INSTITUTE OF OCEANOGRAPHIC SCIENCES

DEACON LABORATORY

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RRS *CHARLES DARWIN* CRUISE 90
17-27 SEP 1994

BRIDGET trials

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ABSTRACT

The principle objective of the cruise was to provide the first sea-trials of a new BRIDGE instrument designed for the detection, investigation and sampling of hydrothermal plumes: BRIDGET. The instrument has been developed as a joint project between the University of Cambridge and IOSDL with the following modules: i) basic frame design and construction (IOSDL); ii) acquisition of the standard sensors fitted to the instrument (IOSDL); iii) design and construction of the "brain" of the instrument, transmitting data signals from BRIDGET to the surface and returning power and command signals from the surface ship (Cambridge); iv) design and production of software to log and display the incoming data (Cambridge). The cruise proved very successful. An initial deployment of the basic frame and pressure tubes to ~3,100m water depth was followed by a further 5 BRIDGET deployments at the "Rainbow" vent-field, 36°15'N, Mid-Atlantic Ridge. Deployments were made in increasingly poor weather conditions, from Force 4/5/6 to Force 7/8, thereby ensuring a thorough sea-trial of both frame *and* instruments.

Initial deployments confirmed the basic viability of the system. During required BRIDGET servicing time, available shiptime was maximised by carrying out inter-calibrations with sensors available from the RVS CTD system and the OSU ZAPS Sled. The latter were also used to better define target areas for later BRIDGET deployments. BRIDGET's key advantage over earlier systems - that it could be towed in any required direction through a hydrothermal plume - was also demonstrated. Three 10km-long tow-yos through the Rainbow plume, hauling and veering at 20m/min., indicated a strong plume at ~2075m, being dispersed West to East away from its source and which could be detected more than 5 nautical miles "downstream". A final N-S line, cross-cutting the W-E lines close to the inferred source, indicated the strongest nephelometer and transmissometer signals ever seen for a N.Atlantic hydrothermal plume.

KEYWORDS

BRIDGE
BRIDGET
"CHARLES DARWIN"/RRS - cruise(1994)(90)
HYDROTHERMAL ACTIVITY
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RAINBOW
TECHNOLOGY
ZAPS SLED

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Departed:	Ponta Delgada, Azores	17 September 1994
Arrived:	Ponta Delgada, Azores	27 September 1994

OBJECTIVES

The objective of this cruise was to provide the first sea-trials of a new BRIDGE instrument, designed as a joint project between IOSDL and the Univeristy of Cambridge - BRIDGET: a deep-tow instrument for the detection, investigation and sampling of hydrothermal plumes.

NARRATIVE

With the exception of those scientists already aboard ship during Cruise 89, the scientific party for RRS *Charles Darwin* Cruise 90 assembled in Ponta Delgada, Azores on Mon. 12th September, ready to board scientific equipment and prepare laboratory space immediately upon arrival of the ship in port on Tues. 13th Sept. The RRS *Charles Darwin* sailed from Ponta Delgada at 0800z on Sat. 17th Sept. 1994. Upon clearing port the Simrad EM12 swath bathymetry system was activated and passage was made direct towards the newly-discovered Rainbow hydrothermal field at 36°15'N, Mid-Atlantic Ridge. XBT's were deployed synoptically throughout the cruise at 0000z and 1200z. The vessel hove to at 0700z on Sun. 18th Sept., midway through passage to the Rainbow area, to complete a shakedown deployment of the BRIDGET frame and pressure cases. The assembly was lowered to 3300m at 36°27'N 29°38'W and recovered without incident at 1200z. Immediately following this, a CTD station was occupied at the same station, to a depth of 500m, and all 12 bottles fired to collect seawater for bottle cleaning purposes. Passage to the Rainbow area was resumed at 1309z.

The vessel arrived on station in the Rainbow area at 36°18'N, 33°43'W at 0919z on Monday 19th September. BRIDGET was ready to go and deployed at 1037z but suffered an electronic malfunction at 1137z and was recovered in-board at 1255z. Following this, the ship set course for 36°17'N, 33°54'W where it hove to, to occupy a vertical ZAPS station. The ZAPS sled was deployed at 1444z and lowered to a depth of 2389m before recovery at 1726z. BRIDGET was redeployed at the same location as the ZAPS sled lowering at 1755z, following a course headed approximately ESE at 1 knot over-the-ground. BRIDGET was lowered to a total depth of 2800m, suffering a succession of electronic malfunctions and eventually recovered at 0118z on Tues. 20th September. Following this station a series of one ZAPS station and two CTD stations were occupied in an area of extremely strong nephelometer/transmissometer signals. The ZAPS sled was deployed at 0214z on Tues 20th September and lowered to 2482m at 36°17'N, 33°53'W before recovery invboard at 0745z. The RVS CTD was then deployed at 0902z and lowered to 2443m at 36°16'N, 33°53'W before recovery at 1255z. The CTD was then redeployed at 1353z and lowered to 2374m at 36°16'N 33°53'W again, before recovery at 1721z. Following this series of profiles it was considered that the source of active venting was sufficiently well-constrained that a net of Oceano Transponder Navigation beacons should be deployed around this area. The Simrad EM12s swath bathymetry was switched off at 1754z on Tues 20th September and deployment of the 6-transponder net commenced at 1833z. Deployment of the net was completed by 0054z on Weds. 21st September and calibration of the net then continued from 0111z to 0640. The ship then made passage to the west of the net for initiation of our 4th BRIDGET deployment which commenced at 36°16'N, 33°58'W at 1039z on Weds. 21st September. BRIDGET was towed West-East at 1-1.5 knots over-the-ground, reaching 36°16'N, 33°47'W at 1837z. Course was then altered to port at 1 degree per minute and BRIDGET was brought back onto a fresh course of 246 at 36°18'N, 33°48'W at 2100z. Tow-yoing through the hydrothermal plume was then continued, back towards the inferred hydrothermal source with BRIDGET crossing the end-of-survey way-point at 36°15'N 33°56'W at 0403z on Thurs. 22nd Sept. Hauling was commenced immediately, and BRIDGET was recovered in-board at 0552z.

A further series of one ZAPS station and two CTD stations were then occupied in the same near-vent area. The ZAPS sled was deployed at 0724z on Thurs. 22nd Sept. and lowered to a depth of ~2400m close to 36°16'N, 33°53'W before recovery inboard at 1523z. A load-test on the TOBI swivel was completed at 1608z and then two further CTD stations were occupied , again at close to 36°16'N, 33°53'W. The first station commenced at 1648z and was lowered to 2345m before recovery at 1839z. The second station was occupied at 1848z, the CTD lowered to 2393m and recovered in-board at 2047z. All of these three ZAPS and CTD stations failed to identify the significant hydrothermal plume profiles observed during the previous stations, occupied just 48 hours earlier, at essentially the same location.

Following these negative results, BRIDGET was again deployed to the west of the transponder navigated grid, at 36°17'N, 33°58'W at 2228z on Thurs. 22nd September. The instrument was again tow-yoed, west-east, some 200-500m above seabed, across the Rainbow hydrothermal vent-field area. The vessel passed across our first BRIDGET way-point (36°16'N, 33°47'W) at 0520z and course was altered to port at 1 degree per minute at 0650z. The ship was steady on course at 246 by 0920z, passing through the start way point for line 2 (36°18'N, 33°47'W) at 1052z. BRIDGET tow-yoes continued along this second line until the vessel reached 36°16'N, 33°52'W at 1344z and hauling was then commenced from

2883m. BRIDGET was recovered in-board at 1626z on Friday 23rd September. Following this, recovery of the transponder net was started. The first transponder (c) was released acoustically at 1754z and recovered inboard at 1834z. Because of failing light, transponder recovery was then suspended and a pair of further ZAPS stations were occupied within the Rainbow plume once more. ZAPS was deployed at 1921z and lowered to 2169m at 36°16'N, 33°53'W before recovery inboard at 2156z. ZAPS was then re-deployed at 2235z on Friday 23rd September and lowered to 2316m at 36°16'N, 33°52'W before recovery inboard at 0623z on Sat. 24th September. Transponder b was then released from the seabed at 0659z and recovery of the other transponders continued until 1317z when the final rig was recovered in-board.

At 1330z on Sat. 24th September the Simrad EM12 swath bathymetry system was re-activated and BRIDGET was re-deployed for a 6th time at 36°18'N, 33°52'W at 1454z. BRIDGET was then towed south following the 2400m contour along the western flank of the Rainbow Ridge at an over-the-ground speed of 1-1.5 knots. BRIDGET was succesfully tow-yoed through some of the largest hydrothermal plume signals ever recorded in the N.Atlantic Ocean and then passed into clear background water as it approached the end of it's initial survey line (36°07'N, 33°52'W) through which the ship passed at 0555z on Sun. 25th Sept. The vessel commenced altering course to starboard at 0627z and was steady on the new course of 270, cutting across the top of the S.AMAR segment, by 0720z. At 0952z, the ship commenced altering course again, to port, and was steady again on course 225 at 1043z. At 1236z this final and most succesful BRIDGET deployment was interrupted by a communications fault between the instrument and the ship. Recovery of the instrument was commenced and BRIDGET was fully recovered in-board at 36°03'N 34°06'W at 1411z. Passage was commenced back towards the Azores, but - because of the minor curtailment of the final BRIDGET tow - there was opportunity for one final ZAPS sled deployment as we crossed back over the Rainbow area. ZAPS was deployed at 1549z and lowered to 2089m at 36°14'N, 33°53'W before recovery inboard at 1736z on Sunday 25th Sept.

Passage was then set directly for port and the RRS *Charles Darwin* entered the harbour at Ponta Delgada, Azores, at 0845z on Tues.27th September. A pilot boat tranfer was then effected within the harbour and all scientific personnel were disembarked and ashore by 1000z. The complete ship's track for the *Charles Darwin* during Cruise 90 is shown in Figure 1. A diary for events detailing all station positions occupied is listed as Appendix A.

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SCIENTIFIC REPORTS

1. BRIDGET Operations

1.1 BRIDGET - Sensors And Sampling Devices

1.1.1 Overview

BRIDGET was designed to be a multi-sensor deep-tow instrument for the investigation of hydrothermal vent plumes. It carries a suite of sensors to both detect and sample plume material. The ability to tow the instrument enables much more data to be gathered, regarding the extent and dynamics of the plumes, than conventional vertical casts. The major advantage of BRIDGET is in its ability to provide power, data handling and transmission for a wide variety of sensing and sampling devices.

During this trials cruise both conventional and experimental instruments were carried on the deep tow. These are listed below and their performance described. The ZAPS manganese detector is described in a separate section of this cruise report.

1.1.2 Sensors

Micro-CTD *FSI*

This unit differs from most other CTDs in that it contains a microprocessor capable of calculating corrected values for conductivity, temperature and depth. The unit is small, low powered and has a digital interface (RS 485) which made it most suitable for use on BRIDGET. Throughout the deep tow deployments the Micro-CTD provided data continuously. Initial inspection of the data at sea seemed to indicate that there was some noticeable error in the conductivity readings. Post cruise calibration and testing will be carried out to check the instrument for accuracy and drift from pre-cruise checks.

Transmissometer *Chelsea Instruments*

This unit was supplied in an all metal pressure case of recent design. Throughout the cruise this instrument gave analogue outputs that were both transmission and pressure dependant. Unfortunately the magnitude of the pressure induced signal was large enough to make small scale signals difficult to see. It seemed that some distortion of the optical windows under pressure was causing the problem. This unit has been returned to the makers for testing.

