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WEST OF SHETLAND DATA BUOY PROJECT - FIRST REPORT

August 1976 - December 1976

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Internal Document No 11

Institute of Oceanographic Sciences
Crossway
Taunton

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Report from the Institute of Oceanographic Sciences to the United Kingdom Offshore Operators Association on the conduct of the West of Shetland data buoy project up to and including buoy deployment on the 4 December 1976.

Issued by:

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INTRODUCTION

During March 1976 the UKOOA Oceanographic Committee decided to terminate the occupation by a weathership of the Fitzroy location and to look for alternative lower cost methods of data collection. The committee set up a West of Shetland Working Party to consider all aspects of the problem which after studying several alternative proposals recommended that UKOOA should adopt a scheme based on the Marex data buoy. In addition to the work proposed by Marex it was recommended that the project should incorporate recommendations put forward by the Institute of Oceanographic Sciences in a feasibility study submitted to the WP. In particular, these included the establishment of a receiving station on the Island of Foula so that waverider signals from the buoy could be monitored.

The WP recommended to the Oceanographic Committee that the project as a whole should be managed by IOS, who would subcontract the data buoy work to Marex. These recommendations were accepted by the UKOOA Oceanographic Committee and the project has gone ahead on this basis.

Scope and Organisation of the Report

This report covers the period from 3 August 1976 up to buoy deployment on 4 December 1976. It is divided into two parts: Part 1 deals with the Marex data buoy and Part 2 concerns the setting up of the receiving station on Foula. Part 2 reports on some activities which took place prior to August 1976.

Part 1 is preceded by a brief description of the project and a schedule of the main events which led up to the deployment of the buoy (Table 1).

There are a number of appendices, which are listed below:

- Appendix A – Diagram of Marex Data Buoy as deployed West of Foula
- Appendix B – Chart giving the position of the buoy
- Appendix C – Map of Island of Foula showing position of receiving station
- Appendix D – Instrumentation specification of Marex Data Buoy
- Appendix E – IOS comments and recommendations on the Marex Data Buoy instrumentation scheme.

Brief description of the Foula Data Buoy Project

The project is based on the use of the Marex data buoy which is moored at a site chosen to be in the same general area as the Fitzroy location and in a comparable depth of water, but close enough to land to enable the telemetry of wave data from the buoy.

The buoy makes hourly recordings of the following parameters:

Wave height	Wind direction
Wave period	Atmospheric pressure
Wind speed	Air temperature
	Sea temperature

The computations involved are carried out by an onboard microprocessor and the results are recorded using a cassette type digital magnetic tape recorder.

The microprocessor and the tape recorder are housed in one of four replaceable waterproof modules, the batteries are housed in two others, and the Datawell heave sensor in the fourth.

The changing of the magnetic tapes and batteries is accomplished by simply exchanging the self-contained modules. This is done at approximately monthly intervals by Marex staff using a chartered fishing boat.

As well as being processed and recorded on the buoy, the wave data is transmitted continuously using a standard waverider modulator and transmitter. A receiving station has been set up on the island of Foula which is switched on for 25 minutes once every 3 hours and during this time the signal is received and samples of the wave data are recorded using both analogue and digital tape recorders.

The receiving station is visited every few days by IOS's agent who is resident on the island to check that the buoy signal is still being received. Battery charging is necessary once per week and the tapes are changed once per month. If for any reason the buoy signal is not received, our agent telephones IOS to discuss the problem and IOS in turn informs Marex. At the end of each month the tapes are transported to the mainland of Shetland for onward transmission to IOS.

As a back-up to the data buoy measurement of waves, Marex deployed a waverider close to the buoy position. In the event of a failure of the data buoy transmission the waverider can be received and recorded on Foula by selecting the appropriate channel on the receiver. In normal circumstances the waverider signal is checked once every few days but is not sampled.

This document reports on the initial stages of a complex and technically advanced project carried out in winter in one of the remotest areas of the British Continental Shelf. It will be seen that the work suffered its share of difficulties and setbacks, but it should also be apparent that these were overcome and that a functioning system was deployed on a very short timescale.

