Geological Survey of Canada

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Demonstration and Deployment of an Integrated System to Instrument an Offshore Well for the Purpose of Recording Wellbore Temperatures - Phase III

by

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SUMMARY

The Earth Physics Branch, Department of Energy, Mines and Resources has been accumulating precision subsurface temperature data and physical property measurements such as permafrost phenomenon from over 100 land based exploratory well sites throughout the Canadian high Arctic for the past 20 years. These measurements have been made in most cases from specially preserved holes drilled in the normal course of resource exploration. Joint cooperative programs between Energy, Mines and Resources, exploration companies and government regulatory agencies has yielded remote geothermal data which has found considerable application to industry, government regulators and the scientific community. This data base, although very complex in nature, lacked valuable information about the earth's crust below the Arctic sea floor.

To this end, the Department of Energy, Mines and Resources undertook a three phase multi-year project to develop both equipment and techniques for the measurement of Arctic offshore thermal dynamics.

Phase 1 of the project involved the development of a methodology of acquiring temperatures from abandoned or suspended offshore exploratory wells in the Canadian Arctic. This phase was completed by EBA Engineering Consultants Ltd., Calgary, Alberta in fiscal year (FY) 1982, resulting in the recommendation of both instrumentation and techniques.

During FY 1984, Dobrocky Seatech Ltd. provided engineering and technical support to the Department of Energy, Mines and Resources, Earth Physics Branch during the development of a unique electronic measurement and logging system for measurement of terrestrial heat flow beneath the ocean floor. Equipment and techniques were designed and implemented which enabled the long term monitoring of changes in wellbore temperatures resulting from activities of offshore exploration.

A sequence of procurement, receiving and acceptance activities involving several manufacturers, bench and field tests of individual and integrated components comprising a geothermal data acquisition system were executed by Dobrocky Seatech Ltd. These involved the supply and integration of a multithermistor temperature cable by the Maloney-Envirocon Company of Houston, Texas, an Underwater Acoustic Telemetry and Recording System by Mesotech Ltd., Vancouver, B.C., and the manufacture of an Environmental Container and supportive miscellaneous hardware by Dobrocky Seatech Ltd.

Final demonstration and deployment were accomplished in FY 1985 by Dobrocky Seatech Ltd., under the direction of Energy, Mines and Resources and with the assistance of Panarctic Oils Ltd. The entire system was deployed successfully in 250 metres of water at Panarctic et al. Cape Allison C-47, in the Canadian high central Arctic between Ellef Ringnes and King Christian Islands (Latitude 77°46.1' N Longitude 100°17.3' W) (Figure 1).

This project has not only improved our understanding of Arctic thermal dynamics, but also has aided in the development of electronic data collection systems capable of long term unattended operation in the earth's most severe of climates.

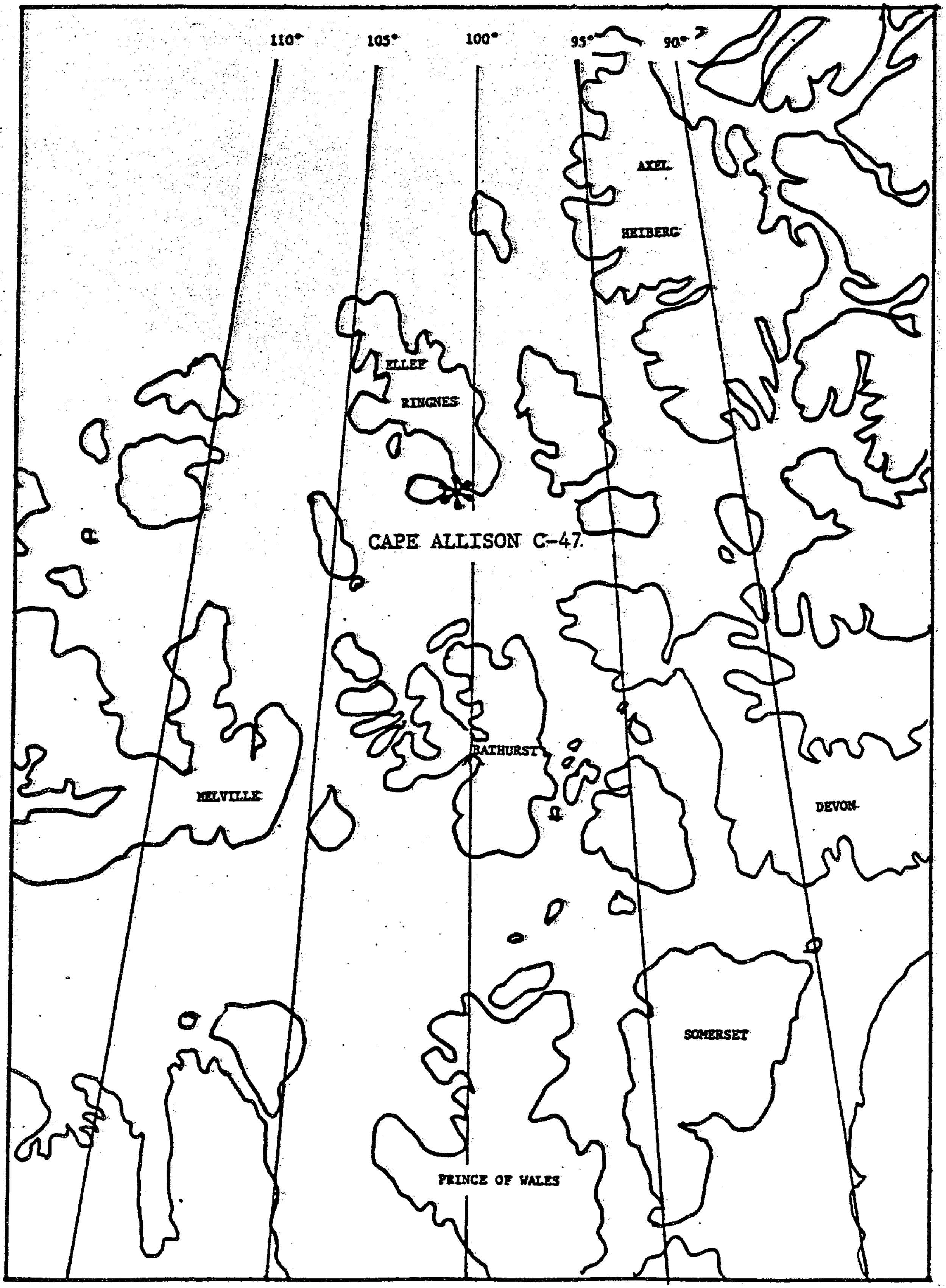

Figure 1 - Map of Deployment Area

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TABLE OF CONTENTS

TABLE OF CONTENTS

continued

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This report describes a unique, multiyear research and development project in support of E.M.R.'s permafrost research program. The project addressed the problem of long-term measurement of subsurface temperatures below the seabed in ice infested waters. The below-seabed measurements were required to complement land-based surveys.

A specialized instrument was designed to collect temperature data from abandoned offshore oil wells. The instrument consisted of:

(1) a 1000 m downhole thermistor chain;
(2) an acoustic transmitting processor attached to the thermistor chain and located near the wellhead;
(3) an acoustic receiving processor on the ice surface; this unit received and stored the acoustically transmitted temperature data.

Downhole temperatures could be measured, acoustically transmitted and recorded by the surface unit, even though ice movement might move the surface unit several kilometers from the wellhead. The operational life expectancy of the seabed-mounted electronic package is five years, and permits reoccupation of the station for several years.

The system was deployed at a Panarctic Oils Ltd. abandoned well in the arctic (Cape Allison C-47). The surface unit, which was unattended, collected temperature data for three months following deployment (May to July, 1985). In November of 1985 the station was reinstalled to collect additional data (system is still in field at present time).

The system performs well, generally exceeds operational expectations and offers a valuable tool for monitoring sub-seabed temperatures in offshore locations.

1.0 INTRODUCTION

The following report summarizes activities of the technical staff of Dobrocky Seatech Ltd. during the implementation and execution of the Department of Supply and Services contract number 07SQ-23235-4-0555. This contract was awarded in support of a Department of Energy, Mines and Resources project titled "Integrated System to Instrument an Offshore Well for the Purpose of Recording Wellbore Temperatures".

This contract concludes a two-year project during which Dobrocky Seatech Ltd. provided technical assistance during the design, procurement and final testing of all electronic subsystems and supportive mechanical hardware. Continued communications between members of Dobrocky Seatech Ltd., the Department of Energy, Mines and Resources, and major component manufacturers ensured the highest degree of success.

During the manufacturing period, members of Dobrocky Seatech Ltd. technical and engineering staff visited the facilities of all subcontractors, to ensure design specifications were maintained, and on schedule. Modifications to subsystems were suggested and implemented under the direction of the Department of Energy, Mines and Resources. Delivery and acceptance of all components followed a lengthy period of testing at the manufacturer's facilities.

Once accepted, a suite of tests at Dobrocky Seatech Ltd. facilities in Sidney, B.C. were undertaken. During this testing a number of engineering faults were defined and subsequently rectified after return to their respective manufacturer.

Testing was completed in three stages. Bench tests were conducted at Dobrocky Seatech Ltd. electronic facilities in Sidney, B.C. Shallow water tests were performed in Pat Bay, under the direction of the electronics manufacturer. Testing was completed under Arctic conditions near Little Cornwallis Island, N.W.T. After specifications had been satisfied, a report was prepared and submitted which detailed the results of each test. A second phase was undertaken whose objective was the design and construction of the supportive mechanical hardware required for the deployment of the total system in an abandoned offshore oilwell in the high central Arctic. The culmination of this phase was the successful deployment after well abandonment, recovery prior to summer ice break-up, and redeployment the following winter.

As of this writing, the system has been redeployed, and is performing well above all expectations.

The following report details the individual activities during each phase of the project. Recommendations have been included to improve the suite of electronic and mechanical subsystems. The technique required during installation and subsequent recovery has also been examined, with recommendations presented.

2.0 SUMMARY OF EVENTS

Following the conceptual development and equipment selection by EBA Engineering Consultants Ltd., Dobrocky Seatech Ltd. was engaged by Energy, Mines and Resources to procure and fully test a proposed system, with a view to obviating both anticipated and unforeseen problems normally associated with state-of-the-art electronics and mechanics.

Specifications were prepared to which this instrumentation must perform. The engineering staff of Dobrocky Seatech Ltd. ensured that these specifications were maintained during the manufacture, through continued communications with individual manufacturers. Individual subsystems underwent a suite of rigorous tests, which defined operational capabilities and verified specifications. In many cases, after both field and bench tests had been completed, initial specifications had been surpassed. Design specifications and resulting manufacturing techniques, plus the tests each subsystems underwent are detailed in the following sections.

2.1 DESIGN CRITERIA

The conceptual design of individual electronics systems had been completed by EBA Engineering Consultants Ltd. Dobrocky Seatech Ltd., after award of contract, visited all subcontracted manufacturers to review requirements and individual specifications to which they were to comply. As the design of each subsystem was in fact conceptual, members of Dobrocky Seatech Ltd. engineering and technological staff worked jointly with manufacturers to ensure that the project direction was maintained. Deviations from specification were authorized by members of Energy, Mines and Resources prior to manufacturing changes.

The following sections detail the specification for each individual subsystem, and the design criteria agreed upon through meetings with members of Dobrocky Seatech Ltd., Energy, Mines and Resources, and the individual manufacturer.

2.1.1 Data Acquisition System Design

The contract awarded to Dobrocky Seatech Ltd. indicated the preferred method of measuring and logging wellbore temperature data was via a Mesotech model 515 Acoustic Telemetered Underwater System, coupled acoustically to a Mesotech model 516/611 Special Acoustic Telemetry Surface Station as indicated in EBA's report to EMR in July of 1983. This system was a conceptual electronics acoustic data gathering device and as such, had not previously been manufactured.

Following placement of a purchase order for the complete Mesotech acoustic data telemetry and recording system, a meeting was scheduled between the engineering staff of Dobrocky Seatech Ltd. and the design and engineering staff of Mesotech Systems Ltd. at the Mesotech facility in Vancouver, B.C. Discussions with Mesotech's senior hardware and software engineers covered such topics and the overall project objectives, the data acquisition design, the physical and electronics specifications that each much attain, as well as internal software performance and data presentation. Plans for delivery and acceptance testing were also reviewed and agreed upon.

It was agreed that the system would meet all specifications as originally indicated, with the exception of the memory storage media. Mesotech suggested that the original EPROM memory be replaced with a state-of-the-art bubble memory system.

Final design and fabrication followed a series of communications between all subcontracted manufacturers to ensure that all mechanical and electronics mating connectors were within specifications. Mechancial design and machining of the housings and control chassis began, followed by wiring, component integration and software development. Discussions with EMR ensured that project direction was maintained and that modifications to the original specifications were in agreement.

The finished product system was assigned new model numbers. The surface telemetry and data logging system was allocated the Mesotech Model #612 and was in future referred to as the Temperature Telemetry Surface Unit (Figure 2.1). The underwater measurement and telemetry system was assigned athe Mesotech Model #532 to be referred to as Temperature Telemetry Underwater Unit (Figure 2.2).

The system has two major modes of operation, Normal and Test. In the Normal mode, the Surface Unit will power up at present logging intervals (e.g., every four hours) for a period of up to two years and request and receive a set of 12 bit resolution data from 18 channels from the Underwater Unit. After receiving all the data, the units non-volatile bubble memory is powered up and the collected data is stored in the next available data location for retrieval at a later date. After recording is completed, the unit reverts to a low power mode, and will remain in this state until the next logging interval occurs, or until the system is switched to the Test mode by the front panel switch. This procedure will repeat until the memory becomes full with 4090 sets of data, at which time the unit will continue to power up at regular intervals and collect data, but no attempt to overwrite the existing data will be made.

When the system is the Normal mode, no display is provided and none of the front panel function pushbottons have any effect.

In the Test mode the operator may, through a series of front panel switches, integrate/display new, or previously recorded data, output recorded data to the serial interface, or erase the system's memory. The system display is active and displays the record number (sequential numbering of data sets recorded), channel number, data, and error codes. If no error is indicated, the Idle mode will be entered. If no further buttons are pressed the Surface Unit will exit the Test/Unit mode and reset to its Normal mode.

