the computer will HALT with 102077B displayed in the T-register. If any other number is displayed (102055B, 102033B, or 102011B) a fault has occurred. In such cases eject the cassette, clean the recorder, and try again with the same cassette. Should this fail, try with another cassette copy of the program after again cleaning the recorder.

4. Following a successful load of the program, eject the cassette and insert a properly labelled blank data cassette with the manufacturer's label to the front. If the program cassette is left in, the DAS will hang-up almost immediately it is initialised.

5. Start program execution by using the register select switch to select the P-register, set the contents to 2B then -

   press STORE
   PRESET
   RUN

   The DAS program will then type the following message on the teletype -

   'NELLA DAN' DATA ACQUISITION SYSTEM

   VERSION OF 10-11-80*

* Version date may vary

At this point the computer should be locked in the RUN position to prevent the DAS being accidentally turned off. For the HP 2108 computer (M-series) turn the operator key to LOCK; for the HP 2113 computer (E-series) open the front panel by turning the key and move the OPERATE-LOCK slide switch to LOCK.

APPENDIX 4: INITIALISATION OF DATA ACQUISITION SYSTEM

Following successful start-up of the acquisition system, the computer will type a series of messages including some questions that the operator must answer. After each answer press RETURN (CR) to indicate end-of-transmission, otherwise the system will hang-up waiting for you to complete the message.

1. After the starting message

   'NELLA DAN' DATA ACQUISITION SYSTEM
   VERSION OF 10-11-80*

the DAS will ask

   OK TO PROCEED? -

If you wish to use the default input and output channel allocation (see Appendix 8 for recommended default allocations to be used in 2 below), answer

   YES (CR)

If you wish to change the numbers of channels allocation (this operation should never be necessary), answer

   NO (CR)

2. The DAS will now ask for the location and type of each data channel (see Appendix   for recommended allocations)

   NEW CHANNEL ALLOCATIONS
   CHANNEL AND 2 SLOTS =

You must answer with each ouput channel number and either the slots in the multiplexer in which the relevant instrument is plugged, or the pseudo-channel numbers which indicate the mode of data conversion to be used. For full details see operator program REFER. When channel allocations are finished, type

   0 (CR)

---

* The version date may vary.

3. The DAS will not type

TYPE 'GØ' TØ START DAS -

Type

GØ (CR)

After the next 10-second interrupt the DAS will print

.HHMMSS - ACQUISITIØN STARTED

4. A series of questions will now be asked to complete system initialisation. The questions are found in the following operator programs:

LTAPE	IZØNE
LDAC	PØSN
SURV	DENAV
DIRTY	WAY
FAIL	LINES
FILTR	CURNT
LPØS	TABLE
ECHØ	SAIL
ØBMAG	CHART
ANØM	INDAC
ADMAG	RWIND

5. Once the questions in these programs have been answered, the DAS starts normal program execution. Note that acquisition of data commenced before the computer went into the question-and-answer phase. You will almost immediately be informed that data are correctly slotted into the output buffer beginning at the time of start of data acquisition by the message

- SYNCHRONISED OUTPUT BLOCK AT SS.DDD.HHMMSS

APPENDIX 5: SYSTEM MESSAGES

When the DAS is operating normally, only five messages should be output on the system teletype and two messages should be output on the teletype on the bridge. These messages are:

(1) Every 2 minutes of processing time a block of data will be written to cassette tape; a message is printed giving the clock time at which the block was output, and the start and stop times of each block. The times should be checked for continuity and correctness.

(2) At an operator-selected frequency, the time, latitude, longitude, water depth 1, water depth 2, magnetic value, and residual magnetic value will be printed. These values should be checked against the values displayed on the instruments.

(3) At an operator-selected frequency the filter error table will be printed. The numbers printed are the number of values outside the threshold for each channel since the table was last printed.

(4) When the operator requests MODE 20 on the TRACOR, the DAS will identify this when it acquires the navigation data and type
- ACTUAL SATFIX POSITION AT TIME .HHMMSS.

(5) Whenever a position update occurs in the TRACOR following a satellite fix compution, the DAS will type on both terminals
- SATFIX DETECTED, DLAT = , DLON =

(6) At an operator-selected frequency the sail line information will be printed on the teletype on the bridge. This information includes the current latitude and longitude; and distance to start and end of line, and cross-course error in nautical miles.