TABLE 1 – Schedule of main events

1976	
3 August	UKOOA WP requested joint IOS/MAREX project
4 "	Marine Technology Support Unit (MATSU) asked Natural Environment Research Council (NERC) to prepare proposal
9 "	IOS representatives met MAREX at Cowes for preliminary discussions
12 "	NERC authorised £10K capital commitment prior to contract
13 "	MAREX proposal received by IOS
13 "	Draft IOS proposal sent to NERC
23 "	IOS proposal sent by NERC to UKOOA
6–7 September	Detailed technical discussions between IOS and MAREX
15–16 "	Preliminary radio propagation trials
17 "	MATSU confirmed authorisation to proceed with project according to proposal of 23 August
30 "	Negotiations with MAREX about continuity of operations clauses requested by UKOOA
7–8 October	Seoond series of radio trials
2 November	Contract between NERC and UKOOA completed. Backdated to 1 August 1976
31 October	Accident to microprocessor
12–15 November	First attempted deployment
27–28 "	Second attempted deployment
4 December	MAREX buoy deployed

PART 1 - MAREX DATA BUOY

Preliminary Technical Discussions:

Discussions were held with Marex on 6 and 7 September to clarify in detail the specification of the instruments, the processor and the recording system to be used on the buoy.

UKOOA's requirement for detailed wave data above a certain wave height threshold was considered, as also was the sampling rate of the wind direction sensor (another point specifically raised by UKOOA).

As a result of these discussions, IOS concluded that the data acquisition processing and recording system was adequate. Although there were some reservations on points of detail, there was clearly insufficient time to resolve these.

Marex stated that they intended to use the prototype processor initially, and that this would be replaced by a tidied-up 'production' version during the first few months of the project. IOS agreed to this arrangement.

The buoy hull was at an early stage of fabrication.

IOS made two recommendations:

1. That the sensors and electronics should be thoroughly tested and calibrated in the laboratory, and
2. that the buoy should be given a trial deployment at Cowes with all systems operating, and that the resulting data should be carefully scrutinised before the buoy was deployed in its operational position.

Radio Propagation trials:

On 15 and 16 September a preliminary series of radio propagation trials were mounted with Marex's help at Cowes. The object was to confirm that an elevated aerial such as would have to be used on the Marex buoy would be capable of transmitting a 'ground', or rather 'sea', wave with an efficiency comparable with that of a normal waverider.

The results were inconclusive and it was decided to mount another series of trials with the transmitter mounted on the buoy hull when this was available.

The second series of trials took place at Cowes on 7 and 8 October. It quickly became apparent that the data buoy transmitter was not functioning properly and this was shown to be due to a fault in the transmitter package. Eventually sufficient output was obtained for an abbreviated series of trials to be completed. The results supported the view that propagation over the range proposed (50 km) would be adequate so long as the transmitter was correctly sited on the buoy and its power output was up to specification.

Recommendations were made to Marex on 11 October on the installation of the radio telemetry system on the buoy, although it was pointed out that Datawell's advice should also be sought. IOS was concerned about the arrangement of the power supplies on the buoy which resulted in a much shorter life between battery changes for the wave measuring and telemetry system than is available in the standard waverider. It was recommended to Marex that at least three months' life should be available and IOS asked them to confirm that adequate capacity would be provided.

Marex subsequently re-engineered the transmitter installation (using a transmitter loaned by IOS) and on 26 October the output was checked by IOS and found to be satisfactory. One of the recommendations made by IOS was that the buoy mast should be shortened to just above the shroud attachments and this had been done. With this modification the wind speed sensor is carried at a mean height of 6.7 m above the water. A drawing of the buoy as deployed is shown in Appendix A.

Microprocessor:
At the start of the project only the prototype microprocessor was in existence, and the intention was to produce a tidied up 'production' version as soon as possible. The first task was therefore to design the circuit boards etc for the production version and to order the necessary components to build two processors. This work occupied Marex from mid-August to mid-September. From about the middle of September work was in progress on programming and debugging the prototype processor in readiness for installation on the data buoy. Marex had obtained a cross-assembler and had installed a terminal to their computer in their electronics laboratory in order to ease the programming task. However, many hardware 'bugs' had to be eliminated and in spite of every effort difficulties with the processor persisted up to the end of October. On 31 October an accident occurred to the processor which resulted in the destruction of many key components. Marex informed IOS as

quickly as possible, and it was agreed that the buoy should be deployed without the processor if this would expedite the commencement of wave measurements in the area.

Marex worked quickly to rebuild the processor which was reported calibrated, checked and ready for deployment on 10 November. However, during pre-deployment checks at Aberdeen it was found that the tape recorder was not operating satisfactorily and the unit was returned to Cowes for further work.

The fault in the tape transport control was eventually rectified and the processor was installed on the buoy for the deployment on 4 December.

<u>Calibration and testing of Meteorological/Oceanographic System</u>

On 30 September a calibration of the heave sensor to be used on the buoy was carried out at NMI*, Hythe. IOS attended and took the receiver which was to be installed on Foula, and thus the heave sensor and receiver were calibrated as a system. Certain other laboratory tests were necessary in order that Marex could apply the calibration to their results, and IOS made recommendations on these to Marex.