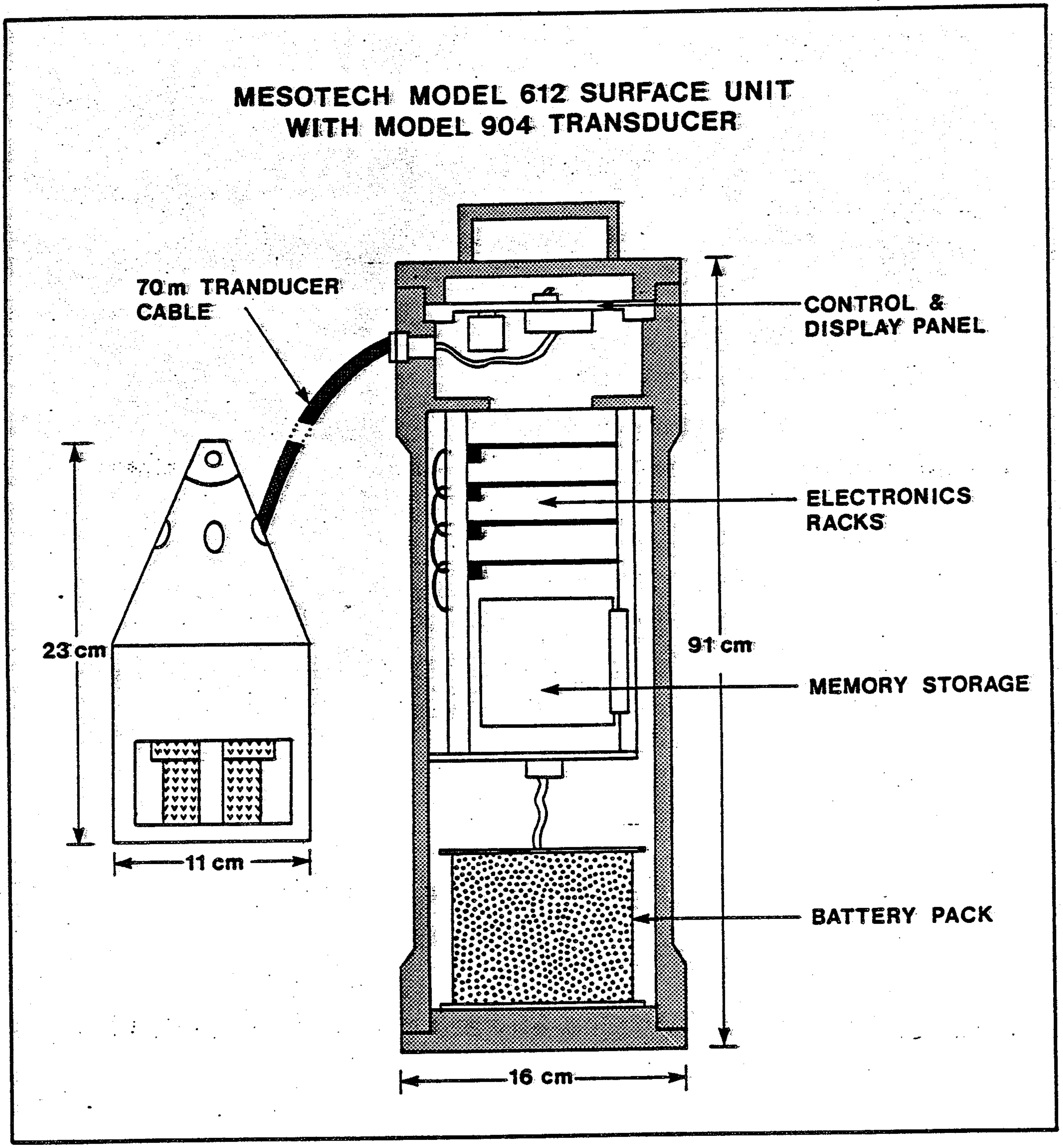


Figure 2.1 – Mesotech 612 Surface Unit

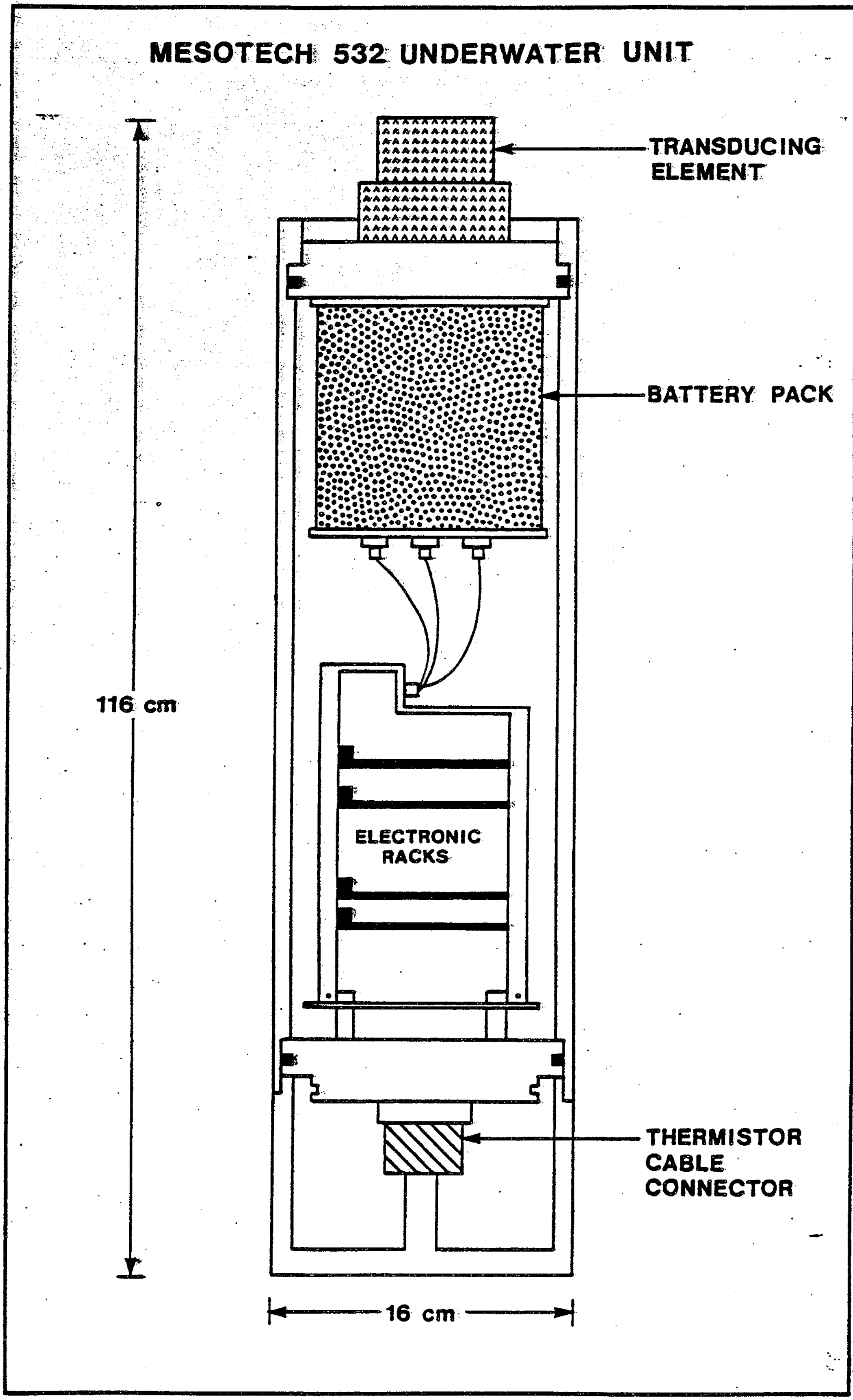


Figure 2.2 - Mesotech 532 Underwater Unit

Other modes of operation include the Memory to RS232 mode, used during data recovery from the system bubble memory, and the Memory Erase mode which will erase the contents of the memory, such that all data currently recorded will be erased and a new system directory initialized.

Data is displayed on a seven digit LED display. All values are shown in decimal form with the exception of the error codes. The leftmost two digits are the channel field and the right five digits are the data field. Record numbers for recorded data range from 6 to 4095. Playback of data always starts with the most recently recorded data set and proceeds backwards in time towards record number 6. Records 0 to 5 are reserved for the systems usage. Telemetry data is displayed sequentially, with the corresponding channel number. After the final channel (18) is displayed, an additional data value is output, which is the two way elapsed time between the surface and underwater units. This value can be used to calculate an approximate range between the two units.

A Mesotech model #904 Underwater Transducer was connected via 70 metres of conducting cable to the Surface Unit to provide remote storage of the Surface Unit in the proposed Environmental Container.

Specifications for all Mesotech systems are summarized in Tables 2.1 and 2.2.

2.1.2 Thermistor Cable Design

Following confirmation of specifications with both the Scientific Authority and Maloney Precision Products, a purchase order was placed through T. Thompson Ltd. for the manufacture, integration and supply of all thermistor cable components. This order included a 1000 metre thermistor cable with a series of 16 Fenwal precision thermistors placed at predetermined intervals along its length plus, all mechanical and electronic terminations.

MODEL 612 TEMPERATURE TELEMETRY SURFACE UNIT

A.	Operating Frequency:	15 - 20 KH_z
B.	Telemetry System:	Mesotech Type 440 FSK-PS Transmit and Receive
C.	Battery Life:	1 year minimum (2 years if Test Mode not over used)
D.	Electrical Transmit Power:	100 Watts
E.	Housing:	NEMA 4 waterproof enclosures
F.	Dimensions:	16.8 cm diameter, 91 cm length
G.	Weight	18 kg
H.	External Connection:	To transducer via MIL spec connector on NEMA 4 housing

Table 2.1 Mesotech 612 Surface Unit

MODEL 532 TEMPERATURE TELEMETRY TRANSPONDER UNIT

A.	Operating Frequency:	15 - 20 KH_z
B.	Telemetry System:	Mesotech Type 440 FSK-PS Receive and Transmit
C.	Max. Operating Depth:	1,000 m
D.	Battery Life:	2 year minimum at 10 sets of 18 readings per day
E.	Electrical Transmit Power:	100 Watts
F.	Housing	Aluminum-alloy 6061-T6, anodized epoxy painted and sacrificial anode protected
G.	Dimensions:	16.8 cm diameter, 107 cm length
H.	Weight:	45.5 kg in air, 13.6 kg in water

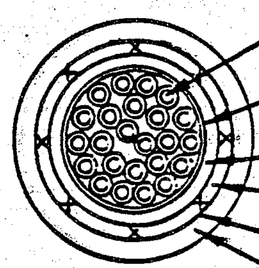
Table 2.2 Mesotech 532 Underwater Unit

Maloney Precision Products reviewed the original cable specifications and suggested that rather than subcontracting Rochester Cable Corp. for the manufacture of the cable as was originally proposed, that they fabricate the entire system at their facilities in Houston, Texas. The advantages of producing the entire system at the Maloney facility was the day-to-day control during fabrication. Intercomparison of manufacturer's specifications indicated that a cable produced by Maloney would be identical to one produced by Rochester. Internal wiring of the cable was discussed by Mesotech, Maloney, and Dobrocky Seatech Ltd., with critical attention given to the mating connectors and the thermistor numbering system. Prior to fabrication, discussions between the manufacturer, EMR and Dobrocky Seatech Ltd. concluded that individual thermistors should be attached to the main thermistor cable by a series of break-outs that permitted the removal of each thermistor during calibration and shipment. Production of the entire thermistor chain began after approval of the Scientific Authority. The resulting "as built" specifications for the entire multithermistor cable are listed in Table 2.3.

2.1.3 Mechanical System Design

The design of all mechanical supportive hardware was undertaken by the engineering staff of Panarctic Oils Ltd. under separate contract to EMR. A series of scheduled meetings between the engineering staffs of Panarctic Oils, Dobrocky Seatech Ltd. and EMR at Panarctic Oils' facilities in Calgary, Alberta finalized all design criteria and techniques.

The uniqueness of this project required that individual mechanical subsystems be designed to enable the insertion of the entire 1000 metre thermistor cable and the Underwater Unit into a recently abandoned exploratory wellbore from a Panarctic Oils' ice strengthened drilling platform in the high central Arctic. The entire system was deployed by a drilling crew using conventional drilling equipment. Hardware was sufficiently robust to withstand the riggers typical of drilling activities, and provide mechanical protection to all subsea electronics



SPECIFICATIONS

Length	1000 m
Diameter	16 mm
Minimum bend diameter	76 cm

ELECTRICAL PROPERTIES

Conductor DC Resistance:	11 Ohms/M' maximum
Voltage Rating:	600 VRMS
Insulation Resistance at 500 VDC:	1000 Megohms/M'

MECHANICAL PROPERTIES

Minimum break strength:		11,800#
Calculated weight:	In air:	227#/M'
	In seawater:	87#/M'
Filled Construction.		
Specific gravity		>1.2
Able to withstand freeze-in		

Table 2.3 - Multi Thermistor Cable Specifications

during and after deployment activities. The Underwater Unit was electronically isolated from a protective housing.

The initial meeting between all interested parties resulted in the definition of a technique to deploy the entire system. The mechanical supportive hardware was briefly discussed, with the final design to be coordinated through further meetings between Panarctic Oils and Dobrocky Seatech Ltd. Subsequent meetings finalized all techniques and defined all mechanical fabrication to be undertaken by Dobrocky Seatech Ltd.

Blueprints detailing four individual subsystems were drawn and submitted by the engineering staff of Panarctic Oils. The first of these subsystems was a series of four Stabilizer Bars (Figure 2.3) which were to be welded to the exterior of the outermost (508 mm) casing. The purpose of these bars was the prevention of lateral motion of the casing walls after the casing had been cut. The casing stub, which remains attached to the BOP stack after being cut, would normally attempt to align itself with the drilling platform situated on the ice surface. The cause of this lateral motion is the horizontal displacement of the ice surface which, between the period of well spud and abandonment, may reach tens of metres. These bars were fabricated under subcontract by Dobrocky Seatech Ltd. and delivered to Panarctic Oils in Edmonton, Alberta prior to the commencement of drilling, and were welded to the exterior of the 508 mm casing at a point which would permit a casing cut at exactly 5.75 metres below the top of the Blind Shear Rams contained within the BOP stock.

Figure 2.4 depicts the final design and placement of the Stabilizer Bars relative to the BOP stack, and gives an indication of the point at which the 508 mm casing must be cut.