Other messages that may be pinted include:

(i) PARITY ERROR ON DRIVE 1

If this occurs frequently, use operator program 'EJECT' to eject the cassette, clean the recorder and insert a blank data cassette. NEVER insert a partly used cassette.

(ii) EJECT TIMED OUT ON DRIVE 1

If this message is printed, it means the recorder has taken too long to eject a cassette. This probably means the cassette is jammed in the drive.

(iii) BCD INPUT ERROR

CHANNEL n 0?035>5

n↑nnn↑n

This message means that an error has occurred in converting data to Hewlett-Packard internal binary form; the likely cause is a transmission error or instrument/cabling fault. The individual BCD characters are given, the faulty data delimited by the asterisks, and the offending characters flagged with the up arrow ↑ . If the problem is permanent, the message will be printed every 10 seconds for one minute, and every one hour thereafter.

(iv) TIME JUMP TO SS.DDD.HHMMSS

Warning that a time jump has occurred. The DAS automatically copes with these on the assumption that the clock face is showing the correct time. You must check the clock, and correct or repair the clock if necessary.

(v) PADDED OUTPUT BLOCK AFTER SS.DDD.HHMMSS

If a time jump occurs such that at least one empty output block would be generated, or the jump is negative such as after a clock correction, the current block is padded with unknowns and output immediately followed by resynchronisation, see (vi).

(vi) RESYNCHRONISED OUTPUT BLOCK AT SS.DDD.HHMMSS

At the start of recording or after a large time jump, the output of data is resynchronised so that the current record is inserted in the correct slot in a regular two-minute output block. The leading part of the block is padded with unknowns.

APPENDIX 6: OPERATOR PROGRAMS IN ALPHABETICAL ORDER

AGMAG	-	User specifies year number for AGRF
ANOM	-	User specifies channel number for AGRF-corrected magnetic data
CHART	-	User specifies channels and recording parameters for strip chart
CLOSE	-	Allows user to stop recording on cassette on failure or end of work
CURNT	-	User defines print frequencies (two) of 'CURNT' data dump
DIRTY	-	Clears BCD error counts, no action on part of user
DRNAV	-	User provides estimate of ship's course and speed (degrees, knots)
ECHO	-	User identifies depth channel, zero if depths not being acquired
EJECT	-	Allows user to eject cassette on specified drive
FAIL	-	User identifies numbers input when equipment has failed or is off
FCURNT	-	User can force a dump of 'CURNT' data values
FILTR	-	User inputs parameters for median filtering
FSAIL	-	User can force a dump of 'SAIL' line data
FTABLE	-	User can force a dump of filter information
HALT	-	Allows user to bring system to an orderly stop before power turned off
INDAC	-	User scales DAC output to give full-scale deflection on strip chart
IZONE	-	User specifies central meridian used in conversion to grid coordinates
LCLCK	-	Identifies number of clocks, allows switching if more than one
LDAC	-	Defines 8-CH DACS available, individual DACS can be turned on and off
LINES	-	User can ask for next pair of way points to be used in line navigation
LPOS	-	User specifies start channel of navigation data
LTAPE	-	Defines cassette drives available, allows switching if more than one
MESS	-	Allows user to record a message on any terminal
OBMAG	-	User supplies output channel number for magnetic data
OPEN	-	Allows user to restart recording on cassette
POSN	-	User provides estimate of ship's position (Lat, Long only)
REFER	-	Allows user to define data input through MPX, MVT and other devices
RWIND	-	Allows user to rewind defined cassette drive
SAIL	-	User defines frequency of 'SAIL' line data dump
STAIR	-	User can test strip chart making 5 sweeps using 'ONE-INCH' steps
SURV	-	User provides survey (or year) number
TABLE	-	User defines print frequency of 'TABLE' filter values
TIMER	-	If more than one clock, provide clock difference on terminal
WAY	-	User can give up to 9 way points to be used in line navigation.

