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Atlantic Long-Term Oceanographic Mooring (ALTOMOOR)

by

Daniel Frye, Steve Merriam, Bob Eastwood, John Kemp, Neil McPhee, Steve Liberatore, Ed Hobart, Alex Bocconcelli, and Susan Tarbell

March 1996

Technical Report

Funding was provided by the Office of Naval Research through Contract Nos. N000-14-94-10346 and N000-14-90-J-1719.

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George V. Frisk

George V. Frisk, Chair
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ATLANTIC LONG-TERM OCEANOGRAPHIC MOORING (ALTOMOOR)

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ATLANTIC LONG-TERM OCEANOGRAPHIC MOORING (ALTOMOOR)

ABSTRACT

The Atlantic Long-Term Oceanographic Mooring (ALTOMOOR) has been maintained offshore Bermuda since 1993 as a testbed for the evaluation of new data telemetry technologies and new oceanographic instrumentation. It is currently a joint project between the Woods Hole Oceanographic Institution and the University of Southern California. This report documents the WHOI contributions which have focused on the development of new data telemetry methods and new mooring technology. Details of the instrumentation evaluations will be published separately.

A new inductively-coupled telemetry technology for ocean moorings has been developed and tested on ALTOMOOR. The inductive link uses standard, plastic-jacketed mooring wire as the transmission path for data generated at the individual instruments installed on the mooring. The signals are inductively linked to the mooring wire via toroids clamped around the wire, thus avoiding the need for multiconductor electromechanical cables terminated at each instrument. Seawater provides the electrical return path. The inductive modems send and receive data at 1200 b/s. A controller in the surface buoy collects data from each of the subsurface instruments and forwards the data to shore by traditional satellite telemetry (Argos) and by short range radio using a nearby ship as a store and forward node. The buoy-to-ship link operates over about 2 km at 10 kBytes/sec. When the ship docks, data are offloaded automatically to a computer on shore which can be accessed via the Internet.

Photo on frontispiece: ALTOMOOR Surface Buoy

ACKNOWLEDGMENTS

The ALTOMOOR project was the product of a large number of individuals at WHOI, at the University of Southern California, at the Bermuda Biological Station for Research, and at the Monterey Bay Aquarium Research Institute. Individuals who contributed to the success of the project include John Bouthillette, Sean Kery, Patrick O'Malley, Al Fougere (now at Falmouth Scientific, Inc.), Ken Doherty, Ken Fairhurst, and Bryce Prindle (retired) at WHOI; Tom Dickey, Margaret Stramska, and Derek Manov at USC; Hans Jannasch at MBARI; and Jeff Benson, Liz Caporelli, Tony Knap, and the crew of the R/V WEATHERBIRD II at BBSR. Henri Berteaux (now retired from WHOI) provided some of the initial impetus for the project.

ALTOMOOR was funded by Dr. Tom Swean of the Office of Naval Research - Ocean Engineering and Marine Systems under Contract Nos. N000-14-90-J-1719 and N000-14-94-0346. Mr. Larry Clark of the National Science Foundation's Ocean Technology Program, provided funding to USC under Grant OCE-96-27281 for much of the instrumentation and scientific data collection performed on ALTOMOOR.

1. INTRODUCTION

The Atlantic Long-Term Oceanographic Mooring (ALTOMOOR) project was begun in 1992, following the Engineering Surface Oceanographic Mooring (ESOM) mooring project [1] which was also located offshore Bermuda. The initial ALTOMOOR goals for the period 1992/1993 were two-fold:

1. Conduct a long-term test of the prototype inductive telemetry link.

2. Test several armored Kevlar lines for fishbite resistance and potential for use in inductively coupled moorings.

The ALTOMOOR project is the latest in an on-going effort at WHOI to improve the utility and reliability of oceanographic moorings and to incorporate technology for real-time data telemetry [2] and [3]. Inductive telemetry [4], which uses standard mooring wire as the communication path between subsurface instruments requires minimal power and provides an economical and practical method for modifying oceanographic moorings for real-time telemetry. The mooring then becomes an instrument network controlled by a small computer in the surface buoy and is linked to the outside world via satellite. When two-way satellite communications become routinely available in oceanic areas [5], the inductive link will allow data from (and commands to) almost any moored instrument to be accessible from shore.

Following the initial ALTOMOOR project, a follow-on project was initiated in 1994, ALTOMOOR II. The new program was jointly funded by the Office of Naval Research and the National Science Foundation. The goals of the new program were expanded to include the test and evaluation of new oceanographic instrumentation. WHOI's goal was to continue with the development of new telemetry techniques and to provide the mooring engineering and field operations needed to maintain the instrumentation testbed. The University of Southern California group, under the direction of Dr. Tom Dickey, took the lead on instrumentation development and evaluation [6]. This report details the WHOI contributions and briefly describes the USC efforts. Test instrumentation from other researchers at the Monterey Bay Aquarium Research Institute, Massachusetts Institute of Technology and Falmouth Scientific, Inc., has also been deployed on ALTOMOOR II.

ALTOMOOR I was deployed in March 1993 37 km SE of Bermuda in 4200m of water. Bermuda was chosen because it provides easy access to deep water and the Bermuda Biological Station for Research operates a vessel suitable for mooring maintenance. A turnaround cruise was conducted in September 1993 and the mooring was retrieved in May 1994. At-sea operations were conducted from the R/V CAPE HATTERAS in March 1993 and from the R/V WEATHERBIRD II in September and May.