Subsequent to the calibration Marex found that the output sensitivity of the heave sensor had to be reduced (this was considered advisable in order to reduce the possibility of signals exceeding the full-scale of the measurement system). They obtained Datawell's advice on this, and in addition took steps to restore the scaling of the transmitted signal to its original level.

The system was not recalibrated, and since IOS was not informed of this action until after the deployment, no recommendation could be given.

Laboratory testing and calibration of the sensors other than the heave sensor and of the electronics took place at Cowes on 30 October and further tests were undertaken between 7 and 10 November after the processor was rebuilt.

Since these tests were undertaken at short notice and under pressure it was not possible for an IOS representative to attend.

Because of the pressure to deploy the buoy, no complete system testing with the buoy deployed was possible.

* National Maritime Institute

Deployment of the buoy:

An IOS scientist was present on all attempted deployments and throughout this period IOS maintained daily contact with the Meteorological Office medium range forecaster and liaised closely with Marex in an attempt to ensure that weather breaks were not missed.

The first attempt to deploy the buoy was made over the period 12 to 15 November. Marex chartered the 150 ft ex-trawler Arlanda owned by J Marr & Co. of Aberdeen, for the purpose.

The buoy was to be put on board at Aberdeen, and the ship was to steam to the deployment area on her way north to her standby duties on the Northern Oil Fields.

The processor was tested at Aberdeen and found to be faulty so Marex decided to return it to Cowes for repair. The output of the transmitter was checked and found to be satisfactory, and it was decided to deploy the buoy without the processor.

The vessel left Aberdeen at 1300 on 13 November, but unfortunately while on her way north a fire broke out in the converter which supplied the Decca navigator, and the ship had to put in for repairs at Lerwick. By the time these were effected and the ship put to sea again, the weather had deteriorated to the point where deployment was impossible. The buoy was offloaded at Lerwick and stored in a warehouse on the quay, and the vessel continued on her way north.

The second attempt to deploy took place over the weekend 27/28 November. In the period since the first deployment Marex had arranged for the buoy to be transported to Scalloway (on the Western side of the mainland of Shetland) in order to reduce the sailing distance to the deployment area.

Some further work had been done on the microprocessor by Marex and it was proposed to install this on the buoy for deployment.

The charter vessel, the Zonia, a sister ship of Arlanda, arrived at 1600 on Saturday, the 27th. Unfortunately the expected break in the weather did not materialize and the weather forecast was not encouraging. In view of the fact that the charter ended on midnight of Sunday it was decided to abandon the deployment attempt.

The third and successful deployment attempt took place over the period 3/4 December. Marex chartered the ex-trawler Scottish Queen, length 120', from North Star Fishing of Aberdeen for the purpose. The trawler arrived at

Scalloway at 1315 on Friday, 3 December. The buoy was loaded, complete with processor and all instruments and the outputs of the waverider and the data buoy transmitters were checked. The ship arrived in the deployment area at around midnight and deployed in the deepest water which could be found. This was 85 fm, rather than the 100 fm marked on the chart so that the mooring (which had been made up to 100 fm) had to be shortened.

The deployment of the data buoy went smoothly and the waverider was moored half a mile to the south shortly afterwards.

Short test wave records were taken on the ship using a standard waverider receiver and these were considered to be satisfactory.

The ship arrived back in Scalloway at 0820 on 4 December.

Details of the deployments were as follows:

Data buoy:	Time	0107 GMT 4 December 1976
	Position	60° 08' N, 2° 59' W
	Depth	85 fm
Waverider:	Time	0125 GMT 4 December 1976
	Position	60° 07' 30" N, 2° 59' W
	Depth	80 fm

The position is shown on the chart included at Appendix B.

PART 2 - THE RECEIVING SITE ON FOULA

Preliminary Visits:

Preliminary inspections of several sites on the mainland of Shetland and on Foula were made during the period 12-16 July 1976. On the basis of these it was decided that South Ness, Foula, was the most suitable location for a radio receiving site.

On 7 September 1976 a visit was made to Foula to make contacts with the local people, and in particular our agent on the Island. A survey of the proposed site was made and the positions of the aerial array and the hut were marked out.

The location of the site on the Island of Foula is shown in Appendix C.

Site Construction Visit:

In the weeks following this visit our agent carried out some of the site works and on 26 September a visit was made to the island to construct the huts which were to house the equipment. The party ran into a great many difficulties which included the total loss of the original huts. However, the job was completed by 21 October, by which time a new hut had been designed and built from scratch.