APPENDIX 7: OPERATOR PROGRAMS GROUPED BY FUNCTION

CONTROL OF NAVIGATION

LPOS - User specifies start channel of navigation data

DRNAV - User provides estimate of ship's course and speed (degrees, knots)

POSN - User provides estimate of ship's position (Lat, Long only)

IZONE - User specifies central medidian used in conversion to grid coordinates

LINES - User can ask for next pair of way points to be used in line navigation

WAY - User can give up to 9 way points to be used in line navigation

CONTROL OF TERMINALS

CURNT - User defines print frequencies (two) of 'CURNT' data dump

SAIL - User defines frequency of 'SAIL' line data dump

TABLE - User defines print frequency of 'TABLE' filter values

FCURNT - User can force a dump of 'CURNT' data values

FSAIL - User can force a dump of 'SAIL' line data

FTABLE - User can force a dump of filter information

STRIP CHART RECORDERS

LDAC - Defines 8-CH DACS available, individual DACS can be turned on and off

INDAC - User scales DAC output to give full-scale deflection on strip chart

CHART - User specifies channels and recording parameters for strip chart

STAIR - User can test strip chart making 5 sweeps using 'ONE-INCH' steps

BASIC DATA CONVERSION CONTROL

REFER - Allows user to define data input through MPX, MVT and other devices

FAIL - User identifies numbers input when equipment has failed or is off

DIRTY - Clears BCD error counts, no action on part of user

SURV - User provides survey (or year) number

CASSETTE TAPE ROUTINES

LTAPE - Defines cassette drives available, allows switching if more than one

OPEN - Allows user to restart recording on cassette

CLOSE - Allows user to stop recording on cassette on failure or end of work

RWIND - Allows user to rewind defined cassette drive

EJECT - Allows user to eject cassette on specified drive

CLOCK ROUTINES

LCLCK - Identifies number of clocks, allows switching if more than one

TIMER - If more than one clock, provide clock difference on terminal

.../2

APPENDIX 7: OPERATOR PROGRAMS GROUPED BY FUNCTION (continued)

MISCELLANEOUS ROUTINES

MESS - Allows user to record a message on any terminal

FILTR - User inputs parameters for median filtering

OBMAG - User supplies output channel number for magnetic data

ANOM - User specifies hannel number for AGRF-corrected magnetic data

AGMAG - User specifies year number for AGRF

ECHO - User identifies depth channel, zero if depths not being acquired

HALT - Allows user to bring system to an orderly stop before power turned off.

APPENDIX 8: ALLOCATION OF DATA CHANNELS

The data acquisition system is designed to give the user considerable flexibility, and also to allow its use in various configurations on different ships. The flexibility is obtained at the cost of greater effort on the part of the user than would be needed in a simple system. In particular the user must type-in the input channels, during which considerable care must be exercised; mis-typing can result in the data being wrongly identified, with consequent loss or corruption, or being saved on tape in a different format.

The following channel allocations should be used at all times -

1 - not identified	- Clock (Survey and Day Number)
2 - not identified	- Clock (GMT time of day)
3, 99, 1	- Tracor clock (GMT time of day)
4, 99, 1	- Latitude (Deg, Min, on input)
5, 99, 1	- Longitude (Deg, Min, on input)
6 - not identified	- Course (in degrees, computed)
7 - not identified	- Speed (in knots, computed)
8, 1, 2	- DIGITRAK water depth (metres)
9, 3, 4	- RAYTHEON water depth (metres)
10, 15, 16	- Magnetometer (nanotesla)
11 - not identified	- Magnetic anomaly (nT)

NB. Multiplexer slots used can be varied should faults develop, but they must always be associated with the above channel allocations.

APPENDIX 9: SWITCH REGISTER USAGE

Whenever the computer is running (i.e. the RUN light is on) the SWITCH or S-register is on. The navigation system uses it in the following fashion:

Bits 0 & 1	- ACTIVE :	causes operator program CHAOS to be entered once per processing cycle for system and bridge terminals respectively
Bit 2	- DISPLAY:	not used in this version of program
Bit 3	- DISPLAY:	turned on & off alternately each 10-second acquisition cycle, showing that data are being acquired
Bit 4	- DISPLAY:	turned on & off alternately each 1-second clock interrupt, showing that clock is functioning
Bit 5	- DISPLAY:	ON when processing is inactive
Bit 6	- DISPLAY:	ON during basic data conversion and computation
Bit 7	- DISPLAY:	ON during listings on teletypes
Bit 8	- DISPLAY:	ON when waiting to output data to cassette
Bit 9	- DISPLAY:	ON only when data being output to cassette
Bit 10	- ACTIVE :	allows emergency abort of tape write if program hangs up; shown by Bits 8 & 9 being ON for a prolonged period; tape is ejected and operator must cancel Bit 10 and then insert new cassette
Bit 11	- ACTIVE :	dumps specified channel of output buffer; the user must type-in the required channel on the TTY
Bit 12	- ACTIVE :	not relevant (dumps analog multiverter buffer)
Bit 13	- ACTIVE :	dumps digital multiplexer buffer
Bit 14	- ACTIVE :	dumps current input record in octal, 4-bit BCD, and ASCII to assist in error tracing
Bit 15	- ACTIVE :	dumps current converted processing record in BCD with error flags to assist in error tracing