Nephelometer (new instrument) Chelsea Instruments

Essentially this was a standard Mk 3 Aquatracka with filters removed to allow more light to be detected as a standard unit was not considered to be sensitive enough. From the first deployment this unit exhibited erratic behaviour. The output would swing between supply rail voltages and occasionally give sensible readings. None of this seemed to be either depth or temperature dependant so some internal fault of the instrument is suspected. The behaviour of a nephelometer without filters would be hard to predict when exposed to natural or chemo-fluorescence. Therefore this unit has also been returned to the makers for testing and replacement of filters.

RVS Nephelometer (standard unit) Chelsea Instruments

During the final two deployments of BRIDGET the Mk 2 Aquatracka unit supplied by RVS with the CTD system was fitted to the instrument. This sensor had been used during the previous cruise and had proved itself to be very stable and reliable. By including it with the BRIDGET sensors a direct comparison of data from the two nephelometers could be made. The versatile design of the hardware and software in BRIDGET enabled this extra sensor to be added to the system with only minor modifications necessary.

Initial intercomparison of results from the two sensors showed that there was less signal to background noise improvement in the new modified instrument than was expected. Enough data was collected for thorough post cruise evaluation of performance to be carried out.

Attitude Sensor (pitch, roll and heading) IOS Deacon Labs.

This unit housed in a single pressure tube housing was built at IOSDL. It produces three analogue outputs representing pitch, roll and heading of the deep tow system. The sensor contains two clinometer units manufactured by Lucas-Schaevitz and a flux gate compass unit produced by KVH Industries. The clinometers are of the electrolytic fluid and capacitance plate type. This design has the advantage of good linear working range (+ and - 45 degrees) and low cross axis errors. The compass unit has a gimballed coil assembly to compensate for vehicle tilt and also has a 45 degree working range. The signals from the attitude unit provided useful information on the behaviour of the vehicle during towing operations under a variety of weather conditions throughout all deployments. Analysis of this information will suggest possible modifications to the vehicle itself such as extra ballasting and changing tow point position.

Acoustic Altimeter *Simrad Mesotech*

The acoustic altimeter is essentially a downward looking echo sounder that converts detected range from bottom to an analogue signal. The unit was slightly modified by the makers to give a 500 metre range. This was mounted at the front of the BRIDGET frame with an unobstructed view vertically downwards. It was included to give warning of approach close to the bottom and thus avoid possible impact and loss of the instrument. Performance during the cruise was dependant on vehicle behaviour as would be expected, but was generally very good. Large amounts of heave affecting the vehicle would reduce the working range of the altimeter to about 130 metres, however under good conditions the full 500 metre range was available, which enabled confident towing of BRIDGET within 100 metres of the bottom.

ZAPS (new instrument) *JWA Associates*

Christina Young of JWA Associates participated in the cruise and describes this unit in another section of this report.

1.1.3 Sampling Devices

Rosette water sampler (modified) *General Oceanics*

A twelve bottle 2.5 litre water bottle array was mounted at the rear of the deep tow frame. To simplify control of the unit by the BRIDGET electronics the internal control circuitry of the rosette pylon was redesigned. This was carried out at IOSDL and enabled water bottles to be tripped by the application of a simple logic pulse to a control line. The new circuit is powered by 12v.dc. and a changing voltage on a monitor line indicates rotation of the bottle tripping mechanism. This output line is read by the main electronics and the information passed back to the ship. The modified pylon worked very well during the cruise and many samples were taken. Unfortunately if the whole system was powered down during a deployment, to reset a processor hang up, the action of powering up the system again would trip the firing mechanism. This could mean that several bottles were tripped prematurely before water of interest for sampling could be found. A software solution to this problem is being implemented.

Multisampler (new instrument) *Challenger Oceanics*

This consists of a single magnetically coupled pump unit which draws water through one of eight preselected ports. Each port is connected through individual water flow meters to its own filter unit. Pump start and stop and individual port opening are selected under direct control from the ship. The RS232 interface on the device communicates with a BRIDGET electronics serial link allowing shipboard control of the multisampler. There were several problems with this unit. Most importantly there seemd to be a pressure related problem which prevented its operation at depths greater than 1500 metres. Port selection was unreliable and the construction of the instrument should have been more rugged. As a result the multisampler failed to collect any useful filter samples during the cruise. It is expected that these problems will be solved and the instrument thoroughly tested before the next BRIDGET cruise takes place.

1.1.4 Conclusions

A lot of experience was gained and much learned during this short trials cruise. BRIDGET proved to have great potential as a sensor platform and survey vehicle which would be able to conduct many types of experiment. Now that the initial instrument building phase has been completed time will be spent rectifying problems and ensuring sensor reliability.

RK

1.2 BRIDGET - Electronics

1.2.1 Introduction

The electronic package taken to sea on the CD90 BRIDGET test cruise was the result of development work at the Bullard Laboratories, University of Cambridge, between March 1994 and August 1994. The hardware is divided into two 8" O/D pressure cases mounted in the deep tow frame between the sensor bay at the front and the Challenger Multisampler mounted in the mid-section. The two pressure cases can be broadly divided into the following two categories; power and signal.

The system communication is via the 8km TOBI cable currently installed aboard the RRS *Charles Darwin*. The laboratory based control terminal consists of a Sun SPARC 2 clone computer running display and logging software developed for the project, a DC power supply capable of supplying 300v at 2A (current system power consumption is 90W), and a modem with associated interface circuitry for communication to the deep-tow.

1.2.2 Power Electronics

The power pressure case contains the power/communications interface circuitry, two Siemens DC/DC switching power supply units both capable of providing 24v at 4A and power regulator circuitry which produces 5v, 9v, 12v as regulated supplies. Added to ths is the provision for Nicad battery supplies of 12v and 18v, both of which use a constant current charging system, whilst the system is powered up. Therefore the power electronics is configured to produce the following supplies for the system electronicsand sensors.

5v - Microcontrollers and associated digital interface electronics.

9v - Modem communications supply.

12v	-	Regulated supply	Sensors	-	Transmissometer
					Attitude (Pitch)
					Attitude (Roll)
					Attitude (Heading)
					CTD
			Electronics	-	ADC Instrumentation Amplifiers
					RS232 Interface electronics
12v	-	Battery supply	Sensors	-	Nephelometer
					Rosette Water sampling system
18v	-	Battery supply	Sensor	-	Altimeter
48v	-	Regulated supply	Sensor	-	RVS Nephelometer

All the outputs from the power tube are supplied via a single Sea Connections 6x4 way 'Pie' bulkhead connector.

1.2.3 Signal Electronics

The signal pressure case contains the processing and data handing circuitry and software. The system is based around the Cambridge Microprocessor Systems (CMS) K100 microprocessor cards and communicates via a proprietary modem operating under the V.42 BIScommunications standard. This standard supports communications at up to 14400bps, data correction (MNP classes 2, 3 and 4) and data compression (MNP class 5), all of the above features are negotiable between the two modems on the line. The modem is configured and operated using the industry standard "AT" command set via software developed for the deep tow. The system is controlled using the CMS K100 microprocessor card which is based around the 68000 microprocessor, which is connected to a CMS K800 eight channel serial card via the CMS Pro-bus.

This central processing section acts effectively as a system control and data routing device. All the sensor data, be it from an intelligent sensor (i.e. CTD, ZAPS, Multisampler) or digitised analogue values (i.e. Nephelometer, Transmissometer, Attitude, Atimeter, Rosette), are passed to the central microprocessor via a serial channel on the 8 channel serial card. The central microprocessor will then produce packeted data which is passed to the modem for communication via the deep tow cable, also it will route data from the ship based control terminal to the appropriate sensor. Added to this the central microprocessor will control the modem and implement dial out to establish and maintain communications. Therefore a full-duplex conversation can be maintained between the ship based terminal and any sensor. The capability is eight autonomous channels, with a requirement for a standard RS232 or RS485 connection to the sensor.

All the analogue sensors are configured into the above scheme of operation by the addition of a second CMS K100 microprocessor card and a 16 channel, 16 bit ADC card again connected via the Pro-bus connection. This configuration allows the process of converting the analogue sensor values, which is inherently slow to be run as a separate entity within the system, and thus the ADC values are presented to the data router as though they were another intelligent sensor channel. Allied to this the 16 channel ADC card has input/output port facilities and it is through this channel that a Rosette bottle may be fired and the new output monitored. Therefore channel 1 of the 8 channel serial card is dedicated to communication and control to and from the analogue sensors.

The analogue sensor outputs pass through signal conditioning circuitry comprising differential precision instrumentation amplifiers which provide suitable scaling of each input. The 16 channel, 16 bit ADC incorporates features such as Sigma-Delta conversion techniques, and temperature compensation.

The physical connections to and from the signal pressure case are via three Sea Connections 6x4 way 'Pie' bulkhead connectors. The current system specification can be defined as follows.

Communications - 10 or 11 character length including parity, start and stop bits. Modem operation controlled by 'AT' commands. Line data rate selection is determined by speed of the originating and answering modems, maximum data rate used on the deep tow cable 14400bps. DTE rate is independent of the line rate set to 19200bps for CMS microprocessor to modem connection and 19200bps for SPARC 2 to modem connection.

1.2.4 Intelligent Sensor Connections

Channel 1 - CTD Sensor, RS232 to RS485 conversion operating at 9600bps.

Channel 2 - Analogue sensors and Rosette control, RS232 connection to CMS K100 microprocessor and 16 bit, 16 channel ADC communicates at 9600bps. Currently 8 of 16 channels used for analogue sensor outputs, and 2 of 8 digital output lines used for rosette control and monitoring.

Channel 3 - ZAPS probe, RS232 connection configured to ZAPS specifications!!

Channel 4 - Challenger Multisampler, RS232 connection configured to Challenger specifications!!

Channels 5 to 8 - Currently unused and available for further system expansion.

The system software is written in Modula-2 and 68000 assembly programming languages, with the application programmes currently 'locked' into battery backed RAM, running under the CMS MINOS operating system.

1.2.5 Trials Cruise System Performance

The cruise CD90 was planned as a trials cruise to test the BRIDGET system; mechanics, sensors, electronic hardware and software.

The electronic hardware package was housed in pressure cases designed at IOS and these proved to be a successful design that allowed ease of handing the electronic package into the deep tow frame and connection to the various sensors. Also it proved to bea convenient design for servicing the electronics and software development when the pressure cases were required to be opened and reassembled.

The initial deployment of the electronic package failed at approximately 1500m where power was lost to the microprocessor or modem systems. However, recovery to approximately 1000m found the system to be working again. Upon subsequent deployment to 1500m it again failed. This problem was cured by the replacement of two 'Pie' connector interconnection leads and this proved successful for the remainder of the cruise.

Further deployments produced no further failures in electronic hardware. However, system failures were encountered due to communication hang-ups. The solution to these problems were in software design both the deep tow and the ship based terminal software. The software is required to be robust to the effects of brief communication stoppages due to the deterioration of line conditions on the deep tow cable. The modem systems are required to re-send corrupt data or re-negotiate the line speed and protocol in the event of such deterioration. The deterioration in the deep tow cable connection would appear to be a problem with the slip rings within the cable system. These appear at the ship cable winch drum and the deep tow swivel.