Design, building and testing of equipment:

During September, the design and building of the electronic equipment was undertaken. The equipment comprised a receiver, a digital magnetic tape data logger, a frequency modulated analogue magnetic tape logger, associated power supplies and switching circuitry. In the time available it was only possible to spend one week in laboratory system testing.

The equipment left Taunton on 5 October to be shipped by air freight to Shetland. After much delay due in part to a strike at the freight terminal, it arrived in Shetland some three weeks later. It was collected by our Shetland agent and stored pending delivery to Foula.

The aerial system was ordered at the end of August and delivery to Sumburgh was promised for mid-September. Unfortunately it was shipped by sea and did not arrive on Shetland until mid-October. It was delivered to Foula where it was received by the site construction party on 19 October.

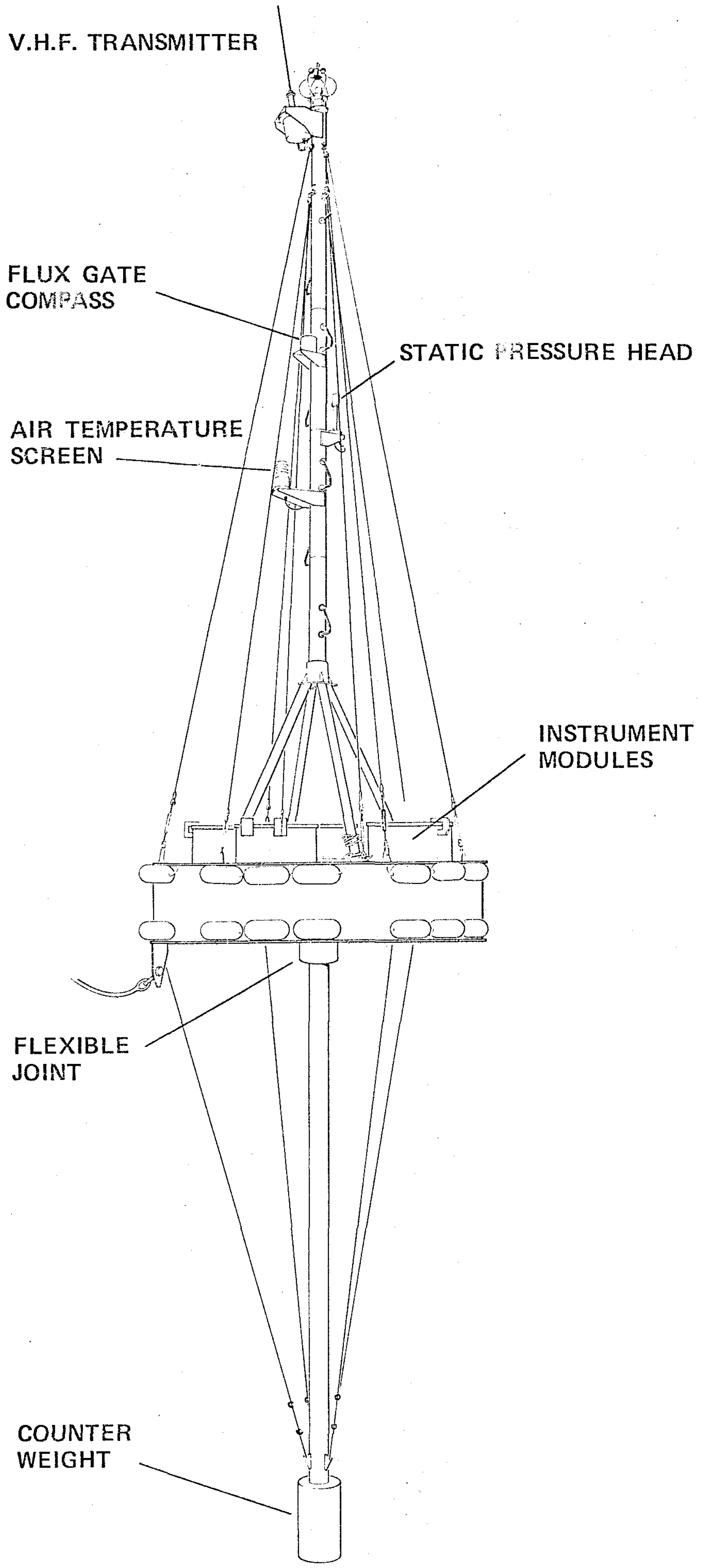
Commissioning of the Installation:

On the occasion of IOS's visit to Cowes on 26 October (see Part 1), Marex considered that deployment on the weekend of 6/7 November was a practical possibility. It was therefore arranged for a party to visit Foula and install all the equipment including the aerials.