The second mechanical subsystem designed was called the Hanger Assembly, (Figure 2.5) and its requirements were two-fold. Primarily, a system was required which would provide a platform to which the Underwater Unit could be secured at a nominal height above the ocean floor, and provide

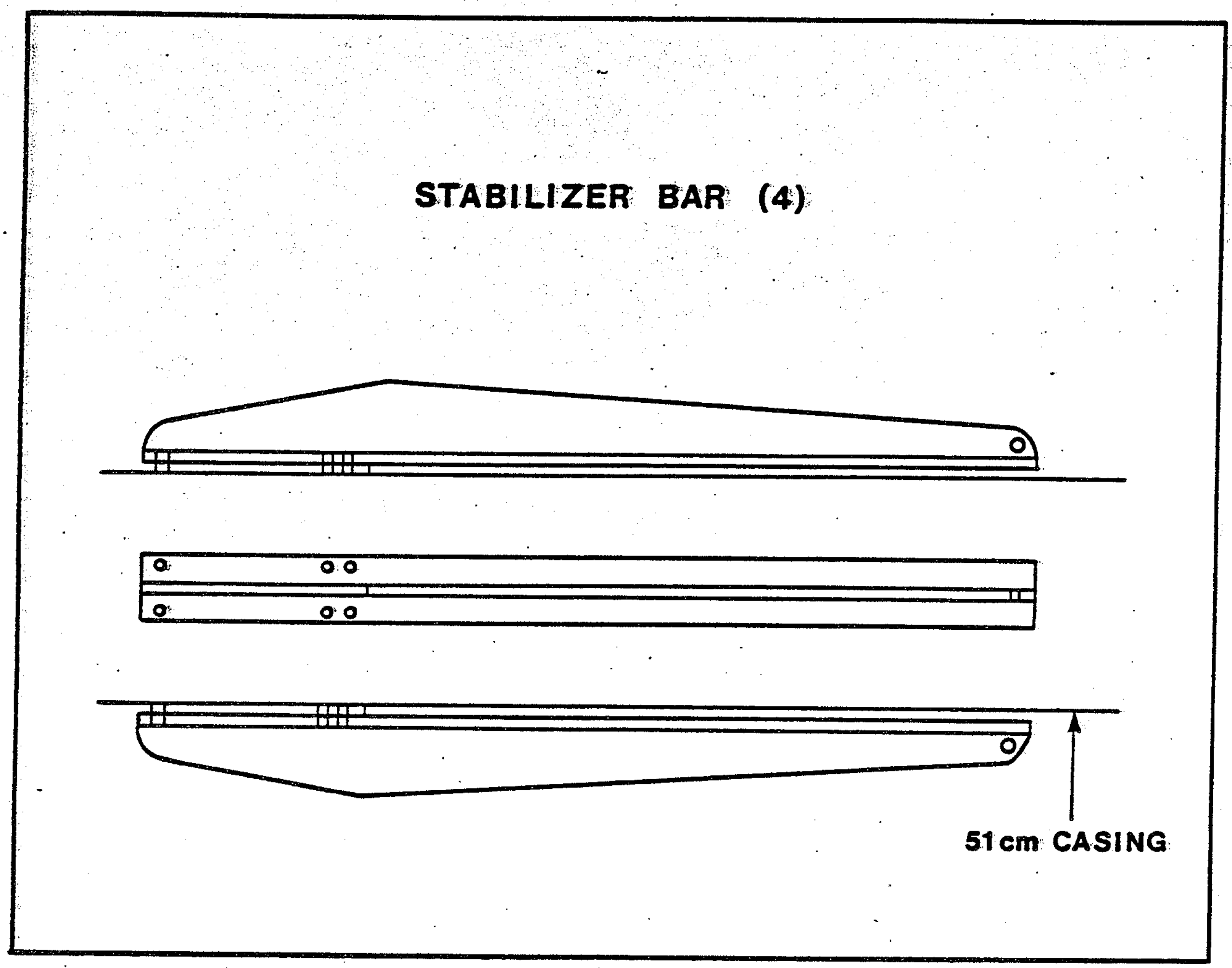


Figure 2.3 - **Stabilizer Bars**

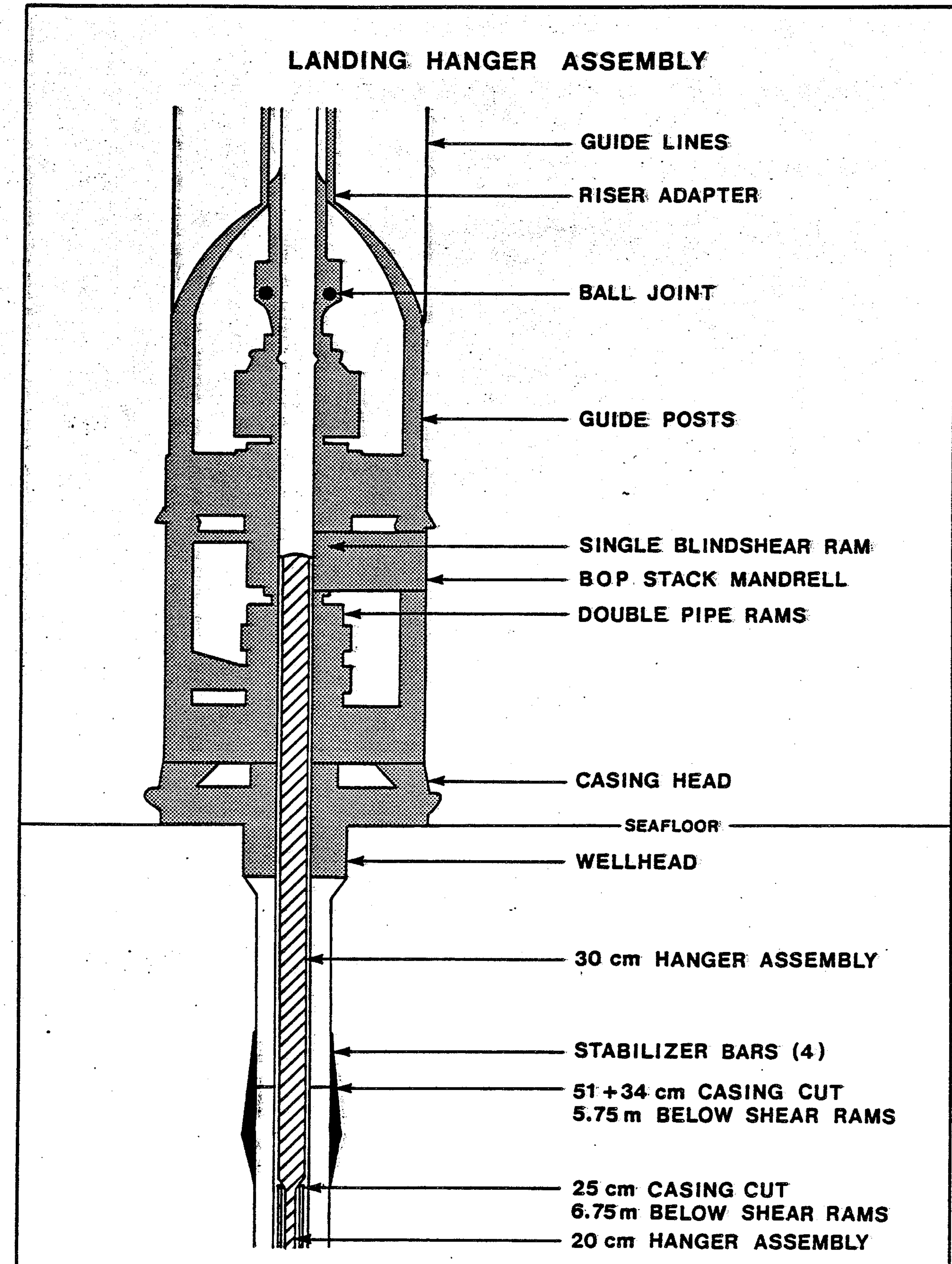


Figure 2.4 - Placement of Stabilizer Bars

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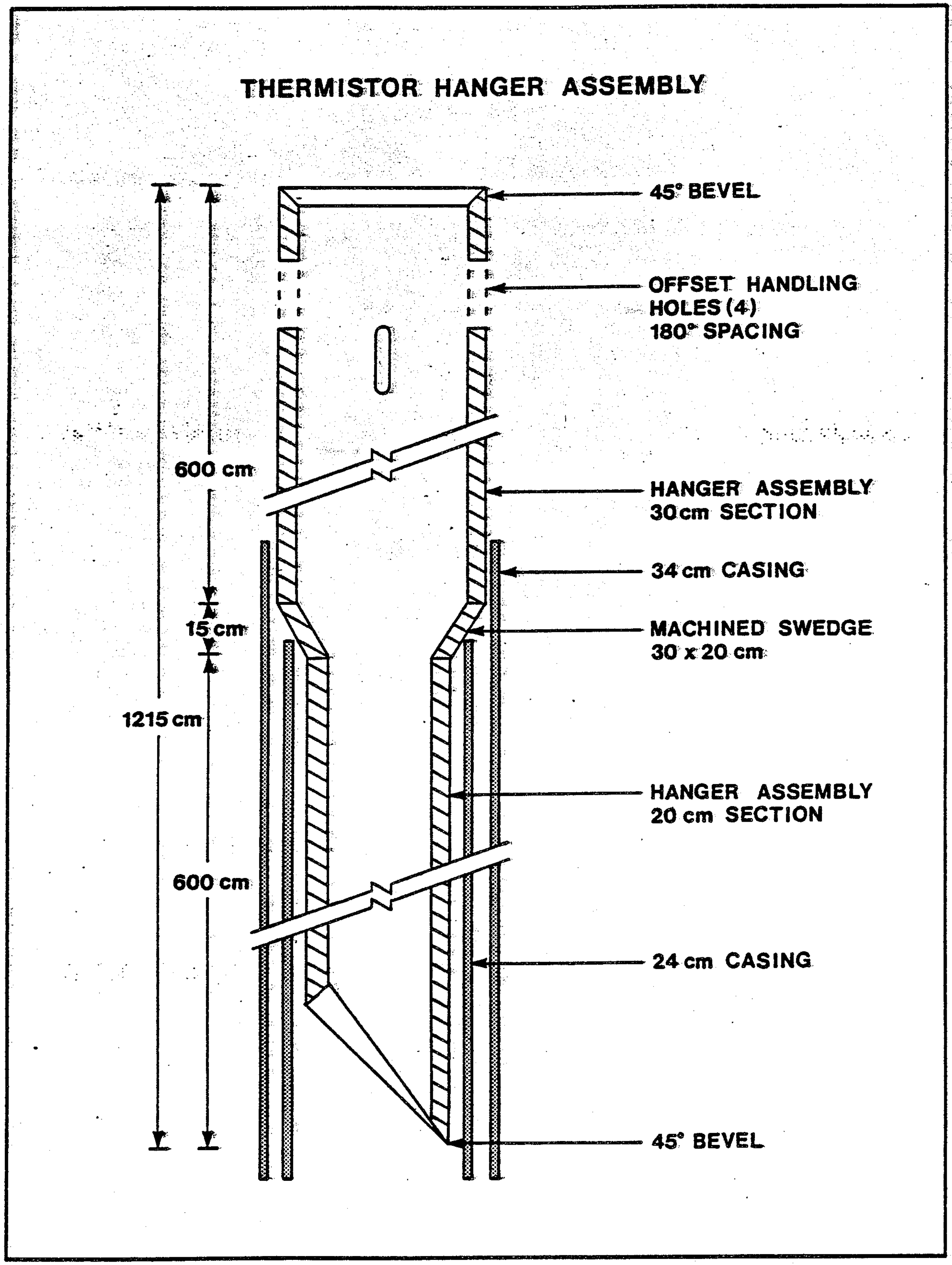

Figure 2.5 - Hangar Assembly

provide mechanical protection to this electronics package during recovery of the BOP stack and the remaining subsea hardware. The second design criteria required the Hanger Assembly to provide a smooth continuous entrance into the abandoned wellbore through which the thermistor cable must pass.

The final structure was comprised of two sections of tubular drilling materials of different diameters (298 mm and 203 mm casings) coupled together in the center with a machined swedge. The total overall length of this system was in excess of 11 metres. A 45 degree bevel was cut in the bottom edge to assist during insertion into the wellbore. The Hanger Assembly was fabricated by Dobrocky Seatech Ltd. and delivered to Panarctic Oils in Edmonton for furtherance to the deployment site.

The third mechanical subsystem was referred to as an Electronics Protection Sleeve, and was designed to provide mechanical protection to the subsurface electronics during "run-in" and subsequent recovery of the BOP stack. This sleeve was of sufficient dimensions to contain the Underwater Unit electronics package including its transducing element. The entire sleeve was designed to land on a beveled upper edge of the Hanger Assembly with the majority of the electronics housed within both the Electronics Protection Sleeve and the Hanger Assembly. A cross sectional diagram of the Environmental Protection Sleeve is found in Figure 2.6. Figure 2.7 indicates the configuration envisaged at the wellhead.

The fourth mechanical subsystem was a simple weight to be attached to the lower end of the thermistor chain. This weight must provide sufficient downward force to overcome friction caused by residual drilling fluids contained within the wellbore. The weight must be small enough in diameter to permit free passage through the smallest casing installed in the well (Figure 2.8).

2.1.4 Environmental Enclosure Design

The severity of the Arctic environment requires that any instrumentation left on the ice surface for prolonged periods of time be protected from extremes in temperature, wind and animal investigation.