One effect of this initial problem was the firing of a rosette bottle if a hard reset was required to reinitialise the system, a problem in itself. Further hardware problems were confined to the inability to successfully EPROM the deep tow software at sea. This did not prove to be a problem due to the ability to lock programs into RAM memory.

1.2.6 Sea Trial - Conclusions

The electronic package proved to be reliable and robust, and deployments of up to 22 hours were achieved without electronic failures. The results from the sea trials and, hence, system improvements can be summarised as follows.

Disable the Rosette firing system on power up and down to prevent the spurious triggering of sampling bottles.
EPROM all deep tow application programs currently 'locked' into battery backed RAM memory.
Produce a sea going integrated laboratory/deck unit incorporating all the existing elements.
Improve the internal connector system used within the electronic pressure cases, to aid servicing and reliability.
Replace the current 5v linear regulator that powers the microprocessor systems and interface electronics with a DC to DC type switcher. This will help to reduce the power losses due to heating within the pressure case and improve efficiency.
Change the layout of the power pressure case internal electronics to utilise the end cap as a heat sink and mechanical support.
Implement the RS485 capability of the CMS 8 channel serial card in order to reduce electronic circuitry within the pressure case.

Further to the BRIDGET development outlined above it should be added that all the slip ring assemblies within the system (i.e. Winch drum connection and deep tow swivel) should be thoroughly serviced before use of the system to minimise the effects of momentary data glitches.

There is need to assess the RVS swivel for future suitability, as well as redeployments using the TOBI swivel given the experience gained.

SR

1.3 BRIDGET - Software

1.3.1 Overview

The software for BRIDGET is divided into two parts: a) data routing, and b) displays. The data routing is achieved at the top end in software, whereas a combination of hardware and software is used at the bottom end to send and receive information from individual sensors. Data and datastream displays are integrated onto a single Sparc 2 workstation, which also provides a facility to talk to individual sensors.

1.3.2 Bottom end software

The BRIDGET CPU bottle contains a 68000 microprocessor card and 8 channel RS-232 serial card for communication between the sea-cable modem and the individual sensors. The software has two main tasks to accomplish: a) initiating the modem dialout sequence at the start of a cast, and b) routing data to and from the wire and the sensors. The data streams from the sensors are combined into a single data stream for transmission up the wire, with a maximum combined data rate of 14400 baud (higher with data compression). Communications between the microprocessor board and the sea cable modem is at 19200 baud to allow the full 14400 baud data rate to be utilised. The sensor data is sent as and when it is received. More specifically, it is sent either when there is a lull in the transmission of the data stream between the sensor and the serial i/o, or when an optimum number of characters have been received for transmission to proceed. This value is currently set to 100. When the data is ready for transmission, a small header (of up to 5 bytes) is attached to give information about the data length, the sending sensor, and a checksum to test data integrity. The RS-232 i/o can be configured for a variety of baud (data) rates, parity and stop bits combinations. Data is assumed to be binary to allow for the widest possible range of new sensors to be fitted. The channels are not prioritised, so, in theory, addition of a new sensor equipped with an RS-232 interface is simply a matter of plugging in.

Information coming down the wire has the same format: it is checked for data integrity, the header is stripped and the data passed to the sensor indicated.

Data channels.

Eight channels of RS-232 output are available in the system (VSO-7) of which four were used during the trials cruise. These were:

VSO	FSI CTD	4 frames/second @ 35 bytes/frame
VS1	ADC	2 frames/second @ 55 bytes/frame
VS2	ZAPS	1 frame/4 seconds variable ≈20 bytes/frame
VS3	Multisampler	1 frame/second @ 70 bytes/frame

The total data rate was thus ≈300 bytes/second, or approximately 1/4 to 1/3 the available bandwidth of the current data transmission system.

The channels VSO-1 represent the core BRIDGET system. Data from the FSI CTD is sent via VSO in ASCII format at 9600 baud. VS1 is used to interface the analogue sensors to BRIDGET. These sensors are arranged so that they are attached to a separate 16 channel/16 bit i/o interface and microprocessor that acts as a stand-alone data gatherer, talking to the Bridget system via an RS-232 link. Spare digital i/o lines on the analogue board are used to trigger the water sampler rosette, and to return the status of the rosette wiper for feedback.

VS2 was connected to the prototype ZAPS manganese probe. This device requires two-way communications so that gain adjustments can be made in mid-depth ocean waters, with the output being monitored either digitally or via an analogue output. For CD90, the digital output was parsed and added into the CTD/ADC data stream so that it could be plotted and logged.

VS3 was connected during CD90 to the Challenger Multisampler, an in-situ filtration device. Two way terminal style communications are needed to allow commands to be sent to open/close filter valves, and to start/stop the pump. Every second, the device transmits a status message giving the current valve location and pump state.

The ZAPS probe and Multisampler illustrate two different sensor requirements. The ZAPS probe requires a setup dialogue, and then returns data to be logged, whereas the Multisampler takes commands and returns a status line which just has to be monitored.

1.3.3 Top end software.

The data stream from the top-end sea cable modem is sent via a 19200 baud RS-232 link to a Sparc-II workstation for logging and display. It emulates the BRIDGET hardware in software, with several important differences. First, the incoming data is not routed to different sensors, but instead to different buffers. Second, data for transmission down the wire originates from a main command window, and not from individual sensors. The first point means that some care must be taken when parsing sensor data streams. The main point is that because the data stream is not fixed frame, then it must be anticipated that the data frame from each sensor will be transmitted in fragments. These fragments must be reassembled and parsed only when a complete data frame has been received.

Sensor logging.

The data streams from channels VSO-1, the CTD and ADC sensors, are used to build the main output file. The file is written in a modified RVS Level C format, at a data rate that is currently driven by the CTD - at present, 4 frames per second. ADC data is added into these frames as and when it is received. When a data frame has been stored, the data is available for plotting.

Data display.

There are four main data displays implemented on the CD90 Bridget system.

1) Raw data display. A numbers only display of the current data frame.

2) Attitude display. A graphical display of attitude information (pitch, roll and heading) via an artificial horizon.

3) Rosette interface. A graphical display of the current state of the water sampling rosette.

4) CTD data plotting.

The CTD data plotting window allows the CTD/ADC data stream to be plotted in real time in a variety of formats - Landscape/Portrait, time-property and property-property plots. A 5000 frame buffer is used so that the last ≈20 minutes of data collected can be used to redraw plots after a change of axis or change of variables. An option is also provided so that the current plot can be printed.

Command window.

This window allows two way communications with individual sensors on BRIDGET. Once a sensor has been selected, the data from the sensor is displayed in the command window. Commands for the sensor can be typed in and are sent on pressing <return>. It is a property of the Open Windows interface that these command strings are sent as complete strings rather than character by character as in a conventional terminal interface. This did not seem to be a problem for the Multisampler, but special software had to be written to allow ZAPS commands to be sent character by character. Because the Command window is not a true terminal, fancy terminal tricks do not work. This did not appear to be a problem for the ZAPS interface.

Rosette interface.

The rosette interface is a graphical display, which indicates the next bottle to be triggered, and provides a <Fire> button with which to do so. The display can be set up to indicate whether rosette positions are occupied or not. Upon firing a bottle, the relevant command is sent down the wire and routed through to the ADC system which handles the bottle firing. The ADC processor monitors the rosette wiper for a change of state to indicate when a bottle has been fired, and sends this information back to the rosette interface window. The rosette bottle is then indicated as fired, and the pointed incremented to the next bottle position.

1.3.4 Cruise narrative.

Bottom end.

Routing - During initial Bridget deployments, it was found that the software was particularly sensitive to line (perhaps swivel or slip-ring) noise which would cause the software to crash. Fortunately, it was possible to reconstruct the bottom end hardware on the bench and to make the software more robust. This was tested by sending large DOS EXE files to data router (essentially, many k's of garbage) to identify weak points and to correct them. In addition, extra code was added to monitor the data stream for a "NO CARRIER" condition from the sea cable modem, which would signal a complete line break. In this case, the system would reset and attempt to redial the surface modem.

Rosette - Before CD90 it was found that the rosette interface did not reliably trigger and return wiper change of state information. The main reason for this is that the rosette interface is not cleanly implemented - it is piggy-backed onto the ADC interface, whereas ideally it should operate on its own data stream. This is not a problem for the bottom end -

the ADC board just treats rosette firing like any other command, but at the top end, the rosette confirmation signals have to be decoded from the ADC data stream, which can be tricky. Once this had been accomplished, no more problems were apparent with the rosette interface, though this situation will have to be monitored in future.

ZAPS and Multisampler - Both these devices required changes to the RS-232 set up parameters. This was not a problem.

Top end.

Routing - The noise problems which affected the bottom end code also affected the top end, and similar testing/changes were made to take line noise into account. Automatic modem redialling was also implemented, though this remains largely untested. During the early stages of the cruise when the system was beset by numerous crashes and data losses, and automatic file backup facility was added. This itself caused problems but was finally fixed by the penultimate tow.

Multisampler - This device was found to go to sleep if not talked to periodically. Changes were made in the software to send a garbage command (kick the Multisampler) every 5 minutes to keep it awake. This is evidently non-ideal.

Plotting - Code was written at sea to allow hard copy of plots whilst BRIDGET was in operation.

1.3.5 Aftermath.

Although the BRIDGET routing code is a lot more robust than during the initial deployment, problems still remain which can cause the modems to hang up during periods of line noise. It is a priority that these problems are solved before future BRIDGET deployments. However, at times when line noise was tolerable, the benefits of being able to talk to sensors individually was apparent, especially in the operation of the Multisampler.

Due to hang-ups at the top end, it was felt that the logging of the raw BRIDGET data stream is a priority for implementation before the next BRIDGET deployment. This can be accomplished either using a second computer to log the data stream from the modem, or by running the logging as a separate process under UNIX on the workstation. To make the logged data stream more meaningful, time markers need to be added to the data stream generated by the BRIDGET data router.

BRIDGET operations require a cool hand at the controls, due to the operation of the modems used for sea cable communication. The 'problem' is that the modems care deeply for the state of the connection, such that when they register line breaks due to swivel or slip ring noise, they will communicate to re-establish the connection. This process results in a ≈7 second data hangup, during which time the data stream is buffered. No data is lost, however, as the buffered data is sent when the line has been renegotiated. This compares with a conventional CTD DPSK link, where a break in the line results in a frame or so of corrupted data. The modems have no concept of an 'acceptable' line error rate. Several line errors in a row can cause the modems to hang up for 14 seconds or more, and eventually cause a complete loss of carrier.

RS-232 protocol for attachment of new sensors to Bridget.

Because of the wide variety of communications protocols encountered during the CD90 trials, the following specification is suggested for the attachment of new instruments to BRIDGET.

Preferred	Notes
RS-232	conversion to RS-485 possible
CTS-RTS handshaking	or no handshaking
9600 baud	but 1200-19200 available
8 bits/character	but 7 bits available
No parity	but parity available
1 stop bit	but fully configurable

Sensors which accept command lines with no character echo are preferred, but terminal-type interfacing is also possible after a fashion.

MR

1.4 BRIDGET - Handling and Frame Design

In general, the mechanical design and construction of the frame worked well. No serious dificulties were experienced either deploying or recovering the instrument - although some modifications will be needed to allow safe handling in less favourable weather than we enjoyed (see below). The instrument towed in the correct orientation, thanks to the stabilising fins. Indications from slant range vs wire out records show that for most of each deployment the wire was close to straight - indicating that the package does not have excessive drag. It proved possible to mount all the sensors, sampling devices and electronics packages within the frame without serious difficulty.