The buoy was not in fact deployed during the period of this visit because of the accident to the processor (see above). The installation party consisted of one IOS engineer, and one engineer from the manufacturers of the aerial system. The work was completed on 9 November, the installation being left in an operating condition. Shortly afterwards, however, a fault developed in the power supplies and the equipment had to be switched off. The trouble was caused by a faulty storage battery, and the decision was taken not to reinstate the system until the buoy was deployed, it being clear that a visit would be necessary on that occasion to check that reception was adequate.

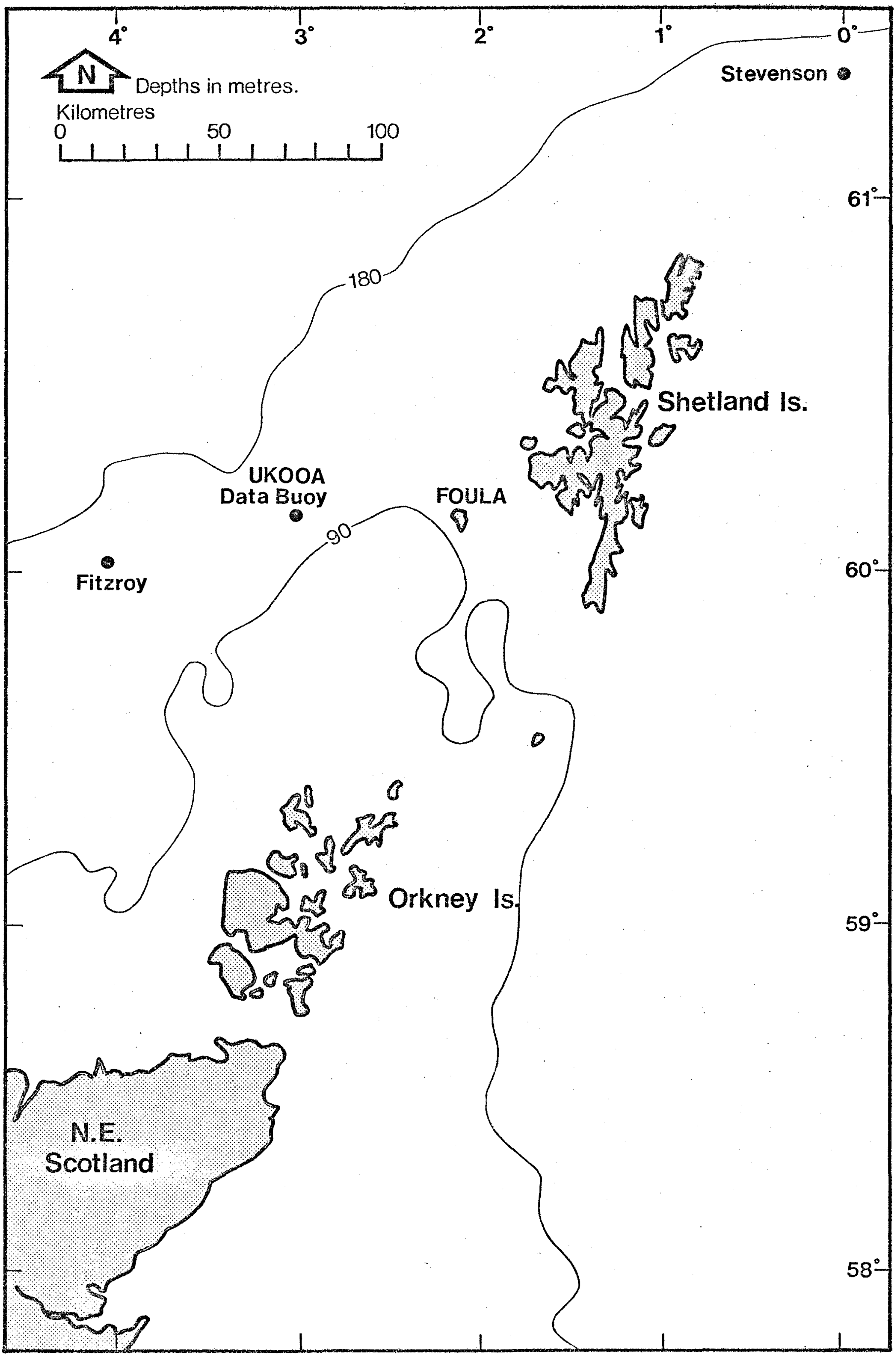
The buoy was eventually deployed on 4 December, but due to bad weather it was 6 December before an IOS party could land on Foula and reinstate the receiving/recording system. It was soon apparent that good signals were being received from both the waverider and the data buoy, and a magnetic tape was brought back for analysis. It was noticed however that there was voice channel interference during the daytime and steps are being taken to trace the source of this.