APPENDIX 10: COMPUTER INPUT/OUTPUT CONFIGURATION

The first nine Input/Output slots (10B to 20B) of the computer are used by program DAN80 to communicate with the peripheral equipment. The program will therefore fit into either an HP 2108 or HP 2113 computer. The following interface cards must be placed in the specified slots at the back of the computer

I/O slot	Instrument	Interface card
10	Facit cassette recorder	Modified Ground true I/O - BMR modification required
11	GED (or NCE) clock	HP 32-bit data source - BMR standard clock face packing
12	KSR 43 (System terminal)	Bufferred teletype/High Speed Terminal - set to 300 baud (30 chars/sec)
13	KSR 43 (Bridge terminal)	Bufferred teletype/High Speed Terminal - set to 300 baud (30 chars/sec)
14	Not used	A spare I/F card must be in this slot
15	BMR multiplexer	Ground true I/O - input and output continuously enabled
16	TRACOR satellite navigator	Ground true I/O - input and output continuously enabled
17	Not used	A spare I/F card must be in this slot
20	W & W recorder	BMR 8-channel DAC - first six channels used

APPENDIX 11: INITIALISATION OF THE TRACOR SATELLITE NAVIGATOR

As part of the initialisation procedure requires headings from the gyro-compass on the bridge, two people are required; one to enter parameters into the TRACOR, the other to call headings from the bridge via the intercom system. Parameters are entered into the TRACOR by pressing the MODE key followed by the number of the required function.

(a) MODE 10 Latitude - enter approximate latitude in degrees and minutes, in format -DDMMT (ENTER)

(b) MODE 11 Longitude - enter approximate longitude in degrees and minutes, in format +DDDMMT (ENTER)

(c) MODE 12 Time (GMT) - enter time to within ± 10 minutes, in format HHMM (ENTER)

(d) MODE 13 Antenna Height - enter antenna height, equal to height of antenna above sea level (20 m) plus the GEOID height shown in Figure 4, in format ± HTU (ENTER)

(e) MODE 18 Log factor - enter 180, that is the number of clicks (contact closures) per nautical mile received from speed log, in format 180 (ENTER)