1.4.1 Suitability of frame for mounting sensors & instrument packages:

The overall concept of the frame is fine. The open structure allows easy access to fitted components for servicing, removal or attachment. The arrangement for installing the two main pressure cases works well, allowing them to be fitted or removed in minutes. The main difficulty is the lack of appropriate pathways or conduits for the very many cables that run around the frame. Inevitably, with two main electronics tubes and a variety of external sampling and sensing systems, the number of cables is large. During the test cruise a good deal of time was taken up before and after each deployment securing them all to various points on the frame with cable ties and adhesive tape. This is both tedious and unsatisfactory. The frame needs a system to be devised to allow cables to be run neatly, securely and conveniently between various locations without resort to several reels of tape on each deployment.

It would also be appropriate to add some general-purpose mounting points to the sensor compartment. For example, we added a second nephelometer during the cruise, and this had to be done using jubilee clips around the main parts of the frame. Extra mounting points and a supply of appropriate materials for fabricating fixings are likely to prove useful on future cruises. The last-minute addition of a mounting for the ZAPS probe worked reasonably well, but is none too elegant.

The fold-out arrangement of the water sampling rosette section is a good concept; but in practice, the bolts securing the central part of the rosette are extremely hard to gain access to, either for raising or lowering the rosette, when the system is fully rigged. BRIDGET was placed on wooden blocks on the afterdeck during the cruise, making access somewhat easier, but this meant that the rosette system 'tail-gate' did not sit properly on deck when opened out.

1.4.2 Deployment and Recovery

After the first couple of attempts, we took to deploying BRIDGET sideways - i.e. with the long axis of the deep tow athwartships. By attaching steadying lines to BRIDGET's nose and tail, this allowed us to control the tendency of the instrument to swing about during launching. Once in the water, BRIDGET happily swung round to face in the direction of travel. The addition of stainless steel eyes to the frame, front and rear, sufficiently large (e.g. semi-circular with internal dimensions of the order of 150 mm) to allow steadying lines to be passed through them and back to strong points on the deck during deployment, would make this process easier. Suitable locations should be found for mounting these brackets.

Recovery proved less straightforward. The approach adopted was to attach steadying lines to either side of the frame, held in place by tape and cable ties that were strong enough to prevent the lines from coming uncoiled during the deployment, but weak enough to be broken during recovery - when a snap-hook was used to capture the ends of these lines and bring them inboard. The main problem was that this relied on reaching the snap-hook, on the end of a pole, down from the after deck to the instrument package before it was brought fully clear of the water. It is absolutely essential to have steadying lines rigged before BRIDGET comes right out of the water, as otherwise even in moderate weather the swinging of the package becomes quite violent. But it is difficult to grapple for the steadying lines with the present arrangement, and there is a serious danger of the snap hook damaging cables, connectors or sensors in the foremost compartment of the BRIDGET frame.

Permanent and robust attachments for steadying lines should be fitted to the frame, together with some means of raising a messenger line (attached to the main steadying lines) above the main framework of the instrument package. A semi-rigid framework, with the messenger line attached, located specifically so as to allow easy grappling with a snap-hook, would be suitable for this purpose. It may also be useful to devise a method of attaching the recovery steadying lines to the nose and tail of BRIDGET, as is done during deployment, since once the package is clear of the water it is easier to control if aligned athwartships than fore and aft. At the same time, a protective mesh should be fixed over the top of the forward compartment of the BRIDGET frame, to protect sensors, cables and connectors from missed attempts with the snap-hook.

1.4.3 Behaviour during deep tow operations

During early phases of lowering the package, the weight on the winch tends to be very small, making it necessary to pay out cable slowly (10 metres/minute). In general, even with large amounts of cable out, we found that 20 metres/minute was the fastest practicable speed for paying out when tow-yoing the instrument. This situation could be improved by adding aditional weight to the frame. Obviously the amount of weight that can be added will depend on the depth of water in the work area - in deep water (over 4 km) very little weight can be added, because the weight of the wire approaches its safe working load, even without the package. In moderate water depths (2 km or so), though, there is plenty of scope for additional weight which would allow faster tow-yoing, providing better horizontal resolution of water column structure. The provision of three weights, each of 0.5 tonnes, with attachment points on the underside of the frame on the centre line and symmetrically to either side, would allow the weight of the package to be increased by 0.5, 1.0 or 1.5 tonnes, depending on water depth and application.

Both the records from the vehicle attitude sensor and signs of stress on the tow cable swivel connection show that during towing, the vehicle both surges up and down in the water, and pitches considerably (by more than ± 30^{O}). This is undesirable for two reasons. Firstly the amount of pitch is likely to have a detrimental effect on the more sensitive and delicate of the sensors and sampling systems, while making the addition of orientation-dependent sensors - such as narrow beam acoustics or three-component magnetometers - impossible. Secondly, it causes wear to the swivel attachment and to the deep tow cable termination.

The best solution would be to reduce the heave on the cable. This is caused by the pitching of the ship, and appears to be transmitted directly down the cable to the deep tow. The result is that the BRIDGET vehicle is alternately heaved up and then allowed to fall, with an amplitude measurable in meters and a period of several seconds, even during very moderate weather. Active heave compensation on the deep tow winch would be the best solution. A shock-absorbing arrangement of spring-loaded sheaves somewhere in the cable run on the vessel would also help a good deal. During the cruise, the tension on the cable while towing varied dramatically (with an amplitude of up to a tonne or more) during the heave cycle. At times, during particularly large heave cycles, the tension went almost completely to zero, and then would return sharply as the vessel's stern started rising again. These snatch loads on the cable may be responsible both for marking of the stainless steel surfaces of the swivel attachment blocks, and for some minor necking of the deep tow cable itself where it enters the termination block at the top of the swivel.

While reducing the heave by modification of the research vessel's winches is the most desirable approach, at the same time it is important to significantly reduce the amount of pitching that results from cable heave. One way of doing this may be to raise the swivel attachment point further above the top of the vehicle itself. Modification of the swivel attachment to achieve this should be straightforward. At the same time, provision should be made for the use of the RVS swivels.

<u>VEHICLE WEIGHTS:</u>

BRIDGET vehicle, including TOBI swivel and fins, but excluding sensors, sampling devices and electronics tubes: 400 kg.

BRIDGET vehicle complete with sensors, sampling devices and electronics tubes, but with water bottles empty: 750 kg.

MS

1.5 BRIDGET - Samples

Because of difficulties with the multi-sampler (see 1.1.3, above) all samples collected were taken using the twelve-bottle 2.5L Niskin rosette mounted in the rear of BRIDGET. The bottles had been pre-treated (see section 3.2, below) by soaking for 24 hours in 500m seawater acidified with 1ml 6M HCl. Sampling was only carried out from later BRIDGET deployments (tows 4, 5, 6) and samples were drawn unfiltered into 500ml acid-cleaned polypropylene bottles, after rinsing three times with the relevant sample. These were then acidified to pH~2 under a laminar-flow clean hood using 1ml 6M QD HCl. A total of 36 samples were taken in this manner for shore-based TDMn (total dissolvable Mn) analysis in the laboratory. Where possible, bottle firing was dictated by high nephelometer anomalies. During initial tows sampling was often triggered inadvertently during system "Hard Resets" (see section 1.3 above) thereby reducing our capacity to carry out such targetted sampling. This difficulty was largely overcome within the lifetime of the cruise, however, as reflected in the increasing predominance of actively fired bottles during BRIDGET tows 5 and 6. Full details of samples taken are given in Appendix B.

CG

1.6 BRIDGET - ZAPS Probe (JWA)

1.6.1 Initial On-board Tests

Due to the failure of the Challenger Oeanics pump designed for use with this unit during the preceding cruise (CD89), Gary Klinkhammer's gear pump (OSU) was connected up to ZAPS for the duration of this cruise. The flow rate from this pump is 27ml/min. It requires 15V for power and draws between 200/400mA current when in operation.

Tests with the pump and empty chemical cartridges found that air was easily trapped within the flow cell. This gives a spurious output from ZAPS. It is doubtful that the window is ever completely covered with water. One of the three flow lines never fills with water. By sealing one line off, the flow improved. Due to the problem of trapped air, the flow cell and cartridges were connected to ZAPS under water, using Milli-Q purified water. To check whether ZAPS was responding correctly to the DEA chemical (excited fluorescence should increase the output), DEA in solution was added to the water close to the flowcell input while the pump was running. There was an increase in signal from 0.2 to 0.4 (0.0 to 1.0 FS). Although not conclusive, this increase indicated that ZAPS was behaving correctly. The absolute performance could not be assessed, as any trace in Maganese suppresses the ZAPS signal. At this stage it was decided that the best test was to deploy ZAPS on BRIDGET. During these tests, communications with ZAPS via RS232 was used with no problems or loss of communication.

1.6.2 Deployments

For deployment, the OSU pump was again used instead of the Challenger pump. The pump was powered separately from a 15V battery pack, not via the main ZAPS module. Once powered up, the pump was permanently on, and not under digital control from ZAPS.

The main ZAPS module was powered via a 15V battery pack, using the 8 pin connector. Communications with the BRIDGET system were established. ZAPS using DSR/TR handshaking, whereas BRIDGET uses CTS/RTS, the connections were modified to cope with this.

This part worked well, communications with ZAPS at 2000m inside a plume were fine. ZAPS lost communications a couple of times, but this was probably due to the "made up" cable between the battery pack, ZAPS and BRIDGET.

ZAPS was deployed twice on BRIDGET. On first deployment, although communications were established and output was being received via BRIDGET, there was no opportunity to change ZAPS parameters. In passes through a plume, no discernible change in signal occurred. After the first deployment, inspection of the cartridge showed that the chemical was solidly packed; this could have prevented a good flow through the system. A new Analine cartridge was installed.

On second deployment, at 1500m depth, ZAPS parameters were changed such that a full-scale signal was set for clean sea water by changing the gain. Also, averaging was changed. The communications via BRIDGET with ZAPS digital control worked fine. Later, when in a plume, no discernible change in signal occurred.

For the third deployment, the optical bandpass filters were changed to measure Optical Backscatter. The initial on-board tests showed that the ZAPS system was too sensitive. This meant using a non linear part on the gain curve for the PMT. Extra blocking filters were added. On power up a short must have occurred, chips U3 and U3 on the power supply board went down. This happened when I changed the filters for a second time.

1.6.3 Conclusions

ZAPS digital control works fine.

ZAPS responds correctly to a DEA fluorescent signal.

ZAPS is not sensitive enough at this stage to respond to the presence of Mn in a plume.

The main areas which are likely to have affected the instrument's performance in deployment are the pump flow rate and the flow cell configuration.

CY

2. ZAPS Sled Operations

2.1 The ZAPS Sled

2.1.1 Introduction

Venting of hot, chemically-rich, buoyant fluids from mid-ocean ridge spreading centres produces hydrothermal plumes with thermal, physical, and chemical signatures quite different from background sea water. These plumes rise several hundred meters above the sea floor where they reach neutral buoyancy and begin to spread laterally. The marine geochemistry group at Oregon State University has designed and constructed an instrument package, the ZAPS Sled, that carries state-of-the-art, *in situ* sensors capable of detecting such plumes and tracing them back to the source of venting. During CD90 the ZAPS system was used to study plumes and constrain the source of venting from the Rainbow hydrothermal field, AMAR segment, Mid-Atlantic Ridge.