ALTOMOOR II was deployed in May 1994 about 90 km offshore Bermuda near the JGOFS Bermuda Atlantic Time Series (BATS) site [7]. Maintenance cruises were conducted in

September 1994, January 1995, April 1995, and August 1995. Future plans for ALTOMOOR are in place to continue the instrumentation test and evaluation efforts for an additional three years. Funding for the future will be provided by NSF, ONR, the Bermuda Biological Station for Research, and by various instrumentation developers who will be testing their equipment on the mooring.

2. *INDUCTIVE TELEMETRY*

The use of inductively coupled telemetry on oceanographic moorings was first implemented by Brown in the 1960s [8] using analog techniques. A simple form of inductive telemetry was used by Van Leer [9] on the Cyclesonde profiling instrument a few years later. Neither of these implementations were developed into general purpose communication devices. An inductive modem was implemented digitally at WHOI by Fougere, Brown and Hobart in 1990 [10] using a telephone modem chip to perform the modulation/demodulation operations. This system was successfully deployed in August 1989 at Site D (40°N, 70° W) in 2700m of water south of New England to test the concept [11]. This test deployment operated for several months in a polled configuration, where polling was initiated on a scheduled basis by a controller located in the surface buoy. The instrument/modem modules were clamped to a long shot (2000m) of wire rope. Controller software problems caused the inductive link to operate intermittently. The mooring parted after several months on station due to a corrosion failure resulting from scratches in the wire rope jacket caused by fishbite. The wire rope failed within a few days of the fishbite incidence because the grounding plates used to provide a good connection to seawater for the inductive link were not properly isolated from the galvanized steel mooring line. The voltage generated by the battery that was inadvertently created caused the corrosion failure. The mooring did successfully demonstrate the inductive modem concept over several thousand meters of wire rope.

Inductive coupling makes use of Faraday's Law to induce signals in a conductor without a direct electrical connection. It is commonly done by encircling a conductor with a ferrite core which has windings wound around it. The core with its winding then acts as a single turn transformer where the mooring wire is the single turn. An alternating electrical current in the winding induces an alternating magnetic field in the ferrite core which induces an alternating current in the mooring wire. The strength of the signal produced in the mooring wire is proportional to the input signal, the number of turns on the core, and the core's magnetic permeability. On oceanographic moorings the ferrite cores are cut into two halves to facilitate their placement on long mooring lines. The resulting gap between the two halves of the core due to surface roughness and misalignment also affects the efficiency of the transfer between the windings and the mooring wire.

Oceanographic moorings generally use 3x19 torque-balanced wire rope as a strength member. This wire is made of improved plough steel, galvanized for corrosion protection and further protected with a jacket of extruded polyethylene. Thus, to make use of this conveniently insulated wire for signal transmission, a signal return path must be created and inadvertent seawater grounds must be minimized. Seawater is used for the return by terminating the mooring wire to silicon bronze grounding plates at the top and bottom of the wire. These connections are made through capacitors to avoid creating a bronze-iron battery which would drive galvanic corrosion in the mooring line if the plastic jacket were damaged. The capacitors allow the transmission of alternating signals, but block the DC component.

The effects of leakage to seawater has been investigated by stripping back the plastic jacket of a 500m shot of mooring wire and measuring when inductive signals fall below the receiver threshold. For the case investigated, up to 40 cm of wire could be exposed before the signal was too small to be successfully demodulated. Thus, small leaks in the jacket and at the terminations due to fishbite or wear and tear can be tolerated in the inductive link.

ALTOMOOR I was designed to evaluate the reliability of inductive telemetry on a long-term basis in the deep ocean. The mooring was configured so that hardwired data transmitted via an electromechanical cable could be collected simultaneously with the inductively-linked data to gather statistics on system reliability.

The inductive modem prototypes used on ALTOMOOR I were replaced with smaller, lower power modems for ALTOMOOR II. The new modems did not use telephone modem chips for modulation/demodulation, but rather used discrete components so that low power operation could be optimized. These second-generation modems have been commercialized and are now available through Falmouth Scientific, Inc., of Cataumet, MA. They are general purpose communication devices that are easily interfaced to most common oceanographic instrumenttation.

3. ALTOMOOR I - 1992-1993

3.1 Mooring Design

The ALTOMOOR I mooring is shown in Figure 3-1. Figure 3-2 shows its location relative to Bermuda and the ALTOMOOR II site. A large surface buoy with 9000 kg of net buoyancy supported approximately 4200m of wire rope, nylon and polypropylene mooring lines. An acoustic release with back-up flotation in the form of glass balls provided the connection to a 3600 kg (air weight) anchor which held the mooring in place. Instrumentation on the mooring included two InterOcean S-4 current meters located at depths of 27m and 207m and an EG&G Vector Measuring Current Meter (VMCM) located at 1807m. All three current meters were equipped with inductive modems and the S-4s were also hardwired to the system controller via an RS485 loop using three-conductor E/M cable. The inductive link and the 485 link operated in unpolled mode, sending data when the instruments transferred data to their internal memories. The transmit-only scheme allowed the use of the S-4s without relying on their internal communication protocol, which often required multiple addressing commands when used in a polled mode. The S-4s were programmed to record and transmit a one minute vector averaged current velocity once per hour. The VMCM averaged current for 15 minutes and recorded this value along with temperature and pressure four times per hour.

Instrumentation on the buoy consisted of a Coastal Climate Weatherpak meteorological station and a tension cell located beneath the buoy to measure tension at the top of the mooring cable. Weatherpak data included 10-minute vector-averaged wind velocity, air temperature and buoy heading and was recorded and telemetered on an hourly basis. The tension cell was sampled four times at 100 second intervals and these values were transmitted via the Argos transmitter. Thus, when a satellite was in range, four instantaneous tension samples were collected.

Instrumentation to measure buoy motions and mooring motion at several depths was also installed on the mooring. This instrumentation and the data on mooring dynamics that they collected are reported on separately [12].