(f) MODE 31 Auto speed - to set in automatic speed mode

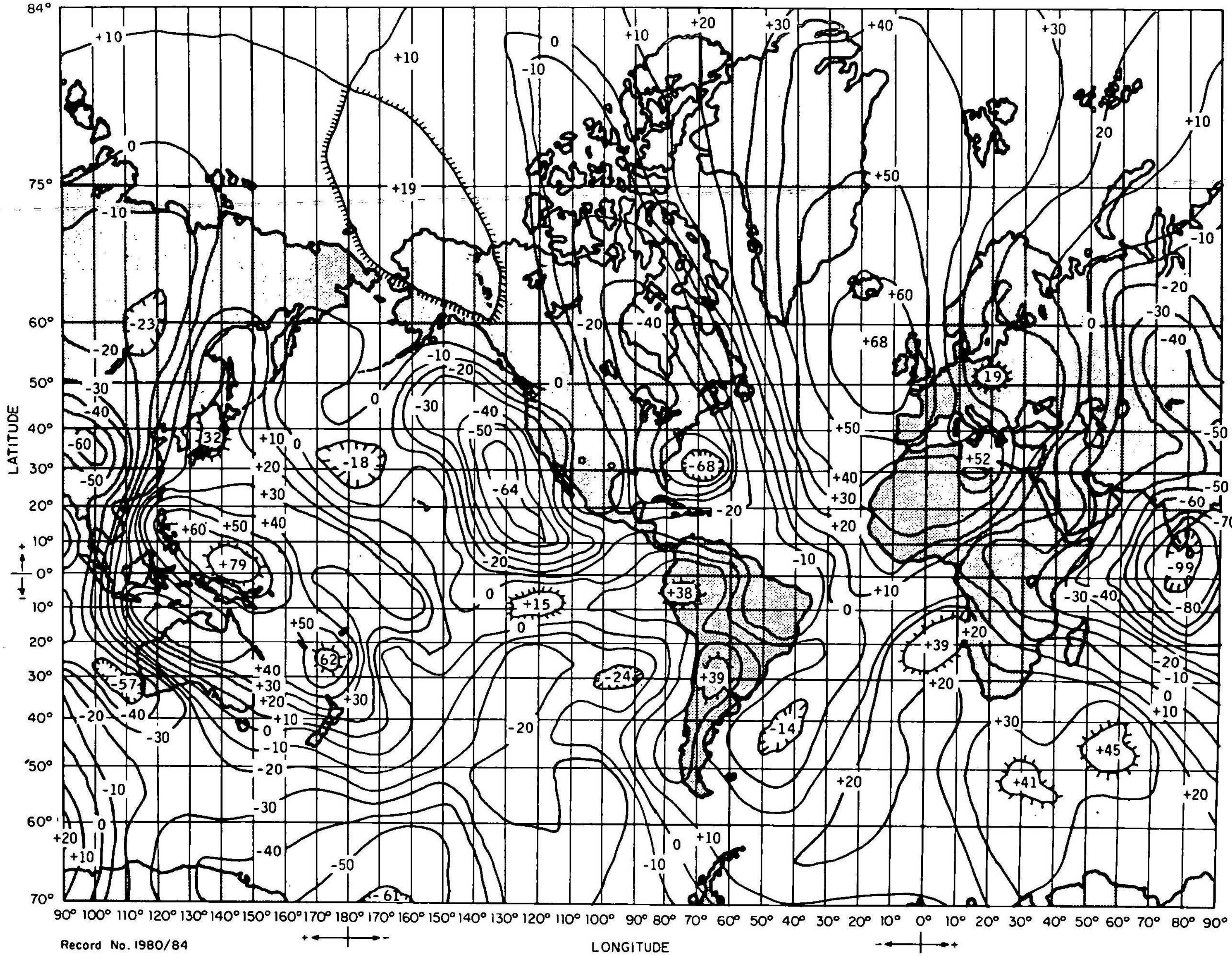
(g) MODE 15 Manual gyro - enter heading provided from bridge, in format HTU (ENTER)

(h) MODE 30 Auto gyro - set to automatic gyro mode when ship's heading is equal to manual heading entered in (g)

(i) MODE 25 Display course - verify that course on TRACOR is the same as actual ship's course, by comparison to headings called from bridge; repeat (g) and (h) as necessary.

The complete list of operator functions is:

MODE 10	Enter latitude
MODE 11	Enter longitude
MODE 12	Enter time (GMT)
MODE 13	Enter antenna height
MODE 14	Enter speed
MODE 15	Enter heading
MODE 16	Enter Waypoint latitude
MODE 17	Enter Waypoint longitude
MODE 18	Enter logfactor (clicks/n.mile)
MODE 19	NOT USED
MODE 20	Display last valid fix
MODE 21	Display last fix quality
MODE 22	Display great circle course and distance
MODE 23	Display waypoint
MODE 24	Display speed
MODE 25	Display heading
MODE 26	Display antenna height
MODE 27	Display next alert
MODE 28	Display rhumb line course and distance
MODE 29	Display log factor
MODE 30	Go auto gyro
MODE 31	Go auto log
MODE 32	Print position data
MODE 33	Test - self test.



Record No. 1980/84

Fig. 4. Geoidal Height Chart

APPENDIX 12: DAILY ROUTINE FOR DATA ACQUISITION SYSTEM

1. Cassette tape changing

The cassette tape should be changed at 12 to 24 hour intervals to avoid the possibility of parity errors developing and to avoid a single tape containing too much data. The following procedure must be used without fail:

(a) take a blank cassette, label with the next sequential tape number (SS/NNN) and approximate start time only (SSDDDHHbb)

(b) use CHAOS program EJECT to eject the cassette in the recorder

(c) immediately the cassette is ejected, remove it and turn the read/write tabs inwards so that it cannot be written on again; place it in its protective box

(d) clean the cassette recorder using Freon and a lint-free cloth (a linen handkerchief is best); make sure the recording head and pinch rollers are cleaned, particularly to prevent oxide build-up on the left-hand pinch roller

(e) insert the labelled new cassette and close the panel; wait until at least two blocks of data have been written onto the new cassette before departing

(f) write the actual start and stop times of the old cassette onto its label (SS.DDD.HHMMSS) and seal the cassette in its box

(g) log the actual start and stop times of the old cassette, and enter the new cassette sequential number and approximate start time.