2.1.2 ZAPS Sled Frame

The ZAPS Sled vehicle is an open framework of 5 cm Type 316 SS pipe. The ZAPS Sled stands 90 cm wide, 90 cm tall, and is 270 cm long with a tapered bow 42 cm wide. This frame hangs from a standard conducting cable by an adjustable 3-point chain bridle to ensure that the sled attains a forward facing, level attitude in the water. The two vertical sides of the sled aft section have 0.95 cm thick polycarbonate panels attached to serve as rudder vanes and give structural hydrodynamic stability. The weight of the frame in air is about 350 kg. The ZAPS Sled is used for tow-yowing at 1-2 knots as well as for vertical profiling.

2.1.3 ZAPS Sled Instrumentation

The central instrument on board the ZAPS Sled is a Sea-Bird 9/11 plus CTD sampling at 24 Hz and fitted with modular temperature and conductivity sensors and a Paroscientific Digiquartz Pressure Sensor. Four analog instruments are interfaced through the Sea-Bird underwater unit. These include:

SeaTech Transmissometer to measure 660 nm wavelength beam transmission through a 25 cm path length

Chelsea Aquatracka Mk III Fluorometer operating as a nephelometer at a wavelength of 420 nm to measure scattered light at 90 degrees to the incident light beam.

Zero Angle Photon Spectrophotometer (ZAPS) that uses solid-state chemistry with analog fluorescence to measure the concentration of dissolved manganese

SIMRAD Mesotech Systems Model 807 Echo Sounder/Altimeter to determine the height of the sled off the bottom within a 500 meter range.

The ZAPS Sled also carried a General Oceanics Rosette array interfaced to the CTD which held six 2-liter Niskin sample bottles for collecting sea water samples for laboratory measurements of manganese for ground-truthing data from the ZAPS probe. The bottles are tripped by signals from the CTD deck unit at any time without interrupting the data steam.

In addition the sled can be fitted with an acoustic transponder that is interrogated with a transducer at the surface to determine the direct slant range and computed horizontal range to the sled. On Cruise 90 a pinger was fit to the sled to aid in near bottom surveys as the altimeter proved to be unreliable.

2.1.4 ZAPS Sled Power

A custom power delivery system was used to supply power to all the underwater instruments, including the CTD. The power delivery system in the SeaBird CTD was bypassed. This custom power delivery system can provide more than 10 times as much power as the system in the CTD, which had proven to be insufficient in the past. The Simrad altimeter, Chelsea nephelometer, and ZAPS probe consume large amounts of current in pulses. The SeaBird CTD, its pump, and the ZAPS pump consume substantial power as well. The total power consumption of all the underwater instruments was approximately 60W, more than double the rated 27 W capacity of the SeaBird CTD system.

By providing the capability to deliver more than 200 W, our improved power delivery system ensures that these power hungry instruments do not interfere with each other or the other instruments in the system.

2.1.5 CTD Data Acquisition and SLED Navigational System

The ZAPS Sled is powered through a purpose-built deck unit that also receives frequencies from the underwater unit and sends converted data via an RS232 port to a Silicon Valley 486 computer that supports an Introl optical disk. Raw CTD data files are stored on the optical disk and echoed to a second, identical computer. This second, navigational computer also receives ship positions from a Garmin MRN 100 GPS Satellite Receiver and imports this data into a proprietary SLED navigation program developed at Oregon State University. This navigation program plots in real-time the ship's position and trackline and the computed horizontal range and position of the instrument package as projected onto the trackline of the ship. This "nav" program also shows a diagrammatic cross-sectional view of the ship, the towed vehicle, and a calculated "bottom depth" derived from the sum of the CTD pressure data and the concurrent altimeter data (height above bottom) from the package. This calculated bottom depth can then be compared to the depth records and/or bathymetric maps of the area to help locate the package with respect to bottom features or obstacles.

A full duplex modem channel was used to communicate with the ZAPS probe and fire the GO rosette to collect water samples. The modem channel was also intended to activate a stand-alone pump, which was not deployed when its batteries failed to recharge. The modem channel, which operated well at 9600 baud on a standard UNOLS conducting cable, did not operate as well on the Charles Darwin CTD cable. However the modem managed to maintain a connection when the speed was reduced to 300 baud. Even at this reduced transmission rate, noise caused erroneous characters to be received periodically. Despite the noise, commands and parameters could be sent to the rosette interface and ZAPS instrument. The rosette was fired successfully on every attempt without interrupting the data stream from the CTD or other sensors. Communication with ZAPS allowed it's parameters to be adjusted once it was deployed.

2.2 ZAPS Operations

The ZAPS Sled was involved in 6 operations during cruise 90 of the RRS *Charles Darwin*. These operations are summarized in the following table.

Table of ZAPS Sled Operations on CD90

Operation No.	Date	Location	Operation Type
CD90-SL11	19 Sept.	AMAR	Vertical
CD90-SL12	20 Sept.	AMAR	Vertical
CD90-SL13	22 Sept.	AMAR	Vertical
CD90-SL12	23 Sept.	AMAR	Vertical
CD90-SL15	23 Sept.	AMAR	Vertical
CD90-SL16	25 Sept.	AMAR	Vertical

2.3 Conclusions

All of the ZAPS operations on CD90 were successful and provided useful geochemical information about the water column in this area. Several lowerings produced exceptional results that added significantly to what we know about hydrothermal venting from mid-ocean ridges.

GK, PS

3. CTD-Nephelometer-Transmissometer Operations

3.1 CTD Operations

An EG&G Neil Brown MkIIIb CTD interfaced with a Chelsea Instruments Mk2 nephelometer and a Sea Tech transmissometer was used. Water samples were provided by a General Oceanics 1015 Rosette multi-bottle array fitted with twelve 2.5 Litre Niskins borrowed from IOSDL/BRIDGET. Two of the bottles were fitted with SIS reversing thermometers to provide calibration check data. Salinity samples were analysed on a Guildline 8400A salinometer. A standard 10kHz beacon was used to monitor near bottom operations. A total of 5 deployments in depths varying from 1000m to 3000m were successfully completed.

Calibration results showed a temperature offset of +0.002°C and a salinity offset of +0.013PSU.

PT

3.2 Water Sampling

Two profiles of 12 samples were collected during Cruise 90, from CTD profiles 14 and 15 which exhibited extremely pronounced nephelometer anomalies. The 2.5L Niskin bottles used were the same IOS bottles which were also mounted on BRIDGET. These bottles had been pre-treated by deployment of the CTD to 500m and tripping of the bottles at this depth during a shakedown station (90-05). The bottles were kept full of seawater during the following 48 hours, after acidification with 1ml 6M QD HCl, to aid in removal of any adsorbed metals.

During CTD operations, bottle firing was targetted upon hydrothermal plumes defined by high nephelometer anomalies. Upon recovery in-board, 500ml unfiltered subsamples were drawn directly into acid-cleaned 500ml polypropylene Nalgene bottles and the samples were then acidified with 1ml QD 6M HCl prior to storage and shipment to the laboratory for TDMn analysis. Details of samples collected are listed in Appendix C.

CG

4. XBT Deployments

A total of 18 XBT deployments were made during the cruise. The primary purpose of these deployments was to monitor variability in sound velocity profiles beneath the ship throughout the survey area, to ensure that the swath bathymetry calibrations established from a sound velocity profile during the previous cruise (Station CD89-03) remained valid. All data were recorded on board ship by RVS personnel and copied to The Hydrographic Office, Royal Navy, upon completion of the cruise. Stations were occupied synoptically at 0000z and 1200z using a combination of T-05 and T-07 probes. Full details of all 18 stations are given below:

XBT No.	Date/Time	Latitude	Longitude	Probe
32	94 260 12:13:00	37 26.48N	26 31.11W	T-07
33	94 260 23:57:00	36 36.96N	29 01.83W	T-07
34	94 261 11:51:00	36 22.56N	29 40.94W	T-07
35	94 261 23:49:00	36 18.66N	32 04.70W	T-07
36	94 262 12:58:00	36 17.17N	33 41.41W	T-05
37	94 262 23:47:00	36 14.73N	33 48.20W	T-07
38	94 263 11:49:00	36 16.00N	33 52.71W	T-07
39	94 264 11:53:00	36 15.84N	33 56.49W	T-07

40	94 265 00:06:00	36 16.53N	33 51.13W	T-07
41	94 265 12:21:00	36 15.81N	33 52.96W	T-07
42	94 266 00:24:00	36 15.97N	33 56.09W	T-07
43	94 266 12:22:00	36 16.92N	33 49.24W	T-07
44	94 267 00:02:00	36 16.12N	33 53.39W	T-07
45	94 267 12:36:00	36 14.92N	33 52.30W	T-07
46	94 268 00:04:00	36 12.60N	33 54.08W	T-05
47	94 268 11:53:00	36 04.89N	34 03.57W	T-07
48	94 268 23:59:40	36 29.42N	32 28.19W	T-07
49	94 268 23:59:40	36 29.42N	32 28.19W	T-07

GW, RP

5. Simrad EM12 Swath Bathymetry

The EM12 120 system on board RRS *Charles Darwin* comprises a single multibeam echosounder generating 81 stabilized beams providing a coverage up to 120 degrees in water depths of 100 to 11000 meters. Acoustic frequencies used are 12.66, 13.0, and 13.33 kHz. Transmission transducers are installed in 24 modules each containing 16 elements mounted alongships slightly to starboard and flush with the keel. Receiving transducers are installed in 14 modules each containing 15 elements mounted athwartships just forward of the transmitting array. The system is continually provided with surface sound velocity, clock, gyro and GPS navigation data. A vertical referencing unit mounted close to the centre of the ship provides roll, pitch and heave information.

The EM12 system was logged continually during cruise 90 with the exception of the period of Oceano Transponder Navigation. Raw multibeam data, logged by the 'Mermaid' swath logging system, was routinely archived to exabyte cartridge and converted to Simrad 'Survey Format' files for use with the 'Neptune' swath data processing system.

Due to the irregular nature of the survey undertaken during this and the preceding cruise (to the same area), it became apparent that it would be essential to maintain the complete data set within the work area on the Neptune processing system. To gain the required data storage it became necessary to 'borrow' one of the large data disks from the ship's ABC system and install it as a second data disk on Neptune. With the second disk installed it was possible to statistically clean and prepare data for gridding as work was completed within particular areas or survey blocks. Data added during Cruise 90 was treated in much the same fashion as CD89 data, thus enabling the final tape/printed 'products' to contain all of the data collected within the area.

During routine cleaning and preparation it was noted that anomalies were occurring in the swath data in areas which had been identified as having high levels of hydrothermal activity. The anomalies had a very distinctive signature and could easily be identified and 'removed' from the data set by reducing their status values. The correlation of these anomalies with the presence of plumes has yet to be established but if proven could lead to an interesting new detection method.

RP, RL

6. Shipboard Computing

The acquisition and processing of swath data has been dealt with in preceding section 5. During cruise 90, it quickly became clear that due to the irregular slow-speed survey the main gridding and contouring effort would have to be postponed. To this end one member of staff volunteered to remain onboard for the passage to the UK. The only significant difference in the logging from cruise 89 to cruise 90 was the absence of ADCP data as it was not thought necessary in the cruise area.