3.2 Telemetry System

The ALTOMOOR I buoy data acquisition and telemetry system was built around a special purpose controller based on a Motorola 68 HC11 microcomputer originally designed for use with the Fast Fish profiler [13]. Appendix A is a detailed description of the controller and its operation on ALTOMOOR I.

The controller was interfaced via an RS485 loop to the buoy inductive modem receiver, to the hardwired S-4 current meters, and to the Argos transmitter. A separate serial line connected the Weatherpak. An Argos transmitter, programmed with two IDS, was used to telemeter the data to the Argos Data Collection System. Each hour sixteen 256-bit data messages

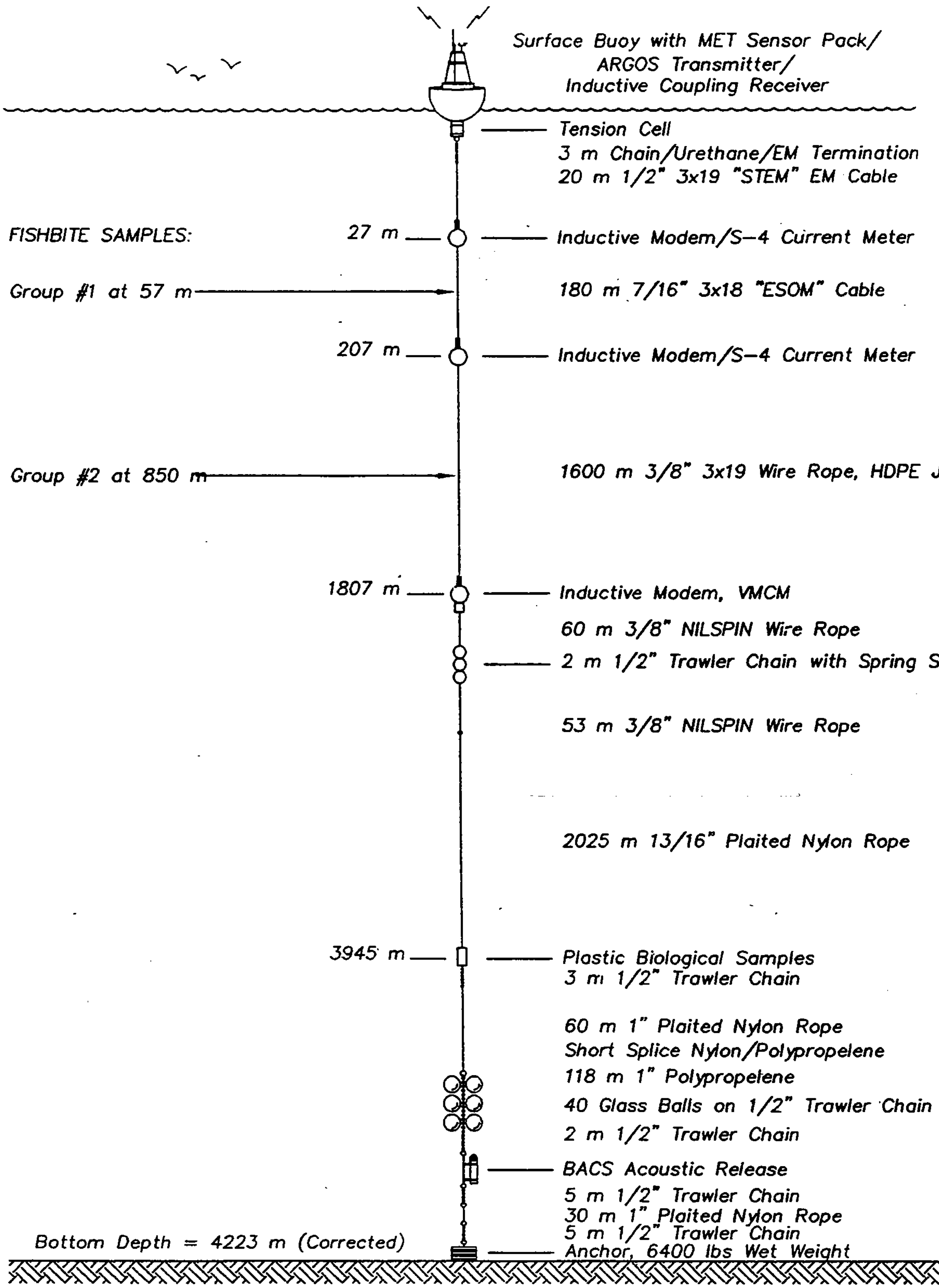


Figure 3-1: ALTOMOOR I mooring deployed in March 1993.