2. On a continuing basis

(a) check that the data values printed on the teletype agree with the values displayed on the various instruments (magnetometer, Raytheon, etc.)

(b) ensure that the clock is interrupting properly (switch Bit 4 turns on and off alternately every second) and that acquisition is taking place (switch Bit 3 turns on and off alternately every ten seconds)

(c) check for any unusual messages on the teletypes including

(i) tape parity error

(ii) input BCD errors

(iii) time jumps/padding and resynchronising of blocks

(iv) write rejected

(d) ensure that data are being successfully written to tape by waiting while two or more blocks are output; check that switch Bit 8 comes on while the DAS waits to write and Bit 9 when data are actually being written.

APPENDIX 13: DAILY ROUTINE FOR MAGNETOMETER

1. At 000 GMT every day and at start of recording:

   (a) check that there is sufficient paper in the stand-alone strip-chart recorder for the next 24 hours of operation; if not, remove the roll and replace with a new roll of paper.

   (b) label chart with date, survey number, Julian day number and time and approximate location.

   (c) using the CAL-RUN-ZERO switch on the magnetometer; reset zero on the strip-chart recorder; use the CALIBRATE controls on the magnetometer for full-scale deflection; do not use the adjustment potentiometers on the strip-chart recorder; calibrate both 100 nT and 1000 nT channels; mark "recalibration" on record.

   (d) read magnetic value from digital display at start of recording and write it on record against the starting time.

   (e) check the clock setting against A.P.O. radio time signals, and record the difference from radio time on the record; do not adjust unless the difference exceeds 5 seconds; suspected abnormal clock behaviour should be checked promptly and monitored closely.

2. Every hour on the hour:

   (a) if no automatic time marks on recorder, zero both pens of the recorder momentarily using the ZERO of the CAL-RUN-ZERO switch on the magnetometer.

   (b) label the resulting hour mark with survey number, Julian day number, and hour in form SS.DDD.HHMM.

   (c) read magnetic value from digital display on magnetometer and write it on record against the hour mark.

   (d) check the noise level on the record; in good weather it should be 2 to 3 nT peak-to-peak, rising to 5 to 10 nT in heavy rolling seas; investigate further if it is excessive.

   (e) check the tuning of the magnetometer using the fine and coarse TUNING adjustment on the magnetometer observing signal amplitude on the METER provided and the CRO; mark record with new tuning value if it is changed.

3. <u>Every six to eight hours on the hour</u>:

   (a) check zero and full-scale calibration of the strip chart recorder using the CAL-RUN-ZERO switch on the magnetometer and mark "calibration" on record.

   (b) <u>only</u> if the error exceeds 2 mm should you recalibrate as in 1(c).

   (c) make sure a calibration check (<u>not</u> a recalibration) is made shortly <u>before</u> 0000 GMT (i.e. at the end of a day's record); similarly at the end of recording.

4. <u>Following any unusual event, e.g.</u>

   (a) after removing a roll of paper from the strip-chart recorder, label <u>both ends</u> of the record with the start and stop times of the roll in form SS.DDD.HHMM, and the strip-chart sequence number in form SS/NNN; log start and stop times.