The 'ABC' system was largely trouble free but a number of problems were identified with apparently established software. In one case the acquisition of part of the acoustic navigation data was delayed for 12 hours. Unreported and undocumented changes to the message format meant that the original Mk.1 Level A could not be used. Attempts to program a Mk.II were hampered by the lack of a self identifying message and the consequent discovery of an inherent design flaw associated with message synchronisation.

RL, RP

7. Scientific Instrumentation

7.1 Oceano/Mors Acoustic Navigation System

The new LBL10 software did not perform satisfactorily. The relay positions did not match the ranges received from the transponders. Often the depth given was greater than any of the ranges. Ship position, however, was generally reasonable. During the cruise the software crashed a large number of times with the error message OVERFLOW IN MODULE LBL5 AT ADDRESS 42AB:16E9. It was also noted that the software regularly crashed at midnight in acoustic navigation mode.

The navigation input handling needs to be improved to allow for non-navigation messages which the Trimble outputs. These messages caused false surface positions and the absolute calibration file could not be generated from the Relative data without crashing the computer (again with overflow errors). The calibration data was obtained by manual selection values. These false positions also caused the screen to jump.

The data output string needs to be investigated further as it is felt that the positions given as the LAT & LONG do not agree with those given by the UTM coordinates.

The remote unit did not provide a usable interface for the bridge. The program was unstable and required rebooting several times. During the transponders deployment no position was displayed for the drop positions which makes the surface navigation mode unusable by the bridge for deployment. The remote display also needs keys to manually pan the display.

The plotter is too slow to set up to be of any use (20+ minutes to set up an A3 page!).

7.2 S40 L&R Gravitymeter

This gave no problems except for the hard disk becoming full causing the system to stop. The data was transferred to floppy disks and the system restarted.

7.3 Simrad EA500

No problems.

7.4 Winch Monitoring System

The readout on the bridge (Dredge/Core) needs checking. The unit did not reset and therefore did not give the correct readout during the last BRIDGET run.

DB

8. Scientific Engineering

The RVS Engineering Division provided technical support for the following scientific operations during cruise CD90/94:

- CTD (deployments)
- ZAPS (deployments)
- BRIDGET (deployments/towing operations)
- Oceano navigation system (deployments)

8.1 CTD deployments

All CTD operations were carried out successfully during the cruise, the only point of concern being the external condition of the cable. Excessive surface rust deposits on the wire may cause problems for science operations working in the trace metal field.

8.2 ZAPS deployments

All operations were carried out via the starboard "A" frame using the CTD wire. The instrument weighs approximately 0.5T in air so excessive movement of the package in air must be avoided. In adverse weather conditions additional measures would have to be adopted to ensure safe and effective deployments.

8.3 BRIDGET deployments

The vehicle was towed on the deep tow conducting cable via the stern gantry. All handling/towing operations were completed satisfactorily. Weighing 0.7 Tonne in air, recovery of the vehicle in poor weather using the present method may cause handling problems.

The vehicle has a significant drag factor which requires the lowering of the vehicle through the first 500m of water to be very slow (10-20 meters per minute). At speeds in excess of this, slack wire can be generated on deck due to the ship's movement. Within the constraints of the tow cable SWL, the package weight could be increased to improve the drag problem. A knock on effect would be a "closer to vertical" cable angle and, therefore, less cable length necessary for any required depth to be reached.

In general all overside operations were carried out by the various interdisciplinary teams satisfactorily, providing a good overall operational performance. It is important that in the future adequate levels of experienced manpower is maintained by the RVS technical and Marine deck departments on a 24 hour basis. This will ensure continuation of the high standard of overside operations required for the safe and effective execution of cruise programmes.

CD, JS

SUMMARY

RRS *Charles Darwin* cruise CD90/94 provided the first sea-trials of the new BRIDGE instrument for the detection, investigation and sampling of hydrothermal plumes: BRIDGET. The instrument has been developed as a joint project between the University of Cambridge and IOSDL; IOSDL took responsibility for i) basic frame design and construction and ii) acquisition of the standard sensors fitted to the instrument: CTD, nephelometer, transmissometer, altimeter, and 12 Niskin-bottle rosette. Cambridge took responsibility for iii) design and construction of the "brain" of the instrument, transmitting data signals from BRIDGET to the surface and returning power and command signals from the surface ship, together with iv) design and production of software to log and display the incoming data. The trials cruise proved remarkably successful. An initial deployment of the basic frame and pressure tubes to ~3,100m water depth was followed by a further 5 BRIDGET deployments made during just 6 days of station time at the newly discovered "Rainbow" vent-field, 36°15'N, Mid-Atlantic Ridge. Deployments were made in increasingly poor weather conditions, from Force 4/5/6 to conditions as poor as Force 7/8 during one recovery, thereby ensuring a thorough sea-trial of both frame *and* instruments.

Initial deployments confirmed the basic viability of the system although some teething problems were encountered in various components of the system (sensor stability, data communications, software processing). During required servicing time between BRIDGET deployments, available shiptime was maximised by carrying out inter-calibrations of sensors from BRIDGET with those available from the RVS CTD system and Dr.G.Klinkhammer's ZAPS sled (OSU). These latter two systems were also used to better define the prime target area for final BRIDGET deployments. Here, BRIDGET demonstrated it's key advantage over earlier systems - that it could be towed in any required direction through a hydrothermal plume. Towards the end of the cruise three approximately 10km-long W-E tows were made through the Rainbow vent-field, hauling and veering at 20m/minute between 1900 and 2300m depth (plume-height was at ~2075m). These sections indicated a strong plume being dispersed West to East away from its source and which could be detected more than 5 nautical miles "downstream". A final N-S line, cross-cutting the W-E lines close to the inferred source indicated nephelometer and transmissometer signals which were clearly the strongest ever seen in the Atlantic. Further, at the conclusion of ths final line, ~20km farther south in the South AMAR segment, the suspected presence of further hydrothermal activity, initially detected by TOBI during CD89/94, was confirmed.

CG

RECOMMENDATIONS

The following recommendations were arrived at during an end-of-cruise meeting aboard RRS *Charles Darwin* Cruise 90:

- Provision of a live track-navigation plotter in the main laboratory was considered to be of vital importance to scientists involved in the operations that were carried out during cruises 89 and 90 - not only to be able to observe the vessel's position in relation to the required survey tracks, but also to have the facility to plan and plot survey lines and determine way-points.

- With only the photo-copier in the Master's cabin now operational; it was deemed of great importance that a second machine was provided for scientific and general use. At the end of a cruise, numerous reports have to be prepared and a second copier - sited, possibly in the Computer Room - would be more readily accessible to the scientific customer and the technical support staff alike.

- The accuracy of the winch readout on the main conducting cable was suspect at the initial stages of deployment. It was requested that a logging system be developed/installed which would continuously monitor and record this essential information on the shipboard level A computer. A similar system is already operative on the Discovery and Challenger and is long overdue for the Darwin.

- Similarly, it was recognised that BRIDGET deployments would have benefited considerably from access to a heave-compensated winch. Again, such a system has been proposed previously for the Darwin but the designated winches were instead installed on the Discovery.

- The performance of the Oceano Transponder system was most unsatisfactory. Only 2.5 hours of useful data were obtained from the cruise, at the cost of some 24 hours of deployment/recovery time. For a trials cruise with only 7 days of station work available this was considered to be a quite unacceptable return. The scientific party, under 4-star service agreement, had been led to expect provision of an operative, fully-functioning system such as the PI's had experienced before (e.g. on the Mid-Atlantic Ridge in 1988, 1993 and on the East Pacific Rise in 1989). At the beginning of the cruise the PSO was advised that the system provided for CD90 was a new, improved version of the Oceano system used by him during CD77 in 1993. However, only after the transponders had been deployed and problems discovered with the system, was it made clear to the PSO that this was an untried system with no back-up. Had the PSO been made aware of all the information from the outset of the cruise it is questionable whether the transponders would have been deployed at all. Instead, the commitment to deploy and, hence, recover had already been made from a position of ignorance. With 4-star level shiptime at a premium within the UK mid-ocean ridge community, it is unlikely that this particular feature of the CD90 scientific operations will be looked upon favourably by the BRIDGE steering committee as the most efficient possible use of limited available resources!

CG, MS

ACKNOWLEDGEMENTS

It is a great pleasure, on behalf of the entire scientific party, to express my thanks to Captain R. Bourne, the officers and crew of RRS *Charles Darwin* Cruise 90. We were very fortunate to sail with such an enthusiastic, helpful and resourceful team . Particular thanks go to the Bosun and deck crew, RVS mechnical support staff and the Master and Chief Officer for their numerous helpful suggestions as we strove to improve our modes of deploying BRIDGET. Special thanks also to the catering/hotel department, whose standards were quite superb, and to the entire scientific support staff from RVS Barry who, as always, provided the excellent shipboard service which can too easily be taken for granted, but which fundamentally underpins all marine science.

RRS *Charles Darwin* Cruise 90 was supported by the NERC CRP "BRIDGE".