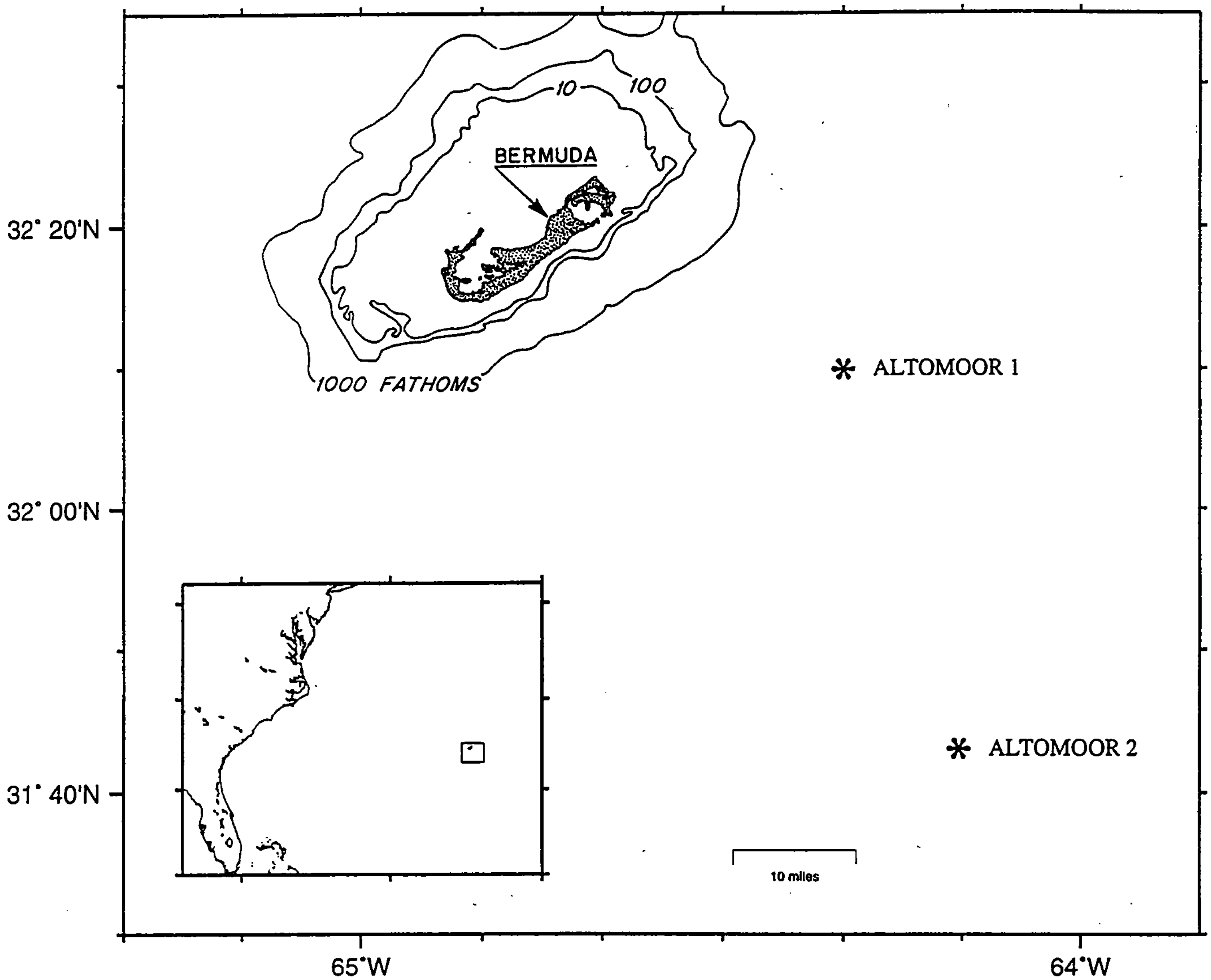


Figure 3-2: ALTOMOOR I and ALTOMOOR II mooring locations

covering the previous eight hours were loaded into the Argos transmitter's data buffer, advancing the satellite message by one hour each hour. This scheme was used to provide enough redundancy in transmission that almost all of the data were collected.

A secondary Argos transmitter was used as an engineering back-up to the main dual ID unit. It was wired and powered independently of the controller and telemetered battery voltage levels from the navigation light, the main electronics system battery, and its own battery. In addition it sampled the tension cell output on four of its analog channels.

Once per hour the controller updated the Argos message buffer with data from the previous eight hours. It collected Weatherpak data by initiating a data request, and collected current meter data by monitoring the RS485 line and the inductive modem receiver in the buoy. The current meters were scheduled to send data at 60 minute intervals, separated in time by 15 minutes, to minimize the chance of data collision. Each S-4 sent data via the inductive link, waited a few seconds and then sent data via the RS485 link. The VMCM transferred its data at 15 minute intervals to the inductive modem and the modem forwarded one sample each hour to the system controller. The VMCM was not part of the hardwired RS485 loop.

Inductive data telemetry is of particular interest for ocean moorings because it utilizes the standard, plastic-jacketed wire rope typically used for moorings without telemetry as the signal path. Seawater is used as the return path and grounding plates are installed at the top and bottom of the instrumented section to ensure a good connection to the seawater. These plates are isolated from the mooring wire with large capacitors, thus breaking the DC connection without breaking the AC connection. Wire rope terminations are not required unless in-line instruments are used because the "connectors" are split-ferrite cores clamped around the mooring wire with no direct electrical connection. This allows sensors or instruments to be located anywhere on the mooring and eliminates the need for electromechanical cables and terminations. Small breaks in the plastic jacket due to fishbite or wear and tear have little effect on the inductive telemetry signal.

The inductive modems used on ALTOMOOR I were designed for two-way communication; however, only the transmit capability was utilized in the remote units and the buoy modem acted only as a receiver. Specifications for the modems are shown in Table 3-1. Their important features include the ability to send data at 1200 b/s (and receive at 300 b/s) at a power drain of 270 mW over a distance of 10,000 meters. Standby power drain is 5 mW during the wait state when data from sensors is received and stored.

For the ALTOMOOR I program the modems were configured to be in the wait state except during the hourly data transfer. Three lithium D cells were used to power each of the modems for up to one year. Most of this energy was consumed during standby. Only a tiny fraction was used in transmission because the transmission duty cycle was less than 0.01%.

Table 3-1: Inductive modem specifications (ALTOMOOR I)

PARAMETER	SPECIFICATION
Frequency	1200/2200 Hz
Baud Rate	1200 bps uplink 300 bps downlink
Power Requirement	270 mW active 5 mW standby
Size	30 cm long x 5 cm diameter with lithium battery pack
Estimated Range	10,000 meters
Power/Bit (transmit)	2×10^{-4} J/b

The modem's signals are coupled to the mooring wire via split ferrite cores. The cores are 3 cm in diameter by 1.5 cm high with 150 turns of No. 30 wire. They are aligned in a specially designed clamp so that the two halves mate precisely when clamped around the mooring wire to maximize energy transfer efficiency.