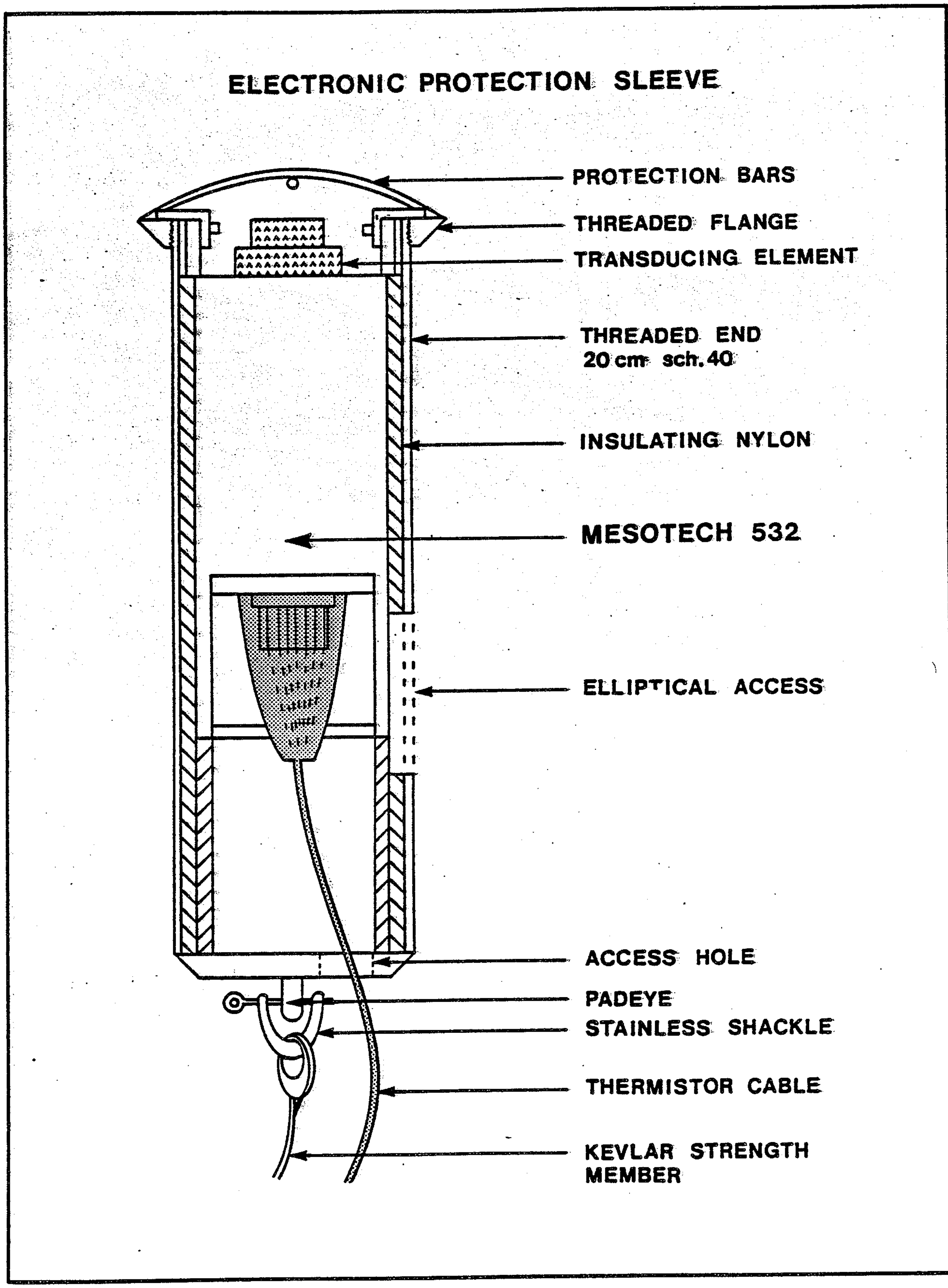

Figure 2.6 - Environmental Protection Sleeve

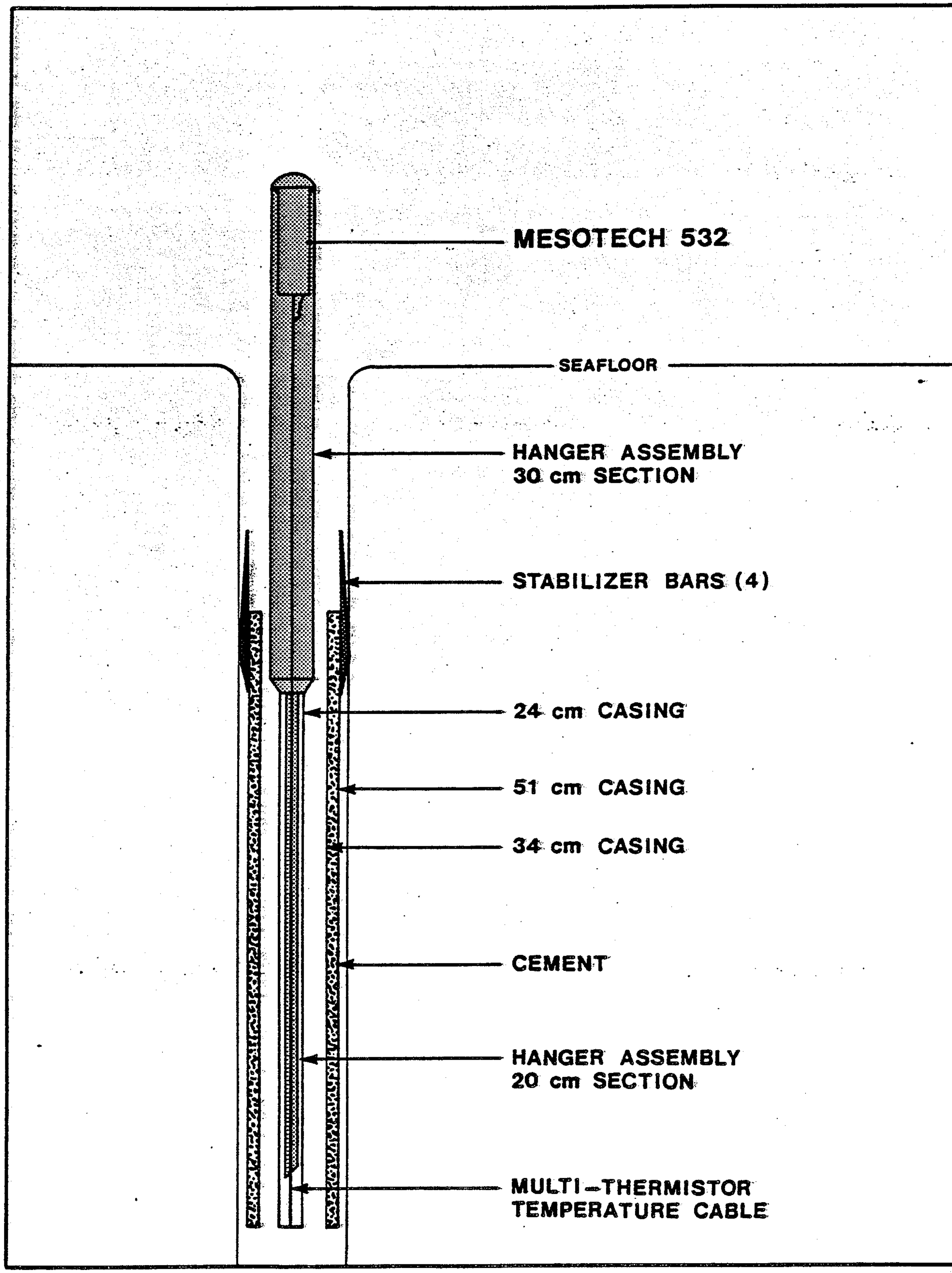

Figure 2.7 - Wellhead

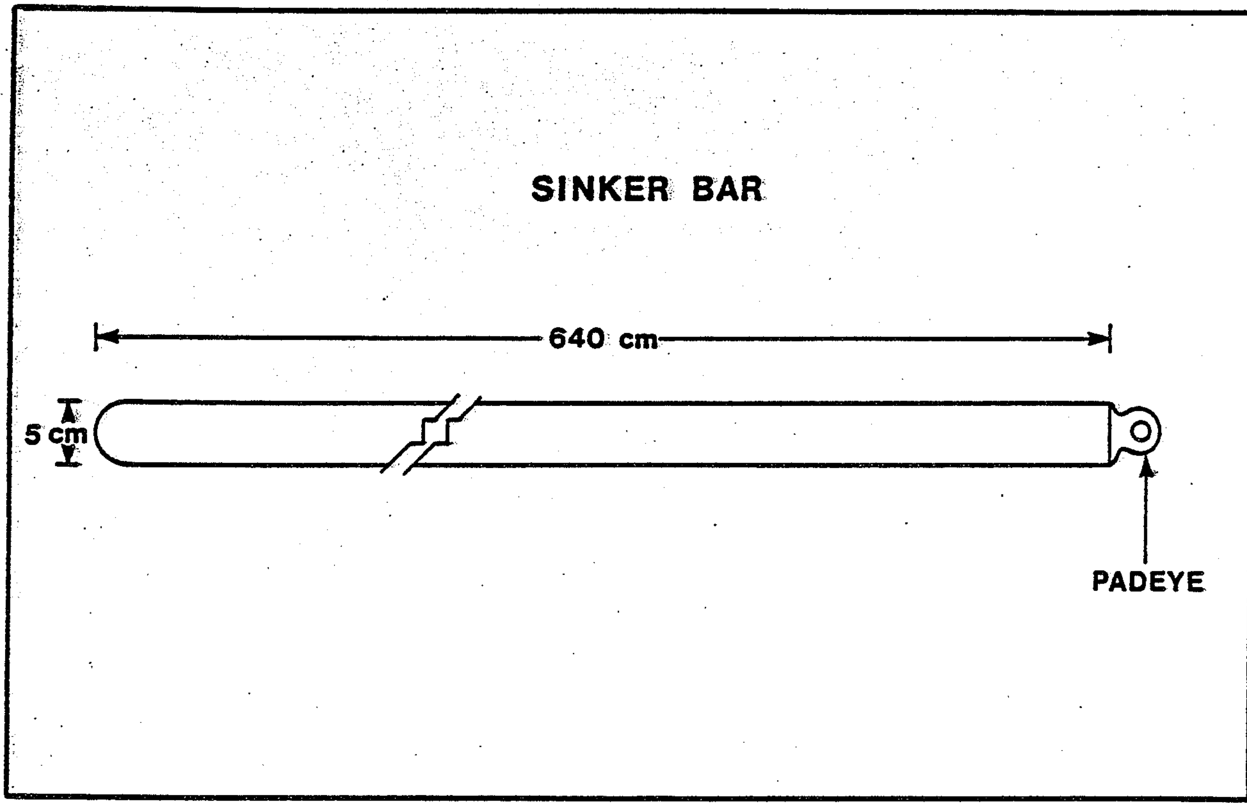

Figure 2.8 - Sinker Bar

As this program required that data be collected from the ice surface after the well site had been completely abandoned, some form of thermal enclosure was required to protect the surface electronics from environmental extremes and animal investigation.

With these considerations in mind, the technical staff of Dobrocky Seatech Ltd. began evaluating existing commercially available enclosures. A number of manufacturers were contacted and specifications for their products compared against project requirements. A number of enclosures were defined that provided the required thermal protection, but were unable to match the size requirements necessary to house the Surface Unit and its supportive cabling. The decision to undertake fabrication of a propane heated thermal enclosure was made, relying upon Dobrocky Seatech Ltd.'s experience with a similar enclosure successfully deployed in the high Arctic in support of a similar remote data gathering program.

The final design (Figure 2.9) employed a two stage, low volume propane burner enclosed in a two tier steel container. The upper tier, housed the Surface Unit encased in two part "pour-in-place" urethane foam. This foam was fabricated in such fashion as to provide a minimum of 12 inches of insulation between the electronics and the steel container. The lower tier housed the secondary fuel supply, propane burner, and electronic reigniter. The upper and lower sections were separated by a dead air space and joined only through an oil filled heat transfer assembly. Ventilation holes in the lower tier provided inlets for fresh air, and permitted exhaust gasses and humidity to escape.

Protection against damage caused by animal investigation was provided by encasing the external rubber wiring in heavy gauged conduit tubing, and by the provision of securing points by which the enclosure could be fastened to the ice surface.

The entire system was fabricated in the Dobrocky Seatech Ltd. facility in Sidney, B.C. and underwent a series of tests both at Dobrocky Seatech Ltd.'s facility and at a cold storage plant in Victoria, B.C.

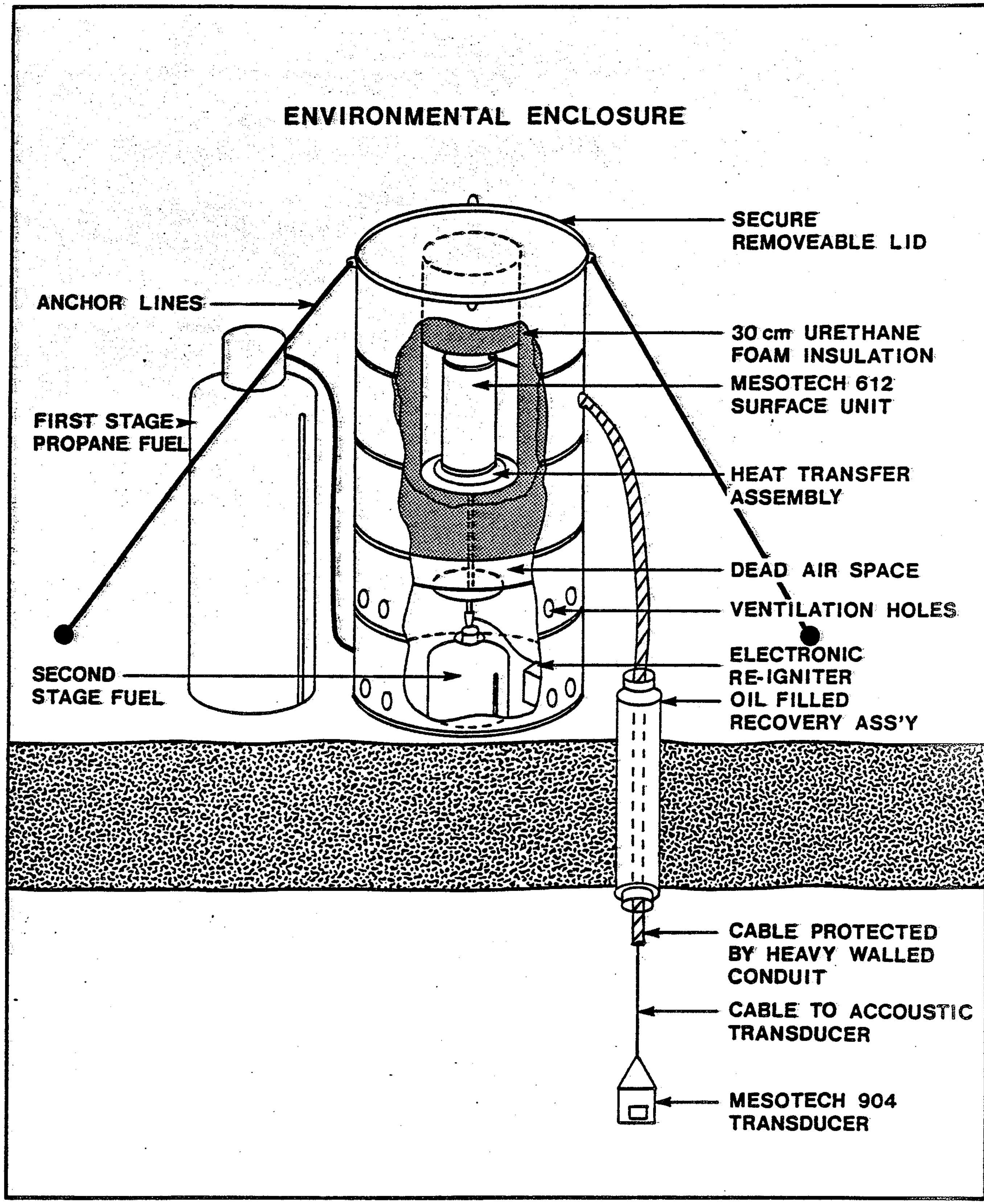

Figure 2.9 – Environmental Enclosure

DOBROCKY SEATECH

2.1.5 Deployment Hardware Design

Supplemental to the mechanical hardware designed by Panarctic Oils Ltd., a suite of surface support hardware was required during the handling and deployment of the thermistor chain. This supportive hardware included such items as a large lowering winch which could be easily fastened to and removed from the drilling rig floor. A large sheave and dynamometer to be suspended from the drill rig draw works through which the thermistor chain would pass, was required to provide an indication of smooth entry of the thermistor chain into the wellbore.

The Lowering Winch provided to the project was a large hydraulic oceanographic winch from Dobrocky Seatech Ltd. This winch was more than capable of containing all of the thermistor chain plus the additional double braided nylon rope required during deployment. The winch was pre-tested and all hydraulic connections inspected to ensure that they would be compatible with the drilling rig hydraulic system. Once the winch had been totally prepared, the entire thermistor chain, less individual thermistors, was wound onto the drum in such fashion as to permit the installation of thermistors as the cable was deployed. The cable was then covered in a protective layer, and the entire winching system shipped to Panarctic Oils in Edmonton, Alberta for furtherance to their Arctic operations base at Rea Point, N.W.T.

2.1.6. Data Recovery System

Under an amendment to the initial contract, Dobrocky Seatech Ltd. was requested to evaluate a system whereby data could be gathered from the Surface Unit without the requirement of returning the entire system to a large computing system. The major requirements for this system were defined as portability (battery powered), dependability and having I/O capabilities which would match the data handling characteristics of the surface electronics. The computer system must also have sufficient resident memory to enable it to store the entire memory of the Surface Unit.