APPENDIX 'A'



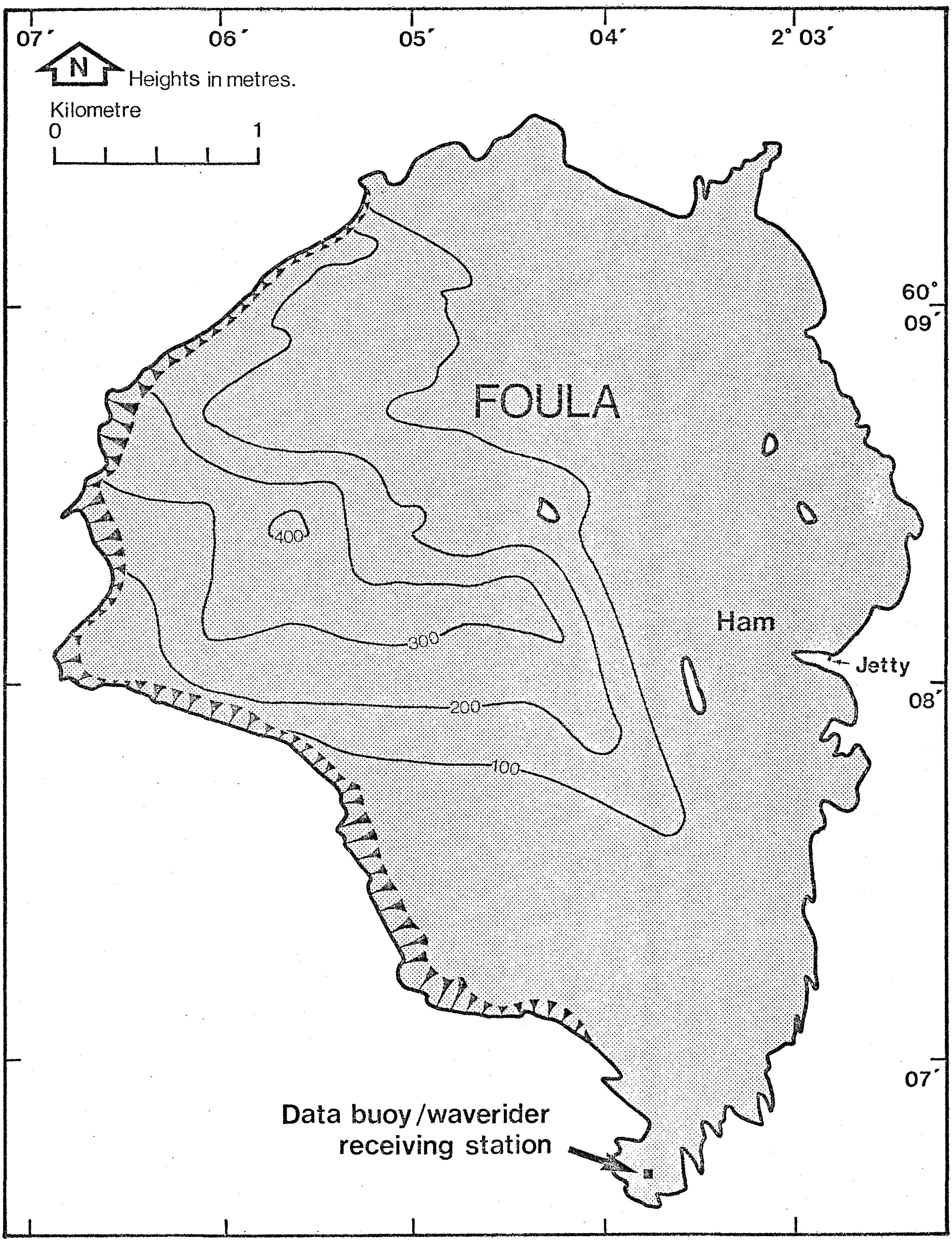
MAREX DATA BUOY

as deployed West of Foula Island — December 4th 1976



4°
3°
2°
1°
0°
N
Depths in metres.
Kilometres
0
50
100
Stevenson
61°
180
Shetland Is.
UKOOA
Data Buoy
FOULA
90
Fitzroy
60°
Orkney Is.
59°
N.E.
Scotland
58°

APPENDIX 'C'



07´
06´
05´
04´
2° 03´
N
Heights in metres.
Kilometre
0
1
60°
09´
FOULA
400
300
200
100
Ham
Jetty
08´
07´
Data buoy/waverider
receiving station

APPENDIX D

Instrumentation Specification of the Marex Data Buoy

Introduction

This appendix concerns itself with the sensors installed, their calibration and accuracy and the readout and sampling schemes used.