Each modem consists of a two board set. An INTEL 80C51FA microcontroller on one board, interfaced to a SILICON SYSTEMS SSI 73K302L single-chip modem and associated analog components on the second. A daughter board was added to collect data from the current meters. This board has two main components, a Microchip PIC -1C57 microcontroller and an LTC485 RS-485 or open collector SAIL interface. This board is always powered and the PIC acts as a buffer/formatter for the data from the current meters. Details of the PIC board can be found in Appendix B.

Modems at the two S-4 locations transferred 17 data characters each hour. S-4 communication was CMOS level RS-232 at 4800 baud. When the PIC board received the first S-4 data character, the remaining data was required to arrive within two seconds or the PIC assumed the reception was in error and received characters were discarded. Once 17 characters were received, space characters and parity bits were eliminated, and a two-character ID was placed before the data creating a 16 character packet. The PIC then switched the power ON to the 80C51/Modem board set, waited 0.4 seconds and then sent the packet to the 80C51 for inductive transmission. The PIC waited for an additional 3.5 seconds and then removed power from the modem board. The 3.5 second delay allowed the modem time to establish a stable carrier that was recognized by the receiver in the surface buoy and then to transmit the data. The

PIC then waited an additional 10 or 20 seconds and then sent the same data with a revised ID to the buoy controller via the RS-485 loop.

The VMCM current meter at 1807m depth required special interface considerations. First, the VMCM normal communication method is 20 mA current loop using SAIL protocol at 300 baud. For power considerations this was modified to open collector SAIL and an open collector SAIL interface replaced the LTC485 on the PIC board. The VMCM was configured so that once addressed, it provided a 30-character data packet and remained in an open state. In the open state it provided new data every 15 minutes. When first powered, the PIC buffer board addressed the VMCM to insure it was in the open state and then started a 15 minute wait period. If VMCM data were received within this period, the wait cycle was restarted. If data were not received after 15 minutes, the PIC readdressed the VMCM in an attempt to acquire data and the wait cycle restarted. After either four data receptions or four, 15-minute timeouts, the PIC powered the modem and it sent two 16-character packets of the last data received. The first packet had an ID and the north and east current components and temperature data plus two characters of VMCM time. The second packet was sent 10 seconds after the first and had a different ID with the north and east current components replaced by rotor 2 and rotor 1 data.

The inductive modem in the surface buoy consisted of the 80C512FA microcontroller and SILICON SYSTEMS SSI 73K302L single-chip modem and associated components including the RS485 interface on one board. It operated by initializing the 73K302L modem and then waiting for the inductive carrier to be detected. With carrier present, each upper case HEX-ASCII character received was passed on to the buoy controller via RS485. Invalid received characters were ignored.

3.3 ALTOMOOR I Experiment Results

The ALTOMOOR I mooring was deployed on March 20, 1993 from the R/V CAPE HATTERAS in 4200 meters of water. The deployment site (32° 09.60'N, 60° 19.32'W) is 37 km from the southeast shore of Bermuda. This location was within easy reach of the Bermuda Biological Station for Research (BBSR) vessel (R/V WEATHERBIRD II) and at the same time provided the needed water depth for the experiments carried out on ALTOMOOR I.

The mooring was designed as a semi-taut array with a scope of 1.0 prior to deployment and a scope of 1.05 after deployment (assuming a zero current profile). The stretch (launch transient elongation) of the synthetic line and wire rope accounts for the scope change. The design current profile used for the mooring design was:

- 70 cm/sec at the surface
- 43 cm/sec at 500 meter depth
- 25 cm/sec at 2000 meter depth
- 10 cm/sec at 4200 meter depth

with linear interpolation between these depths.

The surface buoy is a 2.7m hemisphere made of surlyn foam and previously deployed for 18 months during the ESOM project. The first section of the moored array (upper 1900m) consisted of jacketed E/M cable and jacketed wire rope. This section was located in the fishbite zone [14] and was therefore made up of components proven to be fishbite resistant. The two S-4 current meters had both hardwire (RS485) and inductive telemetry to the surface buoy. The VMCM had only inductive telemetry.

Three samples of reinforced Kevlar were provided by Du Pont Fibers and Composites Development Center for an evaluation of their resistance to long-term environmental exposure. These samples were:

1. VETS 211 3/8" Kevlar rope with Kevlar/Dacron braided jacket (control)
2. VETS 211 3/8" Kevlar rope with Kevlar/Dacron and 6 mils stainless steel wire strands jacket
3. VETS 211 3/8" Kevlar rope with Kevlar/Dacron and 3 mils stainless steel wire strands jacket

Two sets of samples, each 20m long, were placed between 57 and 177m and three sets with each sample length of 30m were placed at 400m, 500m, 850m, and 1000m.

Ideally, inductively coupled systems would use a single continuous shot of wire rope with many clamp-on instruments. At the present time, however, most oceanographic instruments are meant to be used in line. As a result, a reliable way to patch around in-line instruments was needed. On ALTOMOOR I a Mecca connector was used and its pigtail was swaged into the normal wire rope termination replacing one of the filler wires. While this proved satisfactory, the design was improved on ALTOMOOR II. The improved version developed for use on ALTOMOOR II is shown in Figures 3-3a and 3-3b.