The computing section of Dobrocky Seatech Ltd. undertook the evaluation of a series of commercially available computing systems, and recommended that the Hewlett-Packard Model 110 portable computer be purchased, and that software be written to enable the efficient recovery and storage of data from the Surface Unit.

In addition to the computer, Dobrocky Seatech Ltd. also recommended the purchase of the Hewlett-Packard Portable Disk Drive. This unit would be used to make back up data products in the field, and would reduce the possibility of data contamination or loss due to unforeseen circumstances. Both items were purchased, and software written which enabled both the recovery and the recording of data at the deployment site. The entire Data Recovery System was assembled and taken to the deployment location on the first data recovery trip, where the data recorded by the surface electronics bubble memory was transferred and recorded to disk.

2.2 SYSTEMS TESTING

The entire Mesotech Model #612/532 data gathering system underwent a complete (five phase) suite of tests both prior to and after acceptance. The first phase was completed at Mesotech facilities in Vancouver (bench and water), the second phase was conducted in the shallow waters of Saanich Inlet near the Dobrocky Seatech Ltd. facility, the third test was conducted under Arctic conditions in the high Arctic, the fourth and fifth phases were completed at the Dobrocky Seatech Ltd. facility as part of rigorous integrated system test.

During each phase an attempt was made to confirm the systems overall performance. The systems acoustic telemetry range capability and the effects of the under ice water structure on acoustic signal propagation was monitored and documented. Deviations from specifications were noted and suggestions for improvements relayed to individual manufacturers.

The following sections detail individual phases of testing.

2.2.1 Bench Test

The bench testing at the Mesotech facility began with individual component checks at ambient temperatures, and software testing after delivery of the bubble memory media. Following final assembly of all units, the entire system underwent a series of tests. These included tests of the systems ability to read and write data into sequential data records as well at the ability to output this data via the system RS232 connector. A simple software check of all recorded data indicated that the system was functioning as expected with a series of dummy resistors inserted into the data interpretation system. The acoustic transmission was tested and the telemetry verified as functional during an in-water test near the Mesotech facility. The final test was conducted on May 3, 1984, and was attended by the engineering staff of Dobrocky Seatech Ltd. Data transmission and recovery techniques were reviewed and procedures for setting up and manipulating the various data streams were identified. During these tests, the transducer for the 532 Underwater Unit was submerged to a depth of 2 metres. The electronics associated with the Underwater Unit remained on the surface for further evaluation. The Model 904 transducer associated with the 612 Surface Unit was also deployed to a depth of 2 metres, about 40 metres from the Underwater Unit transducer. Each operational mode of the Surface Unit was verified, and the display for each data channel confirmed. These values were verified by field computer by conversion to original values of resistance.

The only problem encountered was a nonrepetitive reading on one channel, which was later rectified when a test instrument was removed from a ground loop.

During these bench tests the engineering staff of Dobrocky Seatech Ltd., inspected and evaluated the system and recommended a suite of temperature cycling, pressure, and vibration tests.

2.2.2 Shallow Water Testing

Shallow water testing was conducted on two occasions. The first occasion was on May 11, 1984 under the direction of Dobrocky Seatech Ltd., with members of Mesotech's engineering and software staff in attendance. The second suite of testing was conducted on April 9, 1985 in an attempt to evaluate the acoustic characteristics of the Underwater Unit when installed in the Electronics Protection Sleeve.

During the first testing, a suitable area of Saanich Inlet, B.C. was chosen which provided a line-of-sight test range for acoustic testing. A two vessel operation was designed which assigned the Underwater Unit complete with watertight connector and dummy load, to a small Boston Whaler equipped with a lowering winch and two oceanographic technicians. The Surface Unit complete with acoustic transducer was placed on board the 45 foot research vessel Seatech 2. This vessel was also equipped with a lowering winch and was crewed by the engineering staffs of both Dobrocky Seatech Ltd. and Mesotech. A location which was approximately 175 metres deep in the center of Saanich Inlet was chosen for testing.

The initial test ensured that the Underwater Unit was watertight to operating depth. This was accomplished by removing the internal electronics from the Underwater Unit, replacing the watertight bulkheads and lowering the empty pressure case to a depth of 174 metres for a period of 45 minutes. The pressure case was recovered and internally inspected for signs of sea water encroachment. Once the engineers were satisfied with the systems integrity, the electronics were reinstalled and acoustic range tests begun.

The initial range test placed the vessels at a surface separation of 400 metres, with the transducing element of the Surface Unit suspended below the Seatech 2. The Underwater Unit remained on location, by anchoring the Boston Whaler. Records of individual channel data were accumulated and stored by altering the surface separation of the vessels and altering the "height-above-the-bottom" of the Underwater Unit. Increments of 500 metre separation were achieved by radar measurements between the two vessels as Seatech 2 steamed along a transect away from the Boston Whaler and the Underwater Unit. At each 500 metre increment, values for each channel were recorded for different Underwater Unit "height-above-the-bottom".

Maximum acoustic ranges were recorded between 2.5 and 3.0 km of surface separation. However, by attaching an earphone to the Surface Unit and adjusting the volume control, strong audio signals were still evident at ranges much greater than 3.0 km. The cause of this data drop out is considered to be the internal timing sequence of the Surface Unit. When a data scan is initialized, an internal timer is reset. If returned signals are not received within a fixed period of time, the system assumes that data is not available and records a series of hexadecimal "FFFF" in place of data. This period of time is equal to the time required for the acoustic signal to travel from the Surface Unit to the Underwater Unit, plus the time required by the Underwater Unit to respond a request, and the time required for that response to return to the Surface Unit. Considering the system received and recorded data far in excess of the required specifications, this timing characteristic was not considered a problem. It is interesting to note however, that data reception in excess of 3000 metres may be achieved by altering the internal timing of the Surface Unit.

During the testing process, most channels maintained their values throughout the entire test. Over the period of the test a few values altered with the depth of the Underwater Unit. Subsequent testing of the dummy load indicated that seawater had leaked into the area containing the precision resistors.

Upon conclusion of the shallow water testing the entire system was inspected by the engineering staffs of both Dobrocky Seatech Ltd. and Mesotech for any signs of water encroachment. The data recorded by the Surface Unit was recovered by computer using the memory to RS232 option, and examined in detail to ensure that it compared with the data which had been manually recorded. The dummy load was inspected and found to contain sea water. A second dummy load was designed which would negate the possibility of leaks.

The second series of testing was conducted by the technological staff of Dobrocky Seatech Ltd. in the same location as the first tests. On April 9, 1985 the Underwater Unit was installed into the Electronics Protection Sleeve. A series of range evaluations were conducted which closely followed those taken in May 1984. The results of these tests indicated that the Electronics Protection Sleeve had little or no effect on the transmissional characteristics of the Underwater Unit.

2.2.3 Arctic Test

Arctic testing was conducted in two seperate phases. Phase one was conducted in May of 1984 at a Cominco Mine site on Little Cornwallis Island, N.W.T. The second testing program was conducted in February of 1985 at the proposed deployment location of Panarctic Oils Ltd. ice strengthened drilling platform, Cape Allison, N.W.T.

Following analysis of data recorded during shallow water testing and completion of critical evaluation of all electronics, preparations were made to undertake under-ice testing. A testing scheme was detailed which would closely simulate actual operating conditions when deployed in an abandoned oil well. This arctic testing was initially to be undertaken at a Panarctic Oils Ltd. ice strengthened drilling platform, but given the lateness of the testing program, Panarctic Oils Ltd. normal support facilities had been removed from the ice. A second testing area was selected with final arrangements being made by members of EMR. The site chosen for testing was Crozier Strait, N.W.T. adjacent to the Polaris mining operation of Cominco situated on the southwest corner of Little Cornwallis Island (LCI), N.W.T. Aside from the obvious logistical support provided by the mine site, the offshore area provided the ice covered deep waters, required for acoustic testing.

After final arrangements had been completed between Dobrocky Seatech Ltd., EMR and Cominco, a target date of May 17, 1984 was decided upon.

One week prior to this date, the Surface and Underwater Units were shipped to Resolute Bay, N.W.T. under the direction of the Polar Continental Shelf Project (PCSP). A small hand winching system required for lowering the Underwater Unit was requested and loaned from the pool of EMR equipment held at the Pacific Geoscience Center in Sidney, B.C. This winch was first sent to Ottawa for conversion and forwarded to Resolute Bay for consolidation with the Surface and Underwater Units. Once all equipment had arrived in Resolute Bay, two senior technologists from Dobrocky Seatech Ltd. and two members of EMR travelled on May 15, 1984, to Resolute Bay. At Resolute Bay a final check of all systems was undertaken. A three wheeled All Terain Vehicle (ATV) was requisitioned from PCSP stores and prepared for shipment to LCI. Discussions between EMR and Dobrocky Seatech Ltd. detailed a final testing scheme.

On the morning of May 16, 1984 a Bradley Air, Twin Otter was secured (under contract to PCSP) and all required hardware and personnel flown to the Polaris mine site on LCI. At Polaris all gear was checked for damage, and arrangements made for field support the next day.

On the morning of May 17, 1984 the entire Surface and Underwater Units electronics were tested in the warehouse facilities of the Polaris mine. A Polaris mine supplied tracked vehicle, Chiefton, was loaded with all required deployment hardware. A crew of two Dobrocky Seatech Ltd. technologists, one member of EMR and one driver, departed the mine site for the testing area approximately 1.6 km southwest of the mine site (Figure 2.10) in Crozier Strait. Upon arrival at the testing site a hole was drilled through 1.3 metres of very soft ice, and a water depth of 335 metres measured via weighted line and metre wheel. The Underwater Unit, with dummy load in place, was lowered to a depth of 331 metres via winch, tripod, and metre wheel. The transducing element of the Surface Unit was lowered through the same hole for the first series of tests. Following a

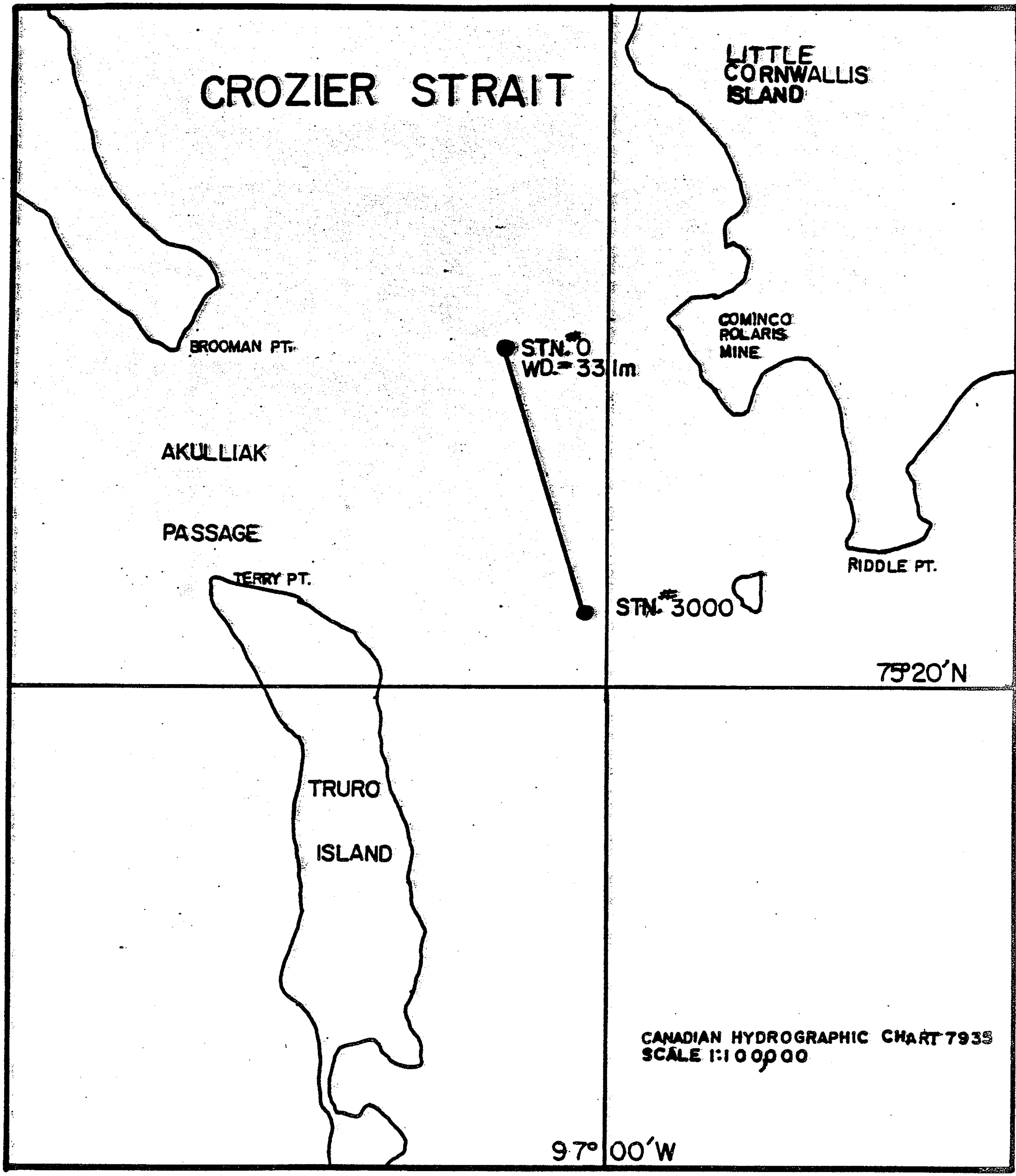

Figure 2.10 - Crozier Strait Test Site

series of different Underwater Unit and Surface Unit depths, the Surface Unit was moved in increments of 500 metres due south of the original deployment hole referred to as "Test 0". At each Surface Unit deployment location, a series of data were collected from different transducer depths. Surface Unit transducer depths of 0 metres (indicating the bottom of the ice), 30 metres, and 60 metres were occupied to evaluate the effects of ice surface proximity and thermoclines on the acoustic reception. A total of 2000 metre surface separation (Test 2000) had been measured by the end of the day, before returning to Test 0 and recovering the Underwater Unit.

The original deployment hole (Test 0) was reoccupied on the morning of May 18. The Underwater and Surface Units were again deployed in the same hole and zero range tests completed. These readings showed excellent repeatability with the previous days data. Testing resumed at a surface separation of 2500 metres (Test 2500) where a temperature profile was also collected to define the presence of a thermocline. This data indicated a thermocline depth of 63 metres. After completion of the testing at 2500 metres, a further 500 metres where measured off in an attempt to define the maximum reception range. A complete suite of tests from 3000 metres proved that no data could be received. It is interesting to note that audio reception was evident as described during the shallow water testing. Again, this loss of data is considered to have been caused by internal timings within the Surface Unit. Efforts were then made to define the maximum reception range, by stepping backwards in increments of 100 metres. A final range from which data could be received was defined as 2750 metres.