CG

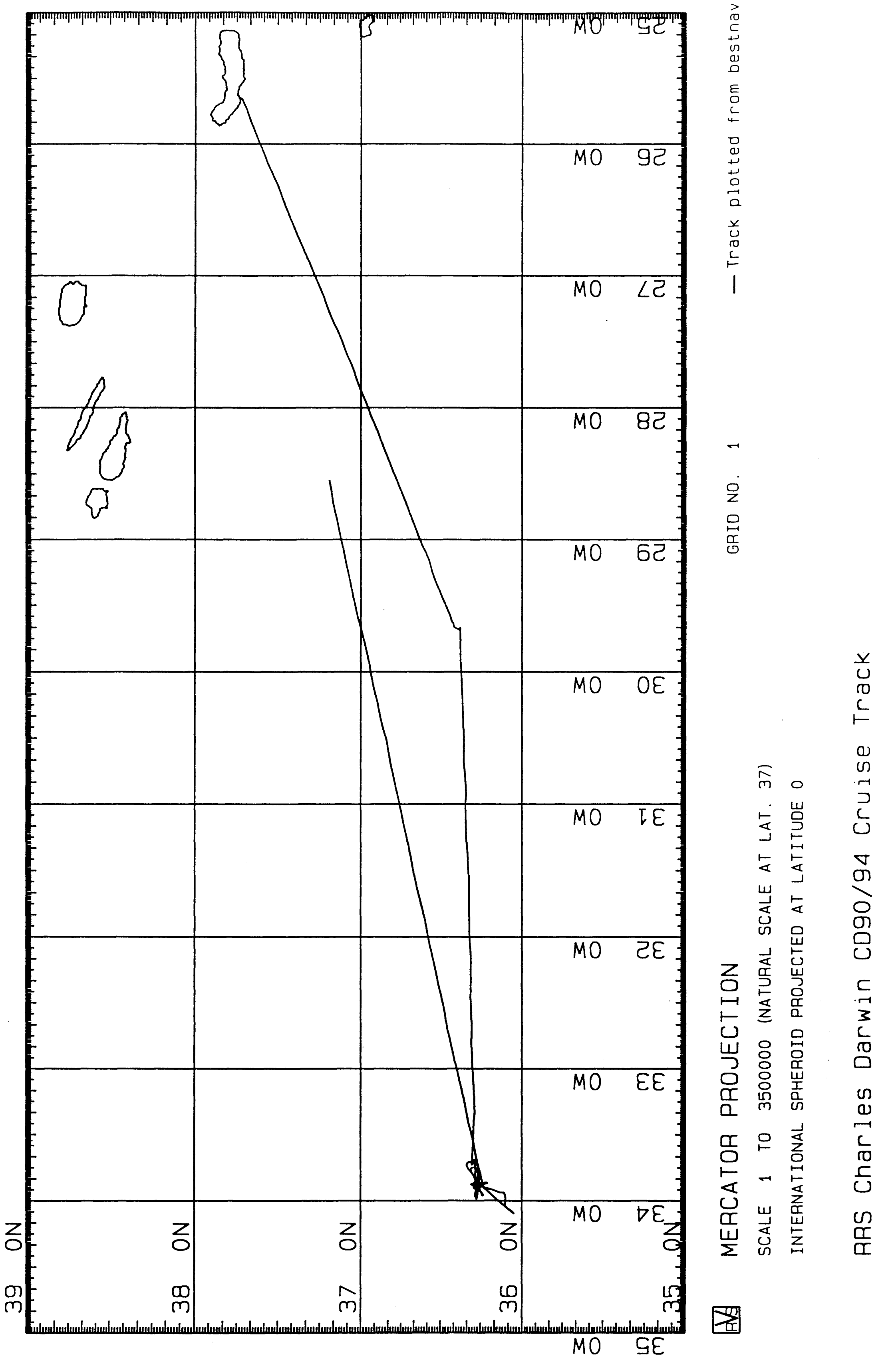

Fig. 1 Track chart: RRS *Charles Darwin* Cruise 90, 17-27 Sep 1994. Principal work area was at the Rainbow hydrothermal field, 36°15'N, Mid-Atlantic Ridge.

Appendix A

RRS CHARLES DARWIN - CRUISE CD90/94.

DIARY OF EVENTS.

Saturday 17th. September 1994.
0754 - Pilot Onboard.
0756 - SBE, Commenced Singling up.
0802 - All Gone and Clear For'd and Aft, Vessel Leaving Berth.
0806 - Pilot Disembarked.
0807 - Vessel Clear of Breakwater.
0818 - Full Away on Passage from Ponta Delgada, Sao Miguel, Azores.
0900 - Lat: 37 40.0 N. Long: 25 49.0 W. Simrad EM 12 Switched On.
1200 - Position Lat: 37 27.3 N. Long: 26 28.5 W.
1219 - Lat: 37 26.1 N. Long: 26 32.5 W. XBT No.32 Deployed, (90-01).
2400 - Lat: 36 36.8 N. Long: 29 02.4 W. XBT No.33 Deployed, (90-02).

Sunday 18th. September 1994.
0700 - Lat: 36 25.1 N. Long: 29 38.0 W. Vessel Hove To on Station.
0704 - Commenced BRIDGET Test Deployment, (90-03).
0712 - Lat: 36 25.1 N. Long: 29 38.0 W. Pinger attached at 50 metres.
0737 - Lat: 36 25.1 N. Long: 29 37.9 W. Transponder attached at 200 m.
0747 - Oceano Transponder Fish Deployed. Port Quarter.
0800 - Lat: 36 25.1 N. Long: 29 37.8 W. Set Co. 225 T.,Speed 1.0 knot.
0930 - Lat: 36 24.8 N. Long: 29 39.5 W. PES & 3.5 Khz.Fish Deployed.
0945 - Lat: 36 24.8 N. Long: 29 39.6 W. Ceased Veering at 3300 metres.
1026 - Lat: 36 24.1 N. Long: 29 40.2 W. Commenced Hauling.
1150 - Transponder Inboard.
1156 - Pinger Inboard.
1200 - Position Lat: 36 22.6 N. Long: 29 40.8 W. BRIDGET Inboard.
1204 - Lat: 36 22.6 N. Long: 29 40.8 W. XBT No.34 Deployed, (90-04).
1210 - Oceano Fish and 3.5 Khz.Fish Recovered.
1220 - Lat: 36 22.3 N. Long: 29 40.4 W. CTD Deployed, (90-05).
1240 - Lat: 36 22.4 N. Long: 29 40.2 W. CTD Veered to 500 metres.
1309 - Lat: 36 22.6 N. Long: 29 39.9 W. CTD Recovered. Co.268. Full Spd.
2356 - Lat: 36 18.6 N. Long: 32 06.6 W. XBT No.35 Deployed, (90-06).

Monday 19th. September 1994.
0919 - Lat: 36 18.1 N. Long: 33 43.3 W. Vessel Hove To, on Station.
0929 - Lat: 36 18.1 N. Long: 33 43.1 W. Oceano Transponder Fish Deployed.
1035 - Lat: 36 18.1 N. Long: 33 43.3 W. BRIDGET Vehicle Deployed (90-07).
1044 - Pinger attached at 50 metres.
1100 - Transponder attached at 200 metres. Commenced Veering Cable.
1137 - Commenced Hauling, BRIDGET Electronic Malfunction.
1200 - Position Lat: 36 17.3 N. Long: 33 42.7 W. Transponder on Surface.
1255 - Lat: 36 17.2 N. Long: 33 41.4 W. XBT No.36 Deployed (90-08).
1255 - BRIDGET Fully Recovered.
1305 - Oceano Transponder Fish Recovered; Set Course 270 True.
1424 - Lat: 36 17.0 N. Long: 33 54.5 W. Vessel Hove To for ZAPS Deployment.
1444 - Lat: 36 17.0 N. Long: 33 54.4 W. ZAPS Sledge Deployed (90-09).
1630 - Lat: 36 17.0 N. Long: 33 54.4 W. Veered to 2389 metres, Comm. Haul.
1726 - Lat: 36 17.1 N. Long: 33 54.3 W. ZAPS Sledge Recovered.
1755 - Lat: 36 16.9 N. Long: 33 54.1 N. BRIDGET Vehicle Deployed (90-10).
1801 - Pinger attached at 50 metres. Commenced Veering Cable.
1900 - Ceased Veering at 594 metres, Electronic Malfunction.
1917 - Lat: 36 16.4 N. Long: 33 52.8 W. Resumed Veering Cable.
2324 - Lat: 36 14.7 N. Long: 33 48.5 W. 2800 metres, Commenced Hauling.
2348 - Lat: 36 14.7 N. Long: 33 48.2 W. XBT No.37 Deployed, (90-11).

Tuesday 20th. September 1994.
0108 - Pinger Inboard.
0118 - Lat: 36 14.9 N. Long: 33 47.2 W. BRIDGET Fully Recovered.

0128 - All Secure, Set Course 281 True, towards ZAPS Site.
0212 - Lat: 36 16.1 N. Long: 33 53.4 W. Vessel Hove To on Station.
0214 - Lat: 36 16.2 N. Long: 33 53.5 W. ZAPS Sledge Deployed (90-12).
0421 - Lat: 36 16.0 N. Long: 33 53.2 W. Cable Veered to 2367 metres.
0426 - Hauling/Veering as Vessel Drifts North to Scientific Requirements.
0642 - Lat: 36 16.6 N. Long: 33 53.2 W. 2482 metres, Commenced Hauling.
0745 - Lat: 36 16.6 N. Long: 33 52.9 W. ZAPS Sledge Recovered.
0842 - Lat: 36 16.0 N. Long: 33 52.8 W. Vessel Hove To on Station.
0902 - Lat: 36 16.0 N. Long: 33 52.8 W. CTD Deployed (90-13).
1040 - Lat: 36 16.0 N. Long: 33 52.7 W. Hauling & Veering as required.
1135 - Lat: 36 16.02 N. Long: 33 52.72 W. CTD at 2443 metres.
1150 - Lat: 36 16.0 N. Long: 33 52.7 W. XBT No.38 Deployed (90-14).
1200 - Position Lat: 36 16.1 N. Long: 33 52.7 W.
1255 - Lat: 36 16.1 N. Long: 33 52.6 W. CTD Recovered.
1310 - All Secure, Set Course 225 True.
1327 - Lat: 36 15.5 N. Long: 33 53.6 W. Vessel Hove To on Station.
1353 - Lat: 36 15.5 N. Long: 33 53.6 W. CTD Deployed, (90-15).
1544 - Lat: 36 15.5 N. Long: 33 53.4 W. Comm. Drifting NE'ly as requested.
1609 - Lat: 36 15.71 N. Long: 33 53.16 W. CTD at 2374 metres.
1644 - Lat: 36 16.0 N. Long: 33 53.1 W. Commenced Hauling.
1721 - Lat: 36 16.3 N. Long: 33 53.0 W. CTD Recovered.
1754 - Simrad Swath System Switched off. Acoustic Oceano Fish Deployed.
1833 - Lat: 36 14.75 N. Long: 33 52.20 W. Transponder Deployed (90-16d).
1946 - Lat: 36 14.70 N. Long: 33 53.70 W. Transponder Deployed (90-16e).
2117 - Lat: 36 15.57 N. Long: 33 54.76 W. Transponder Deployed (90-16f).
2225 - Lat: 36 16.80 N. Long: 33 54.24 W. Transponder Deployed (90-16a).
2336 - Lat: 36 16.75 N. Long: 33 51.89 W. Transponder Deployed (90-16b).

Wednesday 21st. September 1994.
0054 - Lat: 36 15.60 N. Long: 33 50.40 W. Transponder Deployed (90-16c).
0111 - Commenced Calibration of Acoustic Beacon Array.
0150 - Lat: 36 15.8 N. Long: 33 51.9 W. Heave To, Oceano Fish Malfunction.
0231 - Oceano Fish Repaired, Resume Calibration Survey.
0640 - Completed Calibration of Acoustic Beacon Array.
0717 - Lat: 36 14.9 N. Long: 33 52.9 W. Set Course 285 for BRIDGET Deploy.
0908 - Lat: 36 16.2 N. Long: 33 58.1 W. Completing Instrumentation Checks.
1039 - Lat: 36 16.0 N. Long: 33 58.0 W. BRIDGET Vehicle Deployed (90-17).
1047 - Pinger attached at 50 metres.
1108 - Transponder attached at 200 metres.
1117 - Lat: 36 15.9 N. Long: 33 57.4 W. Course 090 True, Speed 1.0 Knots.
1154 - Lat: 36 15.8 N. Long: 33 56.4 W. XBT No.39 Deployed (90-18).
1200 - Position Lat: 36 15.8 N. Long: 33 56.3 W.
1837 - Lat: 36 16.0 N. Long: 33 46.6 W. BRIDGET Passes through End WP.
1846 - Commenced altering course to Port at 1 degree per minute.
2100 - Lat: 36 18.0 N. Long: 33 47.5 W. Steady on Course 246 True.
2400 - Lat: 36 16.6 N. Long: 33 51.0 W.