The system is based on the use of an Intersil IM 6100 microprocessor. This has many advantages over more conventional data logging systems which may be summarised as follows:

1. Flexibility of sampling scheme
2. Simple solutions to more complex readout problems - for example the wind direction sensors and compass
3. Computational ability

The processor installed on the Marex buoy is comparatively simple and it is clear that there is scope for much further development. Marex are to be congratulated on adopting a new technology for this application.

D1 Wind Speed

Sensor:
This is a Brookes and Gatehouse cup anemometer which has beem modified for use on the buoy. The anemometer is carried at a height of 6.7m above the waterline.
Accuracy and calibration:
The modified anemometer has been calibrated up to a speed of 60 knots at the British Hovercraft Corporation wind tunnel at Cowes.
Readout and sampling:
The anemometer provides an electrical output of one pulse per revolution. The number of pulses which occur in the ten minute period which ends on the nominal time of observation is counted.

D2 Wind Direction

Sensor:
This is a Brookes and Gatehouse instrument consisting of a vane which is coupled to a dc-synchro type readout.
Accuracy and Calibration:
The makers claim an accuracy of $\pm$ 1 degree. The operation of the instrument was checked by Marex in the laboratory before deployment.

Readout and Sampling:

The measurement of three voltages and some calculations are required to derive the vane orientation with respect to the buoy. The outputs from the instrument are sampled once every two seconds during the ten minutes preceding the hour. The wind direction is calculated using the following relations:-

$$\theta_w = \theta_c + \theta_v \qquad (1)$$

Where θ_w is the wind direction relative to true North

θ_c is the heading of the buoy relative to true North

θ_v is the orientation of the vane relative to the buoy

The mean direction of the wind over the 10 minute interval, $\bar{\theta}_w$, is calculated as:

$$\bar{\theta}_w = \text{ATAN2}\left\{ \frac{\sum \sin \theta_{wi}}{\sum \cos \theta_{wi}} \right\} \qquad (2)$$

Where the sums are over all the observations in the 10 minute interval.

ATAN2 is a four quadrant inverse tangent algorithm.

D3 Buoy Heading

Sensor:

A Brookes and Gatehouse flux gate compass is fitted.

Accuracy and calibration:

The makers claim an accuracy of $\pm$ 3 degrees. Marex performed a functional check before fitting the instrument.

Readout and sampling:

The instrument provides electrical outputs proportional to two orthogonal (nominally horizontal) components of the earth's magnetic field. These are sampled using the same scheme as for the wind vane.

D4 Wave Height and Period

Sensor:

A Datawell Heave sensor is fitted in the central module. This consists of an accelerometer and electronic double integrator, the output of which is a voltage analogue of the heave of the buoy. The scaling of the instrument has been modified so that the full scale corresponds to $\pm$ 20m.

The heave signal is available for input to the onboard measurement and processing system. However, in order to telemeter the information, the signal is converted to frequency modulated form using a standard waverider modulator.

The fm signal is amplitude modulated onto a continuously transmitted VHF radio wave of frequency 27.015 MHz.

Accuracy and calibration:

The makers claim that the scaling of the output signal is within 3% of the nominal scaling. Since the resolution and repeatability of the sensor are considerably better than 3%, the sensor was calibrated at NMI Hythe. The calibration at Hythe is done using the radio telemetering system, and so it is essential that the receiver and the modulator are also independently calibrated. All three calibrations can in principle be carried out to better than 0.5%.

Readout and sampling:

(a) Telemetered Data - As was stated above, the heave information is transmitted continuously. The receiving/recording system on Foula switches on at three hourly intervals. The sequence is as follows. At 22 minutes to the hour the receiver and aerial array are switched on. At 17 minutes to the hour the data recording commences and continues up to the hour. 2088 digital readings at half second intervals are recorded. In addition, starting at 17 minutes to the hour, a 10 minute frequency modulated tape recording is taken.

(b) Internally recorded data - Samples are taken at hourly intervals, the sequence being as follows. At 25 minutes to the hour the processor and sensor systems are switched on. At 24 minutes to the hour sampling commences and the next 7 minutes are used to estimate the mean of the record. During the period from 17 minutes to the hour until 4 seconds after (ie 1024 seconds) the heave signal is sampled at half second intervals and the following quantities are calculated:

RMS:	The standard deviation of the heave signal
H1:	The highest crest plus the lowest trough (both taken as positive) in the record.
Hmax:	The crest to trough height of the highest zero-upcross wave in the record.
Tz:	The mean zero-crossing period of the record. The definition of a zero crossing adopted requires elaboration. A zero crossing is considered to have occurred when the polarity of the heave measurement (after subtraction of the mean of the record) changes, the old polarity having persisted for a total of at least three samples.