Following recovery of all sub-surface instrumentation and dismantling of field support hardware, the equipment was returned to camp for check out, packing and preparation for return shipment to Victoria. All personell and equipment left Polaris mine on May 18, 1984.

Upon its return to Victoria, the entire system underwent a detailed electroncis evaluation. As well, the contents of the systems bubble memory was examined and compared against the data manually logged in the field. Both the electronics and the data appeared in excellent condition.

A second acoustic and environmental testing program was conducted in February, 1985. This test was conducted as planned, at a Panarctic Oils drilling facility, to not only prove the system's ability to receive data over distances greater than 1000 metres, but also to provide some indication of the system's ability to reject the noises generated during normal drilling processes.

On February 21, 1985 two technologists from Dobrocky Seatech Ltd. travelled from Sidney, B.C. to Panarctic Oils drilling platform Cape Allisson C-47 with all required electronics and hardware to deploy the entire Surface and Underwater Unit system.

Upon arrival at Cape Allison, logistic support was arranged and discussions with senior drilling staff conducted. On February 22, 1985 a suite of interference tests were conducted by lowering the entire system into the drill rigs "moon-pool".

The Underwater Unit was deployed to a depth of 200 metres approximately 1250 metres away from the Surface Unit which had been installed in the "tide shack", on February 23, 1985. All equipment was then secured for the return southbound trip scheduled for Febrary 26, 1985. The Surface Unit was examined many times during the period February 24 to February 26 to ensure that data reception was continuous.

A single technologist returned to the test site on March 12, 1985 to recover the entire system. Both Underwater and Surface Units were recovered on March 13, and the recorded data visually inspected for flaws. Data reception during the entire deployment period was flawless. The entire system was packaged for return to Victoria for further bench testing.

2.3 ENVIRONMENTAL ENCLOSURE TESTING

Upon completion of design and manufacturing, the Environmental Enclosure underwent a series of tests to evaluate the efficiency of the entire system. The first series of tests took place in the Dobrocky Seatech Ltd. warehouse facilities in Sidney, B.C. These tests involved the long term demonstration of the burner and reigniter. The burner was permitted on two occasions to completely drain the secondary fuel supply while being subjected to direct winds which extinguished the flame, the flame was automatically reignited by the electronic reigniter. During the second of these experiments, the burner assembly was installed in the burning chamber of the Environmental Enclosure, and again permitted to drain the secondary fuel supply. During this demonstration a temperature monitoring data logger was installed in the area normally occupied by the Surface Unit electronics. This demonstration indicated that the thermostatic controls of the burner system was more than capable of maintaining a safe working temperature within the enclosure even when the outside ambient temperature rises well above those expected in the Arctic. The third demonstration in Victoria saw the enclosure set up as if it were deployed in the Arctic. A temperature measuring data logger was again installed within the chamber, and the entire enclosure placed within a blast freezer which maintained a constant internal temperature of -40° C. The internal temperature of the chamber was monitored during a one week test. The temperature within the electronics chamber of the enclosure maintained a very stable temperature near +10° C.

The fourth and final testing was conducted at the ice strengthened drilling platform Cape Allison C-47 under the direction and support of Panarctic Oils Ltd. The entire system was deployed in the configuration expected during final deployment, and the internal temperatures monitored. During this demonstration, many problems were encountered. First, a strong wind lowered the burner chamber temperature to a point that the heat transfer tubing was not efficient. This problem was remedied by inserting small pieces of fiberglass insulation into the breather holes to regulate the amount of wind circulating within the chamber. After this problem had been remedied, the internal temperature rose to +10° C, and remained at this point for seven days. When the technologists returned to recover the temperature data, they found that the system had stopped functioning, and that the reigniter batteries had been completely exhausted. The entire system was taken inside a building for closer examination. The cause of the extinguished flame was finally determined to have been an accumulation of oils entrained within the burner nozzle. These oils were of unknown origin. Every time the flame was reignited, the oils held within the burner nozzle would bubble and cause the flame to extinguish. This phenomenon was witnessed and examined in great detail. The burner assembly was returned to Victoria for closer evaluation where conversations with many propane burner experts concluded that the oils found within the burner assembly originated from the rubber hosing between the primary and secondary fuel tanks. A decision was then made to replace the rubber hosing with flexible copper tubing for the final deployment.

3.0 CRONOLOGY OF EVENTS

The following sections present in detail the activities of all parties involved during the deployment, and subsequent recovery/redeployment phases of this contract. An attempt has been made to include only sufficient detail to provide an overview of the events. Greater detail on specific topics such as procurement, design and testing may be found in previous reports by Dobrocky Seatech Ltd. to the Department of Energy, Mines and Resources.

3.1 DEPLOYMENT (MAY 1985)

Following transportation of all required deployment hardware to the deployemnt site in the latter half of April 1985, arrangements for deployment were scheduled to begin on May 6, 1985. Details of this deployment are indicated below.

May 1, 1985

- Dobrocky Seatech Ltd. technologists Mark Hill (MH) and Jim Harrington (JH) departed Victoria enroute to deployment location at Cape Allison C-47.

May 2, 1985

- MH and JH meet with Energy, Mines and Resources personnel Allan Taylor (AT) and Vic. Allen (VA) in Edmonton.

May 3, 1985

- Locate all equipment and prepare for deployment.

May 4, 1985

- Assembled and tested Environmental Enclosure.

May 5, 1985

- Held briefing meeting with all rig personnel.
- Continued acoustic testing.

May 6, 1985

- Assembled battery pack for Surface Unit.

1610 - Met with senior drilling personnel to discuss deployment techniques.

- 9 5/8 inch casing cut as required.

1630 - Regan Spear stuck in 9 5/8 casing.

1800 - Run in Stroker Sub to free Regan spear.

1900 - Regan Spear freed from 9 5/8 casing.

2300 - Rerun 9 5/8 casing cutter and recut casing.

May 7, 1985

0000 - Recover 9 5/8 casing with Regan Spear.

0300 - Cut 13 3/8 inch and 20 inch casings.

0400 - Break casing stubs free.

0430 - Re-enter Stabilizer Bars with 20 inch casing stubs, viewed on subsea camera.

0630 - Raise Hanger Assembly to rig floor and insert into rotary table.

- Lower Hanger Assembly into position with Regan Spear.

0700 - Land Hanger Assembly onto Blind Shear Rams.

0715 - Land Hanger Assembly onto 9 5/8 inch casing cut.

0735 - Release Regan Spear with Stroker Sub.

- Began recovery of drill string.

1115 - Raise Lowering Winch to rig floor and secure.

- Rig up dynamometer and sheeve in draw works.

1225 - Secure Sinker Bar to end of Thermistor Cable and begin deployment.

1235 - Attach Thermistor Pod #14.

1255 - Attach Thermistor Pod #13.

1307 - Attach Thermistor Pod #12.

1320 - Sinker Bar became lodged between top of Hanger Assembly and internal walls of BOP stack.

1345 - Recover entire Thermistor Cable and Sinker Bar for evaluation.

1415 - Weld centering tabs onto Sinker Bar.

1430 - Begin redeployment.

1445 - At Thermistor Pod #12.

- Sinker Bar passed through BOP stack with no problems.

1450 - Attach Thermistor Pod #11.

1502 - Attach Thermistor Pod #10.

1510 - Attach Thermistor Pod #9.

1520 - Attach Thermistor Pod #8.

1530 - Attach Thermistor Pod #7.

1540 - Attach Thermistor Pod #6.

1550 - Attach Thermistor Pod #5.

1555 - Attach Thermistor Pod #4.

1605 - Located broken wires in Thermistor Break Out #3.

1615 - Attach Thermistor Pod #2.

1625 - Attach Thermistor Pod #1.

1700 - Install Underwater Unit into Electronics Protection Sleeve and secure to end of Themistor Cable.

- Begin deployment of Electronics Protection Sleeve.

1715 - Electronics Protection Sleeve landed. All presure released from dynamometer.

- Attemped acoustic testing through Marine Riser with no results. Drilling muds prevented signal from reaching Underwater Unit.

1730 - Attach floats to deployment rope and drop into Marine Riser.

1800 - Remove Deployment Winch and all hardware from rig floor.

2200 - Begin recovery of Marine Riser, BOP stack and casing stubs.

2215 - Casing stubs clear top of Hanger Assembly. Observed Thermistor Chain exiting out of bottom of casing stub towards Hanger Assembly. Electronics Protection Sleeve have become jammed in BOP stack.

2235 - Subsea camera failed. Recover for repairs.

2245 - Continue recovery of Marine Riser.

May 8, 1985

0130 - Camera repaired and lowered to bottom of BOP stack. Thermistor Cable still hanging from bottom of casing stub.

0145 - Discussed alternate deployment technique with Drilling Supervisor.

0200 - Fabricate fishing hook for recovery of floats inside Marine Riser.

0215 - Catch floats and take weight off Electronics Protection Sleeve inside BOP stack. Electronics Protection Sleeve freed from inside BOP stack and witnessed being slowly lowered by subsea camera.

0230 - Follow Electronics Protection Sleeve to the bottom with subsea camera.

0330 - Electronics Protection Sleeve landed in the Hanger Assembly.

0345 - Tested acoustics from hole near tide shack. All systems worked well.

0400 - Recovered deployment rope.

- Freed rig to continue recovery of Marine Riser.

0800 - Deployed Surface Unit in tide shack.

1730 - Surface Unit timing problems.

- Repair and re-install Surface Unit.

2315 - Redeploy Surface Unit.

May 9, 1985

0900 - Surface Unit does not contain the correct number of samples.

- Observe Surface Unit sampling scheme.

1520 - MH off Cape Allison for Victoria. JH remains to evaluate and rectify timing problems.

- JH examined timing sequence.

May 10, 1985

1400 – JH calls MH in Victoria. Appears that timing problem may result from setting Surface Unit to "Memory to Display" mode. This appears to interrupt and reset the internal timing.

May 11, 1985

- JH watches the timing sequence. All working well.
- Next scheduled southbound flight is on May 14, 1985.

May 12, 1985

- JH watches the timing sequence. All working well.

May 13, 1985

- JH reports that Surface Unit has run for three days with no loss of timing.

May 14, 1985

- JH returns to Victoria on scheduled crew change.

The above description completes the deployment phase. As is obvious, a few problems arose with the deployment hardware which were remedied in the field. All problems have been addressed in the section titled "Observations and Recommendations".

3.2 RECOVERY/REDEPLOYMENT (JUNE 1985)

The following chronological account details the activities of a Dobrocky Seatech Ltd. technologist during the recovery and redeployment of the Surface Unit as installed during the deployment phase in May 1985. The purpose of this recovery visit was the evaluation of the Data Recovery System and analysis of the data produced during the initial cooling period of the abandoned well. A crew of two persons, one from Dobrocky Seatech Ltd., and one from Energy Mines, and Resources travelled from Edmonton, Alberta to Resolute Bay, N.W.T. and were accommodated by the Polar Continental Shelf Project (PCSP). Travel to the deployment site was provided by a PCSP chartered Twin Otter. On location the entire Environmental Enclosure and Surface Units were examined, and the Surface Unit returned to Resolute Bay for further testing. The data gathered by the Surface Unit was recovered by the Data Recovery System and recorded to floppy disc for return to EMR in Ottawa for further evaluation. The Surface Unit was returned to the deployment location and reinstalled in the Environmental Enclosure for further data collection.

The chronological account is as follows:

June 14, 1985

1700 - Dobrocky Seatech Ltd. technologist Mark Hill (MH) departed Victoria for Edmonton.

1930 - MH arrived in Edmonton.

June 15, 1985

1030 - MH met with Energy, Mines and Resourses technologist Vic. Allen (VA) at Edmonton airport.

June 16, 1985

- Prepare for field trip.
- Wait for PCSP chartered aircraft.

June 17, 1985

0750 - Load equipment onto PCSP chartered Bradley Twin Otter.

0800 - Off Resolute Bay for Cape Allison.

0930 - In area of Cap Allison searching through low fog.

0945 - Located Cape Allison.

0950 - Landed at Cape Allison.

- Inspected Environmental Enclosure and noted that the internal baffel plate had fallen onto the burner assembly, extinguishing the flame. It appeared as if a minor explosion had loosened the baffel plate which then fell onto the burner.
- Connected Data Recovery System to Surface Unit and attempted to recover the stored data.
- Located problems with the cable between the Surface Unit and the Data Recovery System. Attempted to solve problems.
- Decided to return to Resolute Bay.

1245 - Off Cape Allison for Resolute Bay.

1415 - Arrived at Resolute Bay.

- Returned entire system to camp to evaluate problem.
- Repaired problems in software by rewriting.

1900 - Recovered all data and recorded compete disc file of data.

June 18, 1985

0750 - Loaded aircraft.

0800 - Off Resolute Bay for Cape Allison.

0940 - Arrived at Cape Allison.

0950 - Redeployed Surface Unit into Environmental Enclosure.

1015 - Off Cape Allison for Resolute Bay.

1140 - Arrived at Resolute Bay.

- Examined all collected data. Data looked good.

June 19, 1985

- Packed for southbound.

1805 - Depart Resolute Bay for Edmonton.

2215 - Arrived in Edmonton.

June 20, 1985

0730 - MH off Edmonton for Victoria. VA remains in Edmonton.

0915 - MH arrived in Victoria.

This completed the Recovery/Redeployment trip. As is noted in the above account, a few problems arose in the interconnection of the Surface Unit and the Data Recovery System. This interfacing problem was easily remedied upon return to base camp, where a complete disc file of recorded data was accomplished. Also worth noting are the problems encountered with the Environmental Enclosure. Speculation on this problem has not led to a cause nor any remedial action to be taken in the design of further enclosures.

3.3 RECOVERY (JULY 1985)

In July of 1985, the entire Environmental Enclosure and Surface Unit were undertaken by members of Energy, Mines and Resources. As technological support was not requested of Dobrocky Seatech Ltd., the results and observations cannot be detailed herein. It is assumed however that data was successfully recovered from the Surface Unit via the Data Recovery System. The entire system was packaged and returned to Ottawa for evaluation and maintenance in preparation for deployment in November 1985.

3.4 DEPLOYMENT (NOVEMBER 1985)

In October 1985, Dobrocky Seatech Ltd. was requested to provide technical assistance during the redeployment of the Surface Unit at Cape Allison. A series of redeployment techniques were examined to replace the

Environmental Enclosure. The first technique involved the machining of a pressure case for the Surface Unit, and suspending the entire unit below the ice. The second suggestion involved the fabrication of a "dry well" which would then be inserted into a hole in the ice into which the Surface Unit could be installed. Budgetary restrictions and time restraints resulted in the second form of deployment chosen.

The following account details the activities of a Dobrocky Seatech Ltd. technologist during this redeployment phase.

November 18, 1985

1700 – Dobrocky Seatech Ltd. technologist Jim Harrington (JH) departed Victoria for Edmonton.

2130 – JH arrived in Edmonton and met with Energy, Mines and Resources technician Perry Lanthier (PL).

November 19, 1985

0630 – JH and PL arrive at Wescan Terminals, Edmonton.