Thursday 22nd. September 1994.
0010 - Lat: 36 16.5 N. Long: 33 51.2 W. XBT No.40 Deployed (90-19).
0403 - Lat: 36 14.6 N. Long: 33 56.2 W. Vessel Passing Survey End-Point.
0403 - Commenced Hauling.
0531 - Transponder Inboard.
0540 - Pinger Inboard.
0552 - Lat: 36 14.0 N. Long: 33 57.5 W. BRIDGET Fully Recovered.
0716 - Lat: 36 15.8 N. Long: 33 53.1 W. Vessel Hove To on Station.
0724 - Lat: 36 15.8 N. Long: 33 53.1 W. ZAPS Sledge Deployed (90-20).
1000 - Lat: 36 15.8 N. Long: 33 53.2 W. Hauling and Veering ZAPS Sledge.
1200 - Position Lat: 36 15.8 N. Long: 33 53.1 W.
1234 - Lat: 36 15.9 N. Long: 33 53.0 W. XBT No.41 Deployed (90-21).
1523 - Lat: 36 16.0 N. Long: 33 53.6 W. ZAPS Sledge Recovered.
1608 - Lat: 36 16.4 N. Long: 33 53.4 W. Complete Load Test TOBI Swivel.
1630 - Lat: 36 15.6 N. Long: 33 53.4 W. Vessel Hove To on Station.
1648 - Lat: 36 15.6 N. Long: 33 53.4 W. CTD Deployed (90-22).

1750 - Lat: 36 15.6 N. Long: 33 53.3 W. CTD Veered to 2345 metres.
1839 - Lat: 36 15.8 N. Long: 33 53.2 W. CTD Recovered.
1848 - Lat: 36 15.9 N. Long: 33 53.2 W. CTD Deployed (90-23).
2000 - Lat: 36 15.9 N. Long: 33 53.2 W. CTD Veered to 2393 metres.
2047 - Lat: 36 15.9 N. Long: 33 53.2 W. CTD Recovered; Course 282 True.
2228 - Lat: 36 16.6 N. Long: 33 57.6 W. BRIDGET Vehicle Deployed (90-24).
2235 - Pinger attached at 50 metres.
2253 - Transponder attached at 200 metres; Veering Cable to 300 metres.
2308 - Lat: 36 16.4 N. Long: 33 57.5 W. Commenced altering course to port.
2324 - Lat: 36 16.2 N. Long: 33 57.3 W. Steady on 090 True; Veering Cable.

Friday 23rd. September 1994.
0029 - Lat: 36 16.0 N. Long: 33 56.0 W. XBT No. 42 Deployed (90-25).
0520 - Lat: 36 15.8 N. Long: 33 47.2 W. Vessel at End Waypoint.
0650 - Lat: 36 15.9 N. Long: 33 44.6 W. Commenced altering course to port.
0920 - Lat: 36 19.8 N. Long: 33 44.5 W. Steady on course 246 True.
1052 - Lat: 36 18.1 N. Long: 33 47.3 W. Vessel at start of Line Two.
1200 - Position Lat: 36 17.3 N. Long: 33 48.8 W.
1227 - Lat: 36 16.9 N. Long: 33 49.4 W. XBT No. 43 Deployed (90-26).
1344 - Lat: 36 16.1 N. Long: 33 51.8 W. Commenced Hauling from 2883 metres.
1609 - Transponder Inboard.
1617 - Pinger Inboard.
1626 - Lat: 36 12.5 N. Long: 33 52.0 W. BRIDGET Fully Recovered.
1631 - All Secure, Set Course for position of Oceano Transponder 'c'.
1754 - Oceano Transponder (90-16c) Released Released from Sea-Bed.
1819 - Lat: 36 15.8 N. Long: 33 50.3 W. Transponder Rig on Surface.
1829 - Lat: 36 15.9 N. Long: 33 50.3 W. Rig Grappled.
1834 - Rig Inboard; Set Course 310 True, for ZAPS Station.
1916 - Lat: 36 16.1 N. Long: 33 53.3 W. Vessel Hove To on Station.
1921 - Lat: 36 16.1 N. Long: 33 53.3 W. ZAPS Sledge Deployed (90-27).
2029 - Lat: 36 16.0 N. Long: 33 53.2 W. Commenced Drifting East.
2111 - Lat: 36 15.9 W. Long: 33 52.8 W. Commenced Hauling from 2169 metres.
2156 - Lat: 36 16.0 N. Long: 33 52.7 W. ZAPS Sledge Recovered.
2235 - Lat: 36 16.2 N. Long: 33 53.3 W. ZAPS Sledge Deployed (90-28).
2400 - Lat: 36 16.1 N. Long: 33 53.4 W. XBT No. 44 Deployed (90-29).

Saturday 24th. September 1994.
0531 - Lat: 36 15.8 N. Long: 33 52.4 W. Commenced Hauling from 2316 metres.
0623 - Lat: 36 15.9 N. Long: 33 52.4 W. ZAPS Sledge Recovered.
0650 - Lat: 36 16.9 N. Long: 33 51.9 W. Vessel Hove To, by Transponder 'b'.
0659 - Oceano Transponder (90-16b) Released from Sea-Bed.
0725 - Lat: 36 16.9 N. Long: 33 51.5 W. Transponder Rig on Surface.
0806 - Lat: 36 17.4 N. Long: 33 52.0 W. Rig Grappled.
0812 - Rig Inboard; Proceeding Towards Transponder 'a'.
0855 - Oceano Transponder (90-16a) Released from Sea-Bed.
0920 - Lat: 36 17.2 N. Long: 33 54.2 W. Transponder Rig on Surface.
0925 - Lat: 36 17.1 N. Long: 33 54.2 W. Rig Grappled.
0934 - Rig Inboard; Proceeding Towards Transponder 'f'.
1012 - Oceano Transponder (90-16f), Released from Sea-Bed.
1045 - Lat: 36 15.9 N. Long: 33 54.7 W. Transponder Rig on Surface.
1057 - Lat: 36 15.9 N. Long: 33 54.6 W. Rig Grappled.
1101 - Rig Inboard; Proceeding Towards Transponder 'e'.
1133 - Oceano Transponder (90-16e), Released from Sea-Bed.
1202 - Lat: 36 14.9 N. Long: 33 53.3 W. Transponder Rig on Surface.
1215 - Lat: 36 15.0 N. Long: 33 53.5 W. Rig Grappled.
1218 - Rig Inboard; Proceeding Towards Transponder 'd'.
1241 - Oceano Transponder (90-16d), Released from Sea-Bed.
1241 - Lat: 36 15.0 N. Long: 33 52.3 W. XBT No.45 Deployed (90-30).
1258 - Lat: 36 15.0 N. Long: 33 52.2 W. Transponder Rig on Surface.
1313 - Lat: 36 15.0 N. Long: 33 52.0 W. Rig Grappled.
1317 - Rig Inboard; Set Course 340 True for BRIDGET Deployment Position.
1330 - Lat: 36 15.9 N. Long: 33 52.2 W. Simrad Swath System Re-activated.
1400 - Lat: 36 18.2 N. Long: 33 52.7 W. Vessel Hove To on Station.

1454 - Lat: 36 18.0 N. Long: 33 52.3 W. BRIDGET Vehicle Deployed (90-31).
1504 - Pinger Attached at 50 metres.
1527 - Transponder Attached at 200 metres; Veering Cable; Course 196 True.
2400 - Lat: 36 12.7 N. Long: 33 54.1 W. XBT No.46 Deployed (90-32).

Sunday 25th. September 1994.

0555 - Lat: 36 07.3 N. Long: 33 52.2 W. Vessel at end of First Line.
0627 - Lat: 36 06.8 N. Long: 33 56.3 W. Commenced altering to Starboard.
0720 - Lat: 36 06.0 N. Long: 33 57.3 W. Steady on Course 270 True.
0952 - Lat: 36 06.1 N. Long: 34 01.2 W. Commenced altering to Port.
1043 - Lat: 36 05.8 N. Long: 34 02.5 W. Steady on Course 225 True.
1200 - Lat: 36 04.9 N. Long: 34 03.7 W. XBT No.47 Deployed (90-33).
1236 - BRIDGET Communications Malfunction; Commenced Recovering Vehicle.
1350 - Transponder Inboard.
1402 - Pinger Inboard.
1411 - Lat: 36 03.1 N. Long: 34 05.8 W. BRIDGET Fully Recovered.
1413 - Oceano Acoustic Fish Inboard; Set Course 043 True, at Full Speed.
1542 - Lat: 36 14.1 N. Long: 33 53.3 W. Vessel Hove To on Station.
1549 - Lat: 36 14.0 N. Long: 33 53.1 W. ZAPS Sledge Deployed (90-34).
1640 - Lat: 36 14.0 N. Long: 33 53.0 W. ZAPS Deployed to 2089 metres.
1718 - Lat: 36 13.9 N. Long: 33 52.5 W. PES Fish Inboard.
1736 - Lat: 36 14.1 N. Long: 33 52.3 W. ZAPS Sledge Inboard.
1736 - All Overside Science Completed; Set Course 077 True, Full Speed.

Monday 26th. September 1994.

Tuesday 27th. September 1994.

0800 - EOP, Approaching Ponta Delgada.
0830 - Pilot Boarded.
0845 - Vessel Rounding Breakwater.
0900 - Pilot boat alongside, commencing transfer of scientific party.
1000 - Scientific party all ashore. End of Cruise 90.

R.A.Bourne
Master.

Appendix B
TDMn samples collected from BRIDGET deployments

Station No:	CD90-17	BRIDGET 4	2.5L Niskins
Bottle No.	Depth (m)	Time	How fired
1	2114	16.40	FIRE
2	?400m	?11.10	?HR
3	2608<>2616	11.58	HR
4	1089<>1330	12.22	HR
5	1089<>1330	12.26	HR
6	1330<>1952	12.50	HR
7	2057<>2199	14.47	HR
8	2057<>2199	14.48	HR
9	2057<>2199	14.49	HR
10	2182<>2207	16.01	HR
11	2182<>2207	16.03	HR
12	2182<>2207	16.05	HR

Station No:	CD90-24	(BRIDGET 5)	2.5L Niskins
Bottle No.	Depth (m)	Time	How fired
1	1995<>2151	?4.30	HR
2	1995<>2151	?4.38	HR
3	1995<>2151	?4.54	HR
4	2159<>2246	1.52	HR
5	1893<>2159	2.09	HR
6	2231	3.00	FIRE
7	2039<>2231	3.30	HR
8	2039	3.33	HR
9	2108	3.34	FIRE
10	2108	3.34	FIRE
11	2085	3.50	FIRE
12	2088	3.57	FIRE

Station No:	CD90-31	(BRIDGET 6)	2.5L Niskins
Bottle No.	Depth (m)	Time	How fired
1		15.17	HR
2	2178	17.18	HR
3	2103	19.35	FIRE
4	2140	20.08	FIRE
5	2110	20.10	FIRE
6	2100	20.30	FIRE
7	1950	21.40	FIRE
8	1960	21.41	FIRE
9	2115	21.48	FIRE
10	2150	21.50	FIRE
11	1978	22.07	FIRE
12	1955	22.09	FIRE

Notes: HR = Collected passively during "Hard Reset".
FIRE = Collected actively under shipboard control.

Appendix C

TDMn samples collected from CTD-Nephelometer-Transmissometer stations.

Station No: CD90#13
Cast: CTD 14
Bottles: IOS 2.5 litre

Bottle #	Depth (m)
1	2362
2	2250
3	2150
4	2049
5	2035
6	2124
7	2408
8	2150
9	2098
10	2037
11	2001
12	1900

Station No: CD90#15
Cast: CTD 15
Bottles: IOS 2.5 litre

Bottle #	Depth (m)
1	2377
2	2300
3	2210
4	2168
5	2132
6	2066
7	1968
8	2065
9	2048
10	2045
11	2059
12	2059