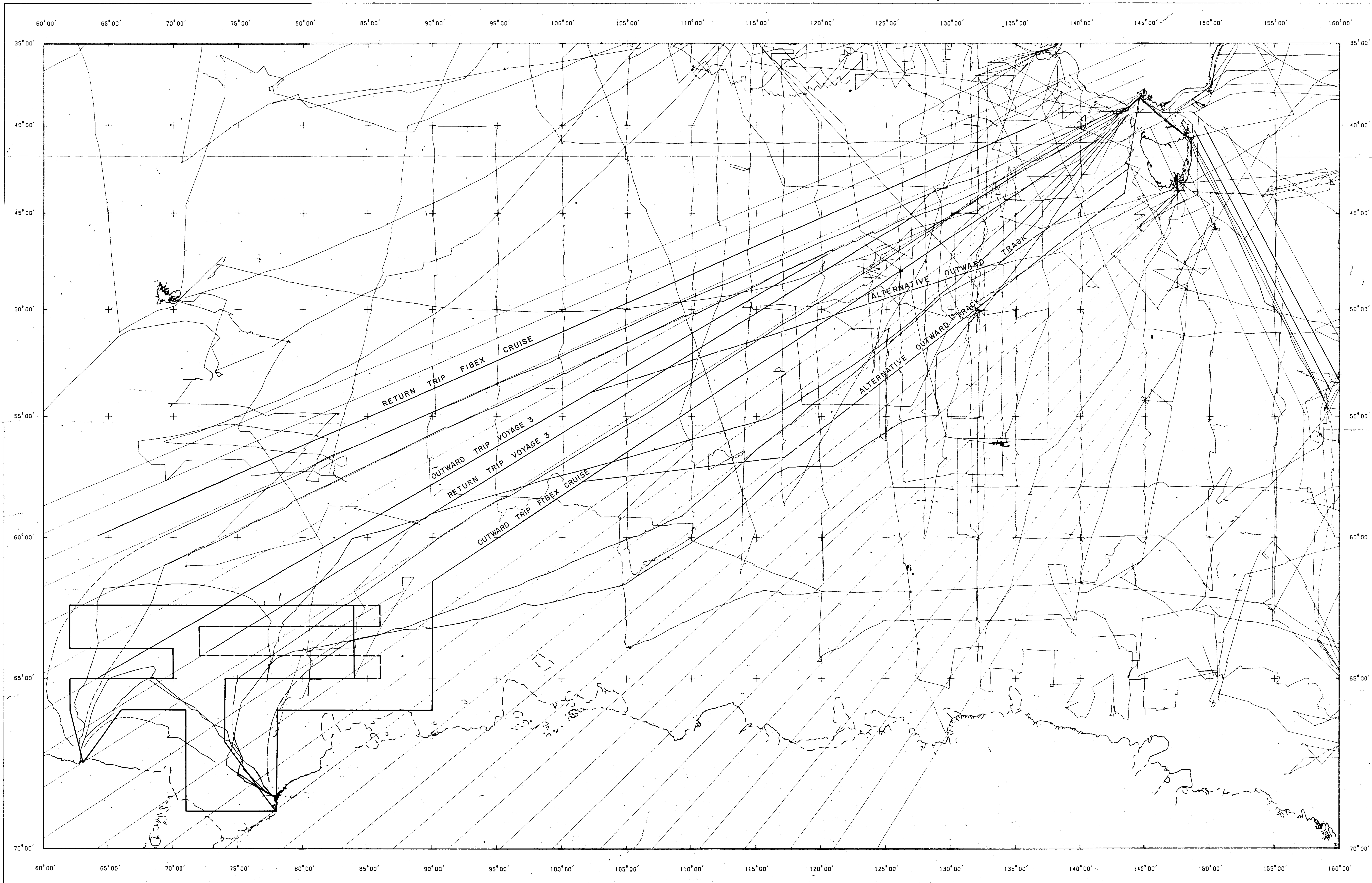
   (b) if a long break in work is anticipated, turn off recorder and mark the break clearly with the time and reason for break if known, then pull paper forward for next commencement of work as in 1(a) to (d); for short breaks between work, continue recording and note cause of break on record.

   (c) after any power failure check the setting of the clock against A.P.O. radio time signals and adjust as necessary; the magnitude and time of all clock adjustments should be marked on the record.

SOUTHEAST INDIAN OCEAN

SCALE 1:10000000

EDITION OF 1980.05/05



Record No 1980/84

23/02/5

EXISTING TRACKS
NELLA DAN 1979/80 TRACKS
PROPOSED TRACKS
PROPOSED FIBEX TRACKS

A.P.L. SPHEROID
STANDARD MERCATOR PROJECTION
WITH NATURAL SCALE CORRECT
AT LATITUDE 55°00'

Fig.5. NELLA DAN MARINE SURVEYS, 1979-1980
TRACK MAP

SOUTHEAST INDIAN OCEAN