0930 – Notified that aircraft was down for maintenance.

1200 – Departed Edmonton for Rea Point, N.W.T.

1715 – Arrived in Rea Point.

– Met with senior Panarctic Oils personnel and were told that they would remain in Rea Point for a few days.

November 20, 1985

– Set up and test Surface Unit.

November 21, 1985

- Awaiting aircraft and positioning system.

November 22, 1985

1425 - Depart Rea Point for King Christian Island (KCI).

1625 - Arrived at KCI.

- Discuss requirements with camp personnel.

November 23, 1985

0930 - Load helicopter for first trip to Cape Allison.

0950 - Helicopter departed for Cape Allison.

1000 - Arrived at Cape Allison.

1025 - Unload helicopter. Awaiting satelite pass for positioning system.

1045 - Satelite pass indicates 500 metres from well head.

1110 - Drilled hole through ice approximately 30 metres from well head. Noted that Surface Unit was very slow to respond in cold.

1115 - Recorded two sets of data from the Underwater Unit.

1140 - Reloaded helicopter and returned to KCI.

1200 - Arrived at KCI. Lunch.

1245 - Loaded helicopter. Off to KCI with helper from Panarctic Oils.

1315 - Arrived at deployment location. Set up in preparation of deploying Dry Well.

- Repeated attempts at deploying Dry Well fail. Dry Well swings about under helicopter. Very difficult to handle. JH hit by Dry Well as it swings below helicopter.

1400 - Dry Well installed with great difficulty.

1405 - Surface Unit turned on. No visible interogations. Surface Unit very cold.

1425 - Deployed Surface Unit into Dry Well. No visible response from Underwater Unit. Surface Unit too cold to operate.

1430 - PL installed fiberglass insulation in Dry Well.

- Finish deployment. Install cap on Dry Well.

1445 - Depart Cape Allison for KCI.

1500 - Arrived at KCI. Pack for Rea Point.

1540 - Off KCI for Rea Point.

1725 - Arrived at Rea Point.

November 25, 1985

1400 - Package equipment for shipment southbound.

November 26, 1985

1245 - Depart Rea Point for Edmonton.

1700 - Arrive in Edmonton.

1900 - Depart Edmonton.

2100 - Arrive in Vancouver.

November 23, 1985

0745 - Depart Vancouver.

0830- Arrive in Victoria.

This completes the redeployment phase. As is obvious by the details above, the Dry Well proved problematical during deployment. Not only was it unmanagable, but the severe cold caused the Surface Unit to cease functioning. The extended period of time required to deploy the Dry Well and Surface Unit subjects the internal electronics to unfavorably cold conditions. The electronics technologist involved in the deployment feels that the Surface Unit should regain its ability to receive data as soon as it warms up from the surrounding waters, however severe damage to the electronics may already have taken place. This warming process may take a considerable length of time, as ice would undoubtedly have formed on the exterior of the Dry Well as soon as it contacted the cold sea water.

4.0 OBSERVATIONS AND RECOMMENDATIONS

The following summary of observations and recommendations have been compiled in an attempt to improve upon the efficiency and hence reduce the "rig time" required during deployment. Each of the major components utilized during this project have been evaluated with the resulting observations, and where applicable, recommendations for improvement noted. This evaluation may prove beneficial to any future project which may require a similar high degree of mechanical and electronics expertise.

4.1 THERMISTOR CABLE

The initial thermistor cable was designed and constructed in a continuous 1000 metre length, with 16 individual thermistors placed along its length. Modifications to the length and number of thermistors was undertaken upon the advice of Panaractic Oils Ltd. when it was discovered that an unscheduled cement bridge plug would be installed at a depth of approximately 900 metres below the ocean floor.

The resulting modified cable was 830 metres in length, containing 14 thermistors. A special purpose stainless steel clevis was molded to the lower end of the cable to facilitate connection to the Sinker Bar. The upper end of the cables Kevlar strength member was terminated by conventional whipping techniques over a 1/2 inch stainless steel thimble.

During deployment operations the following observations were made:

a) The outer polypropolene jacket of the cable tended to "bunch up" below each of the thermistor break outs as the cable passed over the deployment sheeve. This may have been caused by the internal stretch of the Kevlar strength member. This did not have any adverse effects of the deployment of this system, but had the individual thermistors been placed greater than 200 metres apart, serious damage may have resulted as the excess areas of the outer jacket passed over the sheeve.

b) During a recovery and redeployment operation of the lower cable section, the thermistor at break out #14 was inadvertantly permitted to pass over the deployment sheeve. This resulted in a bent connector in the thermistor pod and possible broken wires in the break out. The faulty connector was repaired by replacing the thermistor pod with a spare and taping the break out in such position as to place the internal broken wires in contact. Care was taken from this point onwards to ensure that this situation did not reoccur.

c) During the deployment process, the internal wiring in break out #3 indicated an open circuit situation which is believed to have resulted from the longitudinal stress placed on the internal break out wires. This break out had been repaired by the manufacturer on one previous occasion, and was considered to have been servicable prior to deployment.

d) The upper end termination of the Kevlar strength member was functional, but not as secure nor waterproof as the stainless steel clevis which had been molded to the lower end. The reason for not terminating both ends uniformally with a clevis was that during the initial design and construction, the specified length of the electrical "pig tail" and supportive Kevlar strength member did not permit molding of a clevis.

In future thermistor cable projects, more consideration should be given to both the mechanical and electronic terminations in an attempt to provide one single electro-mechanical termination at the upper end, and a similar molded mechanical connector at the lower end.

4.2 THERMISTOR BREAK OUTS

The individual thermistor break outs were designed to provide a means by which the thermistor pods could be removed and reattached for both calibration and final deployment. The construction of the break outs proved to be problematical when the manufacturer inadvertantly molded one on in the reverse direction, and two more indicated open circuit situations, suggesting broken internal wiring. After repair, all break outs appeared functional until stress was placed on the cable during deployment. One break out again appeared as an open circuit.

Overall, the break outs proved an asset during the deployment process, but consideration should be given to designing break outs where the thermistor pod could plug directly into a molded socket on the side of the cable. Greater consideration should also be given the soldered internal terminations. The addition of a short coiled section of wire in each splice would reduce the chances of broken wires resulting from Kevlar stretch.

4.3 THERMISTOR PODS

Thermistor pods were designed and redesigned in an attempt to provide mechanical protection to the encased thermistor element, and provide a means of removal and reinsertion into thermistor break outs. Two methods of encapsulating the thermistor bead were attempted, with the final decision of a two section epoxy capsule resulting. This was an improvement over the original single epoxy pod which when heated and cooled caused the internal solder terminations to break free of the cast connector because of the different thermal expansion and contraction rates.

As the prime function of these pods was the mechanical protection of the sensors, some consideration should be given to encasing the sensing element in a small, oil filled stainless steel capsule. This capsule should be internally threaded on one end to permit attachment to the already threaded electronic connector. Such pod would retain the mechanical protective properties of those used, and would permit easy inspection should a problem be suspected.

4.4 MESOTECH MODEL 612 SURFACE UNIT

The design of the Mesotech 612 Surface Unit took into consideration many options which would not normally have been considered during design of typical data logging instrumentation. Many of these options were included to assist the field operator during deployment and recovery of data. After final evaluation, the Mesotech 612 Surface Unit proved to be a functional field data collection instrument which was more than capable of meeting and surpassing the stringent requirements of this project. Should a second similar system be produced, a few modifications would improve upon the reliability and prolong the systems deployment life expectancy. These modifications are briefly noted below.

1) Future data logging systems should be designed in such fashion as to provide watertight bulkheads, switches and displays. Attention must be paid to external connectors through which moisture in the form of condensation may pass freely. If external connectors must be used, watertight Military type connectors must be used. If switches are to be included in future designs, consideration must be given to installing them in such location as to ensure that moisture in any fashion will not be able to enter the elctronics compartment. Displays, be they LCD or LED must be mounted by secure gaskets which will ensure watertightness.

2) Power requirements for this instrumentation are suprisingly small. At present the battery pack required to power this system is contained within the same case as the electronics. This form of design requires that provision be made for the entire housing when designing any form of environmental container. A reduction in size is not possible. If a short term installation was envisaged, reduction in the size requirements would not be possible because of the battery compartment size. An improved version of this data logging system would have a power supply which may be removed from the internal electronics. This has many attractive possibilities. Battery exchange in the field would be greatly simplified by disconnecting one supply and reconnecting a second fresh set of batteries. The ability to remove or even place the power supply in a remote location, such as under the ice, will greatly simplify the design of enclosures.

3) To further reduce the overall size of the housing required by the Surface Unit, it is suggested that the front panel with all associated switches and displays, be removed. Redesign of the initialization and data display electronics would provide a system whereby the functions of the front panel would be contained within a "black box". This black box would then contain all the necessary switches and display electronics. Connectors would be provided for interconnection of the main datalogger and the display module. Many of the functions of the display module can be assumed by a small portable system such as the portable data recovery system purchased for this project. The data logger envisaged after redesign would contain nothing more than the bubble memory storage media and the necessary logic to support collection and storage of data. The entire system could be contained within a very small, sealed housing, with provision for attachment of power, remote transducing element, and the data display and interrogation module.

4) To further improve upon the capabilities of the Surface Unit, it is suggested that a pressure cylinder be designed and fabricated to house the memory and logic electronics plus a battery pack. The transducing element would be secured to the end bulkhead in a fashion similar to that used by the Mesotech 532 Underwater Unit. This pressure case would then enable the Surface Unit to be deployed below the ice surface to any depth. The advantages of this design are many. The electronics, when deployed below the ice, will remain in a relatively stable temperature, free from animal investigation. Deployment is simplified by lowering the entire system on synthetic rope, to a depth which would reduce the slant range from one unit to the other. This form of deployment is routinely used by Dobrocky Seatech Ltd. during deployment of remote current meter and tide guage programs. Recovery of the system is simply a matter of fishing below the ice with commonly used fishing assemblies. This design would negate the necessity for an environmental enclosure or dry well, and would greatly reduce the time required to deploy the system.

5) The commercial grading of the internal electronics components of the Surface Unit should be upgraded to meet military grade specifications. Standard "off the shelf" electronics were used during fabrication. It is

suggested, that had military specifications be used during design and manufacture, that temperature failures would have been less likely. Future products should be constructed wholey of military specification components and cycled to sub zero temperatures prior to acceptance.

4.5 MESOTECH MODEL 532 UNDERWATER UNIT

The Underwater Unit performed well during all testing and final deployment phases. Minor design changes enabled the system to be deployed within the wellbore with what is hoped to be a life expectancy in excess of five years. Increased battery power was provided by replacing the manufacturers battery pack with a specially designed Lithium power pack. Other than replacing the battery pack and securing the internal electronics prior to deployment, little was done to improve upon the "as built" system. There are, however, a few modifications which would improve upon the systems life expectancy.

1) Considering that the Underwater Unit was designed as an expendable item, improvements upon the life expectancy are of utmost importance. Before any design changes are made, an evaluation of the potential failures must be undertaken. If primary importance to the life expectancy is the systems ability to withstand the constant electrolytic interaction between the aluminum housing and the steel mounting structures. This electrolysis was reduced to minimum during deployment by encasing the aluminum housing in nylon sheeting. This will reduce the amount of corrosion, but will not cancel its effects. To completely negate this problem the only solution would be the design of a pressure case which would not be effected by electrolysis. An electronics case could be fabricated from relatively thin walled PVC tubing with bulkheads machined for either end. To compensate for the seawater pressures during deployment, the internal void between electronics and housing could be filled with nonconducting silicone oil. This would produce a totally noncorrosive electronics housing.

2) The second consideration and potential cause of failure, is the battery packs ability to provide power to the system for extended periods of time.

Lithium batteries were chosen for the initial deployment because of their ability to retain power for many years. There is no reason why a battery pack can not be fabricated which will enable data recovery for in excess of ten years after deployment. As the overall length of this system is of little concern, the dimension of the battery pack is governed only by the life expectancy of the individual storage cells.

4.6 ENVIRONMENTAL ENCLOSURE

The Environmental Enclosure was designed to provide an environmentally secure housing for the Mesotech #612 Surface Unit. In addition the Enclosure was to be capable of withstanding small animal investigation.

After a very complete suite of tests and demonstrations, which have been reported under separate covers, a working system was assembled and prepared for deployment. During these tests confidence was gained in the systems ability to operate for very long periods of time at temperatures near those expected during actual deployment.

At the deployment site a wooden platform was constructed on which the Enclosure would stand. The platform was located in an area slightly off the ice strengthened drilling pad on natural sea ice.

After the Surface Unit had been finally deloyed, the Enclosure appeared to be functioning as expected. When the final recovery was made in mid June, it was found that the internal burner had extinguished, and that there had been a minor explosion in the burner chamber which had caused the protective baffel plate to fall onto the burner. The batteries for the systems reigniter had been exhausted, as a result of the systems inability to reignite.

The suggestions for improving upon the design of the Environmental Enclosure are quite simple, a second manner of protection should be considered.

A dry well system which extends below the ice surface could be considered, but the costs of fabrication and transportation are prohibitive. The time, manpower, and logistical support required to install a weighted dry well are also a great concern.

It is recomended that a pressure case be fabricated for the Surface Unit which has the transducing element securely attached to the end cap of the case, in a fashion similar to that used in the Underwater Unit. An attachment point would also be required on the opposite end for securing a synthetic rope. The entire system could be deployed to any depth, where temperatures, and animal investigation would not be of concern.

4.7 ELECTRONICS PROTECTION SLEEVE

The Electronics Protection Sleeve was designed as a means of protecting the delicate transponder electronics of the Underwater Unit, during deployment. It also serves as a means of mechanically connecting the Thermistor Chain to the Underwater Unit. The initial design criteria required that it be compact enough to permit passage through the BOP stack and provide electronic isolation from the remaining subsea hardware.

Electronic isolation was achieved by lining the internal void between the sleeve and the Underwater Unit with sections of nylon plate thus ensuring that the electronics and the sleeve would never be in contact. The outer dimensions of the sleeve were reduced to a size that would ensure unrestricted passage through the BOP stack.

Prior to deployment a series of guides were welded to the bottom of the sleeve to ensure ease of penetration through the BOP stack (Figure 4.1).

During the deployment process, the Electronics Protection Sleeve became lodged, in what is believed to have been, the Blind Shear Rams of the BOP stack. This was not witnessed untill the stack had been pulled from the sea floor. The cable was noticed exiting from the bottom of the casing stubs by the subsea camera.

A further modification to prevent any hang ups, would be the overall stream lining of the upper end cap. A series of guides similar to those welded at the bottom would ensure that the lip of the cap would pass through any minor obstacle.