Tz is then computed as 1024/Nz seconds; when Nz is the number of zero-upcrossings.

Mean of the record:

The mean of the record is estimated by the mean of the sample values which comprise the last four waves, or the last 240 values, whichever is the smaller number of values. The mean is thus re-estimated many times during each record. As well as being used in the subsequent calculations, the maximum and minmum values of the estimate which occur in the record are recorded for subsequent use in quality control.

Unprocessed wave data:

Once per day at 1200 GMT, a 2048-value raw data series is recorded on a separate tape recorder. This data is used for quality control of the data. In addition, there is a facility for recording a 2048-value unprocessed wave data series once per hour if the waves measured at the routine observation exceed a given threshold. The threshold has been set at RMS = 1.75m.

D5 Barometric Pressure

Sensor:

A KDG aneroid electronic barometer type 8100, range 950 to 1050 mb is used. The instrument package is fitted into the processor module and is connected to a static pressure head which is mounted on the mast.

Accuracy and calibration:

The makers claim an accuracy of 0.5 mb. Marex performed a check calibration using a water manometer.

Readout and sampling:

The sensor package provides an electrical output which is an analogue of atmospheric pressure in the range quoted. Readings are taken at two second intervals throughout the ten minutes preceding the hour and the average is taken.

D6 Air and Sea Temperatures

Sensors:

Platinum resistance thermometers type E13418 manufactured by Rosemount Engineering are fitted. The air temperature thermometer is carried in a screen on the mast, the sea temperature thermometer is fitted into the bottom of the processor module.

Accuracy and calibration:

The makers claim an accuracy of 0.2°C. Marex carried out laboratory spot checks at several temperatures.

Readout and sampling:

An electrical output is obtained using the manufacturer's 'transmitter'. A single measurement of air temperature and a single measurement of sea temperature are taken at each hour.

D7 Data recording

The data are recorded on Memodyne cassette recorders; one each for the processed Met/Ocean data and the unprocessed wave data.

Each hourly record of processed data starts with the day number and time. To improve the reliability of data recovery, each record is written to the magnetic tape four times consecutively.

APPENDIX E

IOS comments and recommendations on the Marex Data Buoy instrumentation scheme

E1 Wind Speed

The anemometer should be recalibrated at the end of the contract.

E2 Wind Direction

1. The calibration of the instrument should be checked before deployment and at the end of the contract.
2. It is recommended that the sampling rate of the wind vane should be high enough to adequately sample any wind components induced by the buoy's motion.
3. The method of obtaining the mean direction, although not giving a true vector mean, is accepted.

E3 Buoy heading

1. The calibration of the compass should be checked before deployment.
2. The buoy should be 'swung' with the compass fitted and if necessary the readings obtained should be used to apply a correction for compass deviation.
3. The same comments about sampling rate as made in E2 apply.

E4 Wave height and period

1. Independent calibrations of the heave sensor, modulator and receiver should be carried out before deployment and at the end of the contract. Since the calibration information from the heave sensor is obtained used the modulator and receiver, the calibration of these components must be determined by separate laboratory tests. If this is not done it will not be possible to apply the calibration information to the internally recorded information.
2. The method of re-estimating the mean after every fourth wave seems undesirable. While the computation and logging of this quantity gives a useful quality control check, we do not recommend applying it to the data.

We recommend that the mean and standard deviation are computed in a straightforward way.

3. We have reservations about the algorithm adopted for defining zero crossings and recommend that this is reviewed jointly by IOS and Marex before the production processor is programmed.
4. The criteria that an unprocessed wave data series should be recorded should be that the standard deviation of the hourly record is 1.75m or more.

The raw data sampling scheme should be reviewed in the light of further information on the reliability or otherwise of the telemetry link.

E5 Barometric Pressure

The instrument should be calibrated before installation and at the end of the contract.

E6 Air and Sea temperatures

The instruments should be calibrated before installation and at the end of the contract.

The air thermometer and its housing should be thoroughly cleaned at each module exchange visit.

The present sampling scheme is unsatisfactory. It is recommended that a number of readings are taken over a period and averaged.

E7 Data Recording

No comments at this stage.

E8 Calibration - General

It is recommended that calibration results, and in particular any changes in calibration, are presented and discussed in the final data report.