The lower part of the mooring consisted of nylon line and a short length of polypropylene line used to avoid tangling of the heavier nylon with the glass balls (backup flotation for recovery). A mooring response instrument was located at the end of the 2025m shot of nylon and a self recording engineering instrument (tilt, tension, pressure, temperature) was just below it.

Three mesh packages containing biodegradable plastic samples were placed at 3700m, married to the nylon rope. These samples are part of the "Studies on Marine Microbial Degradation of Bioengineered Polymeric Packaging Material" project conducted by the WHOI Biology Department and supported by the US Army Natick RD&E Center [15].

Two problems were encountered following the March 1993 deployment. First, the upper S-4 stopped sending data about two weeks after deployment. Both the RS485 (hardwired) link and the inductive link failed at the same time. This was due to an electrical failure in the S-4,

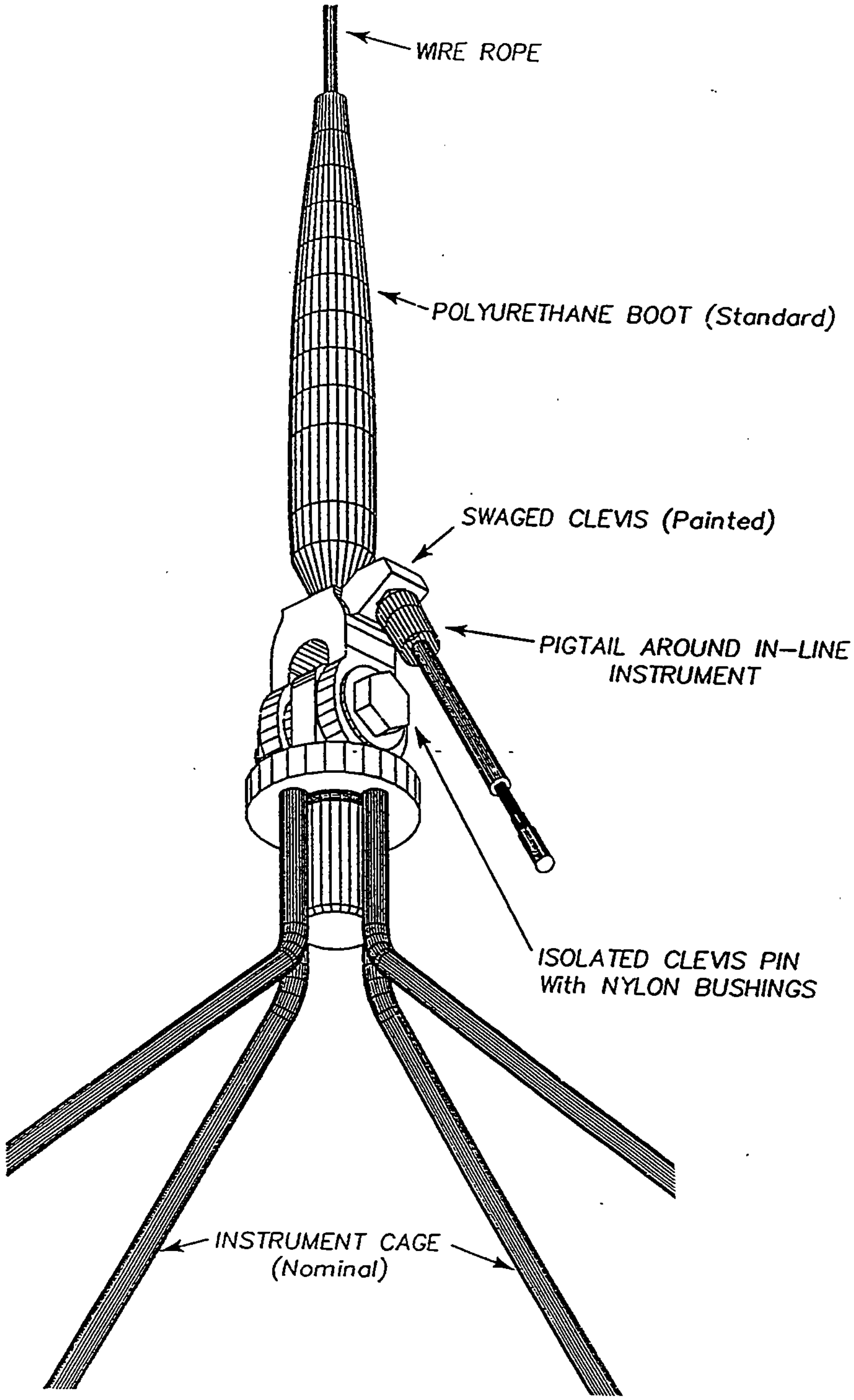


Figure 3-3a: Electrical termination of a wire rope shot used in ALTOMOOR II. Note that all metal parts in contact with the wire rope are isolated from seawater.

Figure 3-3b: Electrical termination of a wire rope shot used in ALTOMOOR II. Note that all metal parts in contact with the wire rope are isolated from seawater.

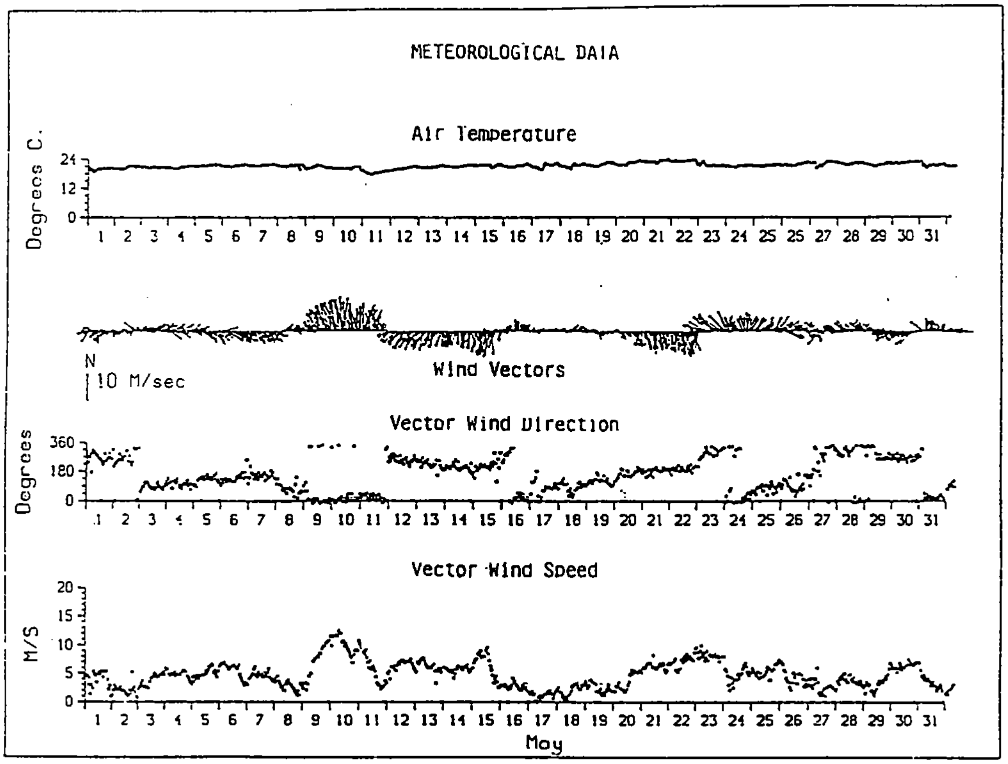
probably the result of the rough treatment this instrument saw just beneath the surface. The second problem was more subtle. The inductively telemetered data had a number of missing values which were deleted from the data stream by the error detection system. This problem was due to a subtle timing problem in the modem firmware and was corrected during the September turnaround.

In September 1993, a turnaround cruise was conducted and ALTOMOOR I was recovered on September 20, 1993. New batteries were installed in the buoy and the current meters and the mooring was redeployed on September 23. Following anchor deployment, the upper S-4 (27m depth) began transmitting continuously due to an electronic failure in the instrument. This effectively overloaded the RS485 link with the result that almost no data from the other current meters was able to get through to the Argos link. The fact that an occasional transmission from one of the lower instruments was received allowed the source of the problem to be determined. To repair this problem without retrieving the entire mooring, divers removed the inductive modem on the 27m S-4 and plugged the S-4 connector. This action opened the communications link and good data from the other two current meters began to be collected.

ALTOMOOR I continued to collect and telemeter current and weather data until March 1994. The subsurface data was lost at this point, but surface data continued to be sent until the mooring was retrieved in May 1994. Following retrieval, an examination of the mooring line and instruments revealed a problem at the 207m S-4, which appeared to be the result of human intervention. The cabling harness at the S-4 was pulled away from its frame and its connections to the S-4. The inductive modem and the mooring line were unplugged. The S-4 connector was bent and one of the pins broken off. This effectively unplugged both the inductive link and the RS485 link. This S-4 continued to record current data until 22 April 1994 when it failed. The 27m S-4 which was inoperative after being unplugged in September was fouled with fishing line. No other mooring degradation was observed and the electrical and inductive connections to the buoy were still in good shape. From the cuts on the connectors and the fishing line left on the mooring, it was concluded that fishermen were responsible for the damage. Figure 3-4 shows several examples of the inductively linked and hardwired data collected via satellite during the first and second deployment periods. The May and July periods illustrate the early inductive link problems - seen as missing data points in the S-4 records and zeroes in the VMCM data. In October all of the problems have been resolved.

Fishbite Tests

The Kevlar sample ropes were tie-wrapped to the mooring wire on deployment and half were removed during the maintenance turnaround after six months at sea. The rest of the samples were recovered after fourteen months at sea. They were examined in Woods Hole to determine the extent of fishbite damage and the protection provided by the steel thread reinforced jacketing. Fishbite damage was observed on several of the Kevlar lines, both the controls and



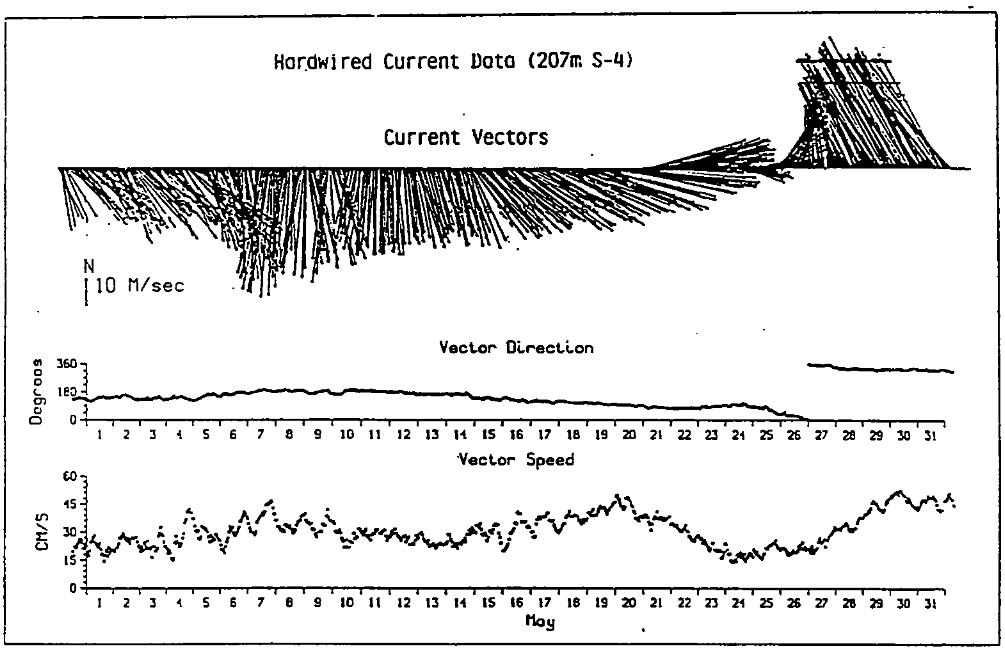
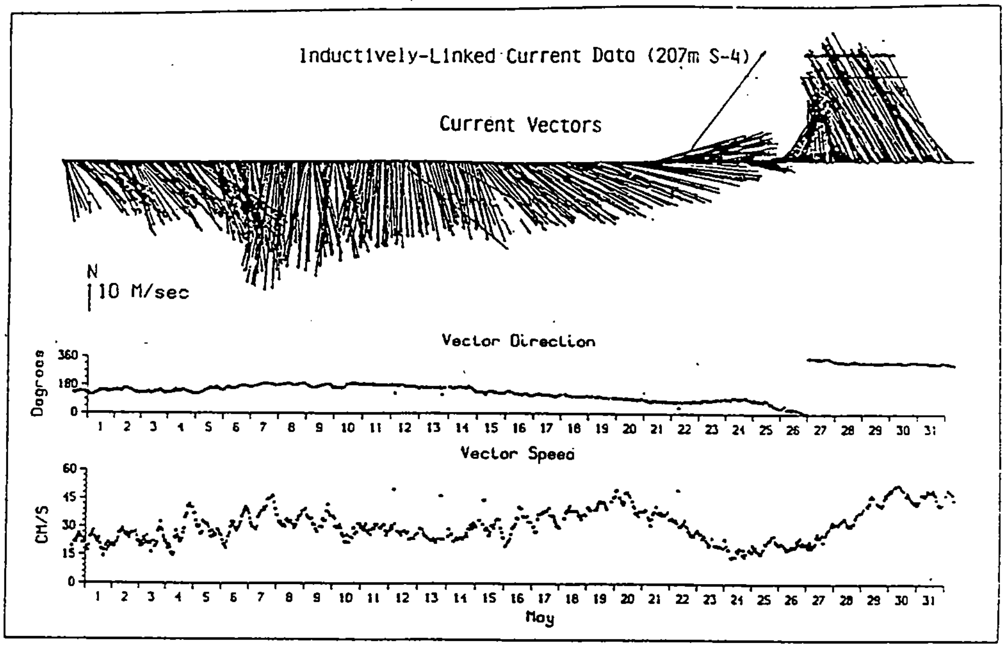


Figure 3-4a: ALTOMOOR I data from May 1993.
Current meter data shows hardwired and inductively-linked data for comparison



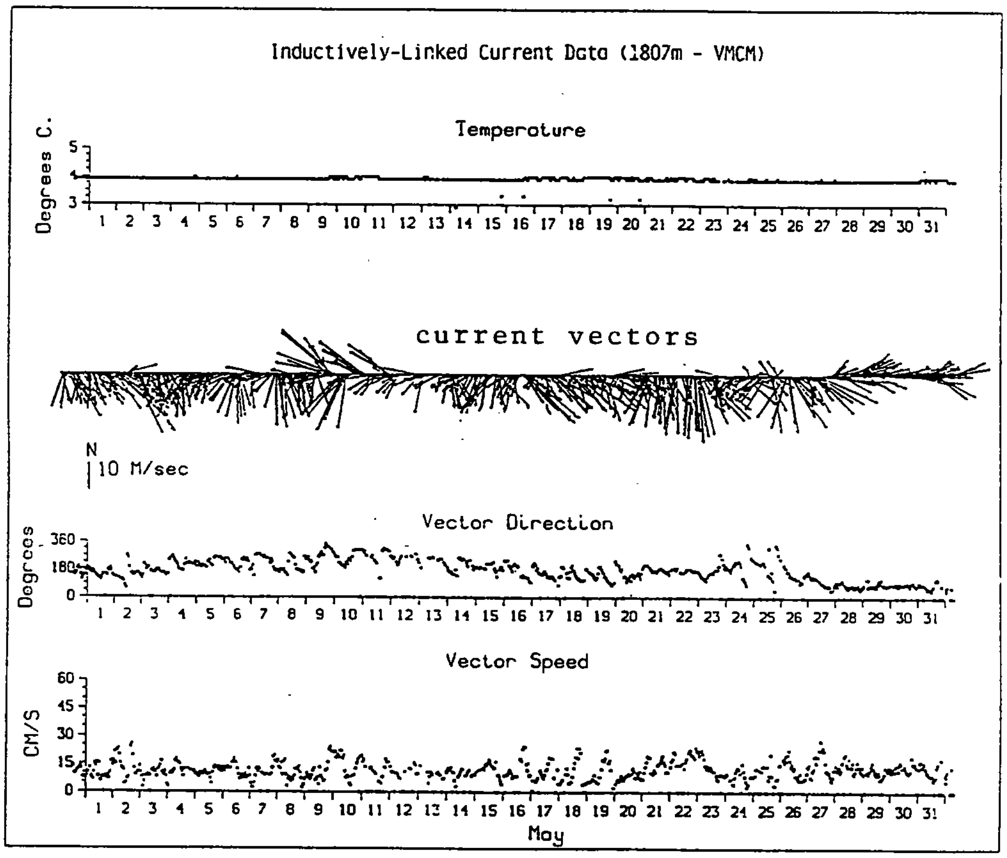