MODIFIED ELECTRONICS PROTECTION

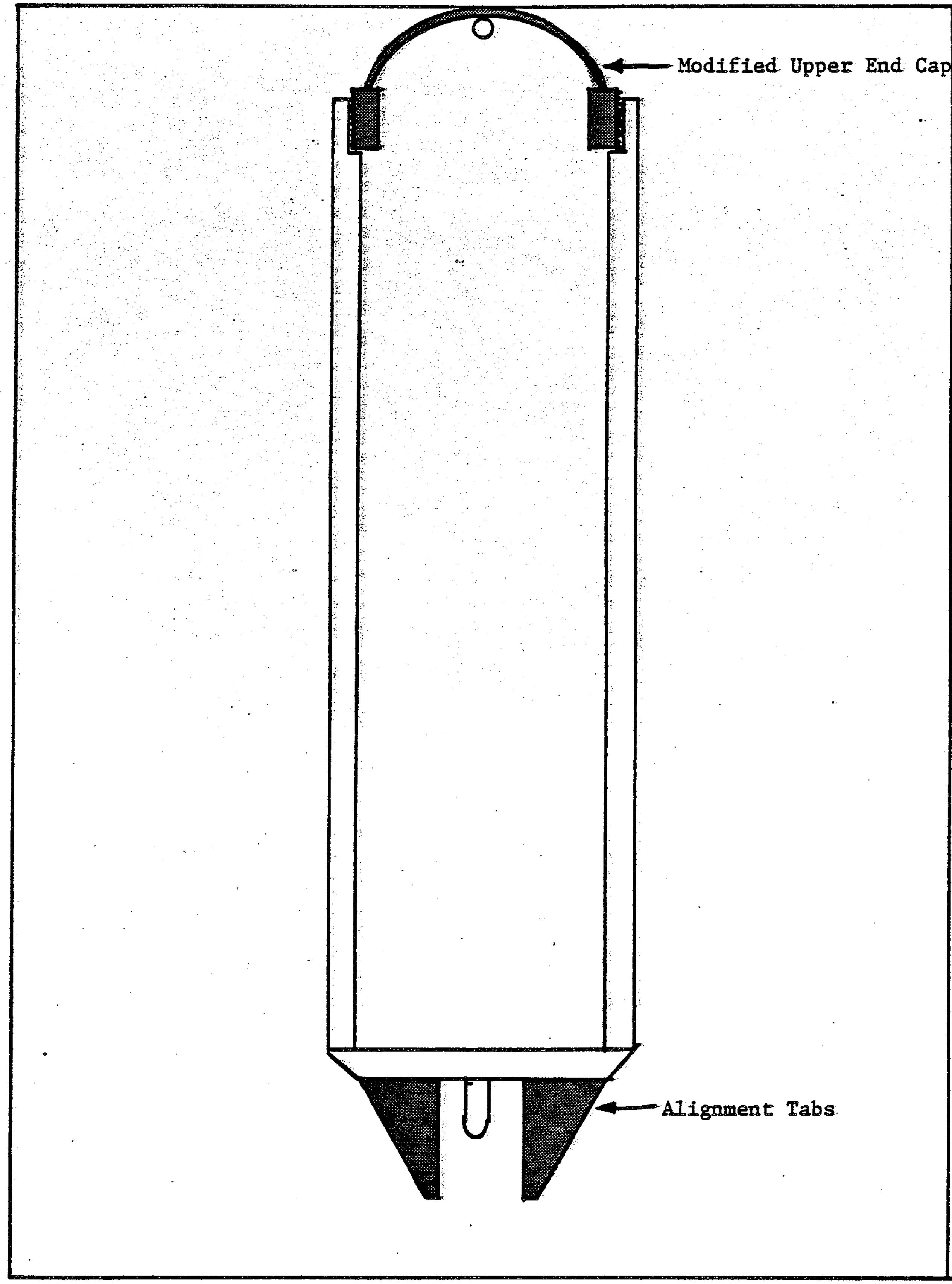

Figure 4.1 - Modified Electronics Protection Sleeve

4.8 HANGER ASSEMBLY

The Hanger Assembly was designed to provide both a platform to which the Underwater Unit could be mounted, and mechanical protection for the electronics during recovery of the BOP stack and casing stubs.

The recovery of the BOP stack and casing stubs was witnessed via the subsea camera system. In view of the fact that the Electronics Protection Sleeve had become lodged in the BOP stack, and was not contained within the Hanger Assembly as planned, in was envisioned that the upperportion of the Hanger Assembly would have performed as designed.

The only modification to the Hanger Assembly which would have improved upon its performance, would be the inclusion of a series of centering bands near the bottom end of the assembly. A centering device similar to that in common use in the oil industry for centering subsea tools, would ensure that the bottom of the assembly would not become hung up under circumstances where casing cuts become offset due to horizontal motion.

4.9 SINKER BAR

A Sinker Bar was designed to aid in the deployment by providing the necessary negative buoyancy to ensure the thermisor cable remained taught during deployment. This bar, although simple in design, caused a major delay during deployment. The cause of the delay was thought to have been when the sinker bar became jammed in the area between the Hanger Assembly and the inside walls of the BOP stack.

The portion of the cable that had already been deployed was recovered, and a series of tabs welded to the bottm end of the Sinker Bar (Figure 4.2).

The inclusion of these centering tabs should be considered during any future deployments.

MODIFIED SINKER BAR

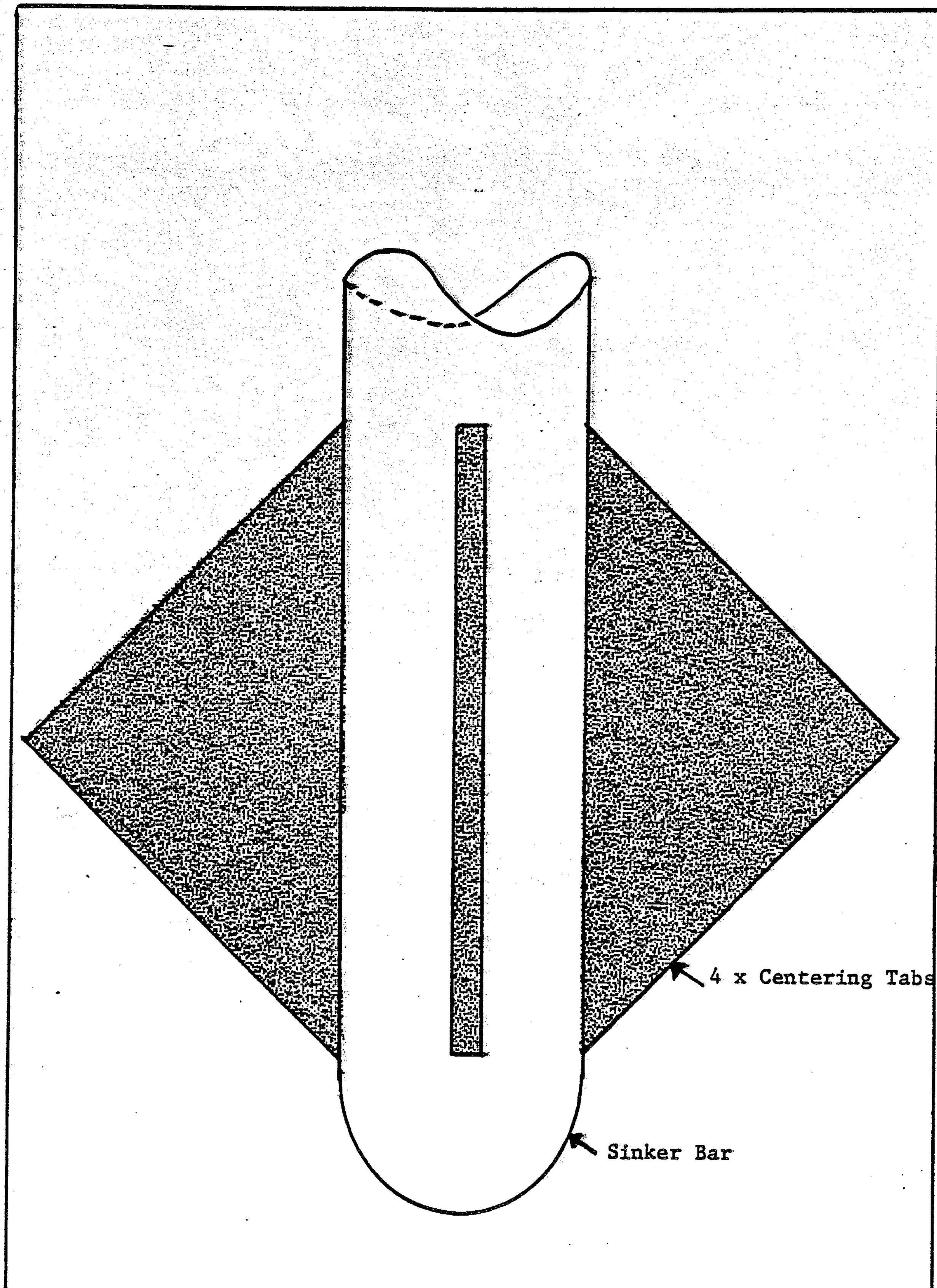

Figure 4.2 - Modified Sinker Bar

4.10 STABILIZER BARS

A set of four Stabilizer Bars were welded to the exterior of the 20 inch casing at a point where the casing cut was to be made, in an attempt to reduce the horizontal movement of the BOP stack and the resulting casing stubs would undergo after the final casing cut.

The performance of these Stabilizer Bars was impossible to witness because of their location below the sea floor. The results of their presence was certainly obvious. A total horizontal ice motion of more than 2.5 meters would have, under normal abandonment procedures, caused the BOP stack and attached casing stubs to have moved horizontally, to align themselves with the rotary table directly above. As this did not occur, we can assume that the bars restrained this movement, and were a success.

The only modification to the design of these bars would be a reduction in their overall width dimension to permit ease of insertion into the rotary table.

4.11 DRY WELL

A Dry Well was fabricated for redeployment in November 1985. The purpose of this Dry Well was the replacement of the Environmental Container. This well was fabricated of heavy quage steel and of sufficient internal diameter to encase the Mesotech #612 Surface Unit. The well was sufficiently long as to permitt deployment to a depth which would ensure the Surface Unit would remain in the sea water after a normal yearly growth of natural ice. Heat from the sea water would be conducted through the walls of the well, into the Surface Unit chamber, thus maintaining the electronics at a temperature slightly below freezing (Figure 4.3).

The Dry Well, although conceptually adequate, proved to provide many problems during its deployment. First and most importantly, the system is very heavy and very awkward to deploy. A 600 lb. dry well swinging below a helicopter is very hard to insert into a small hole in the ice. Secondly, the dry well becomes very cold, and causes the internal electronics to

DRY WELL

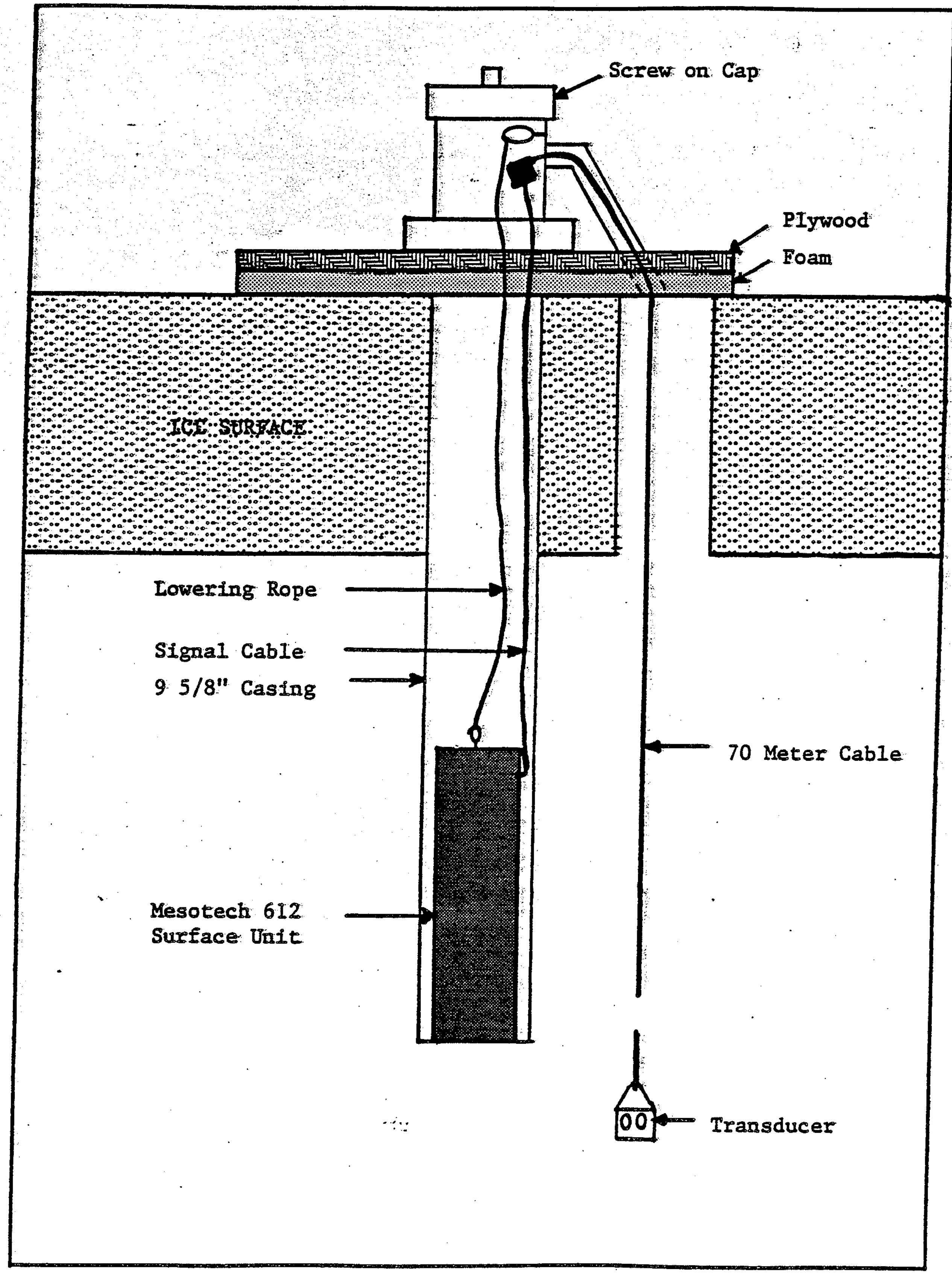

Figure 4.3 - Dry Well

remain well below freezing for an extended period of time. During the redeployment process the electronics of the Surface Unit ceased to function when they became cold.

An alternate to the dry well system is described in section 4.6 (Environmental Enclosure).

4.12 DATA RECOVERY SYSTEM

The portable computing/data gathering system purchased for this project consisted of a Hewlett-Packard battery operated disc drive. A series of software were written which enabled the recovery and display of data from the Mesotech 612 Surface Unit. Data products were eventually recorded to 3 1/2 floppy discs for future analysis.

This system proved, as do all Hewlett-Parkard computing products, to be very reliable in field situations. The only addition to this system that would enhance the recovery and presentation fo data would be the inclusion of a portable Hewlett-Packard Think Jet printer.

Rack mounting of this entire system into a protective case with a larger battery capacity would guarantee a rugged, dependable computing tool for many years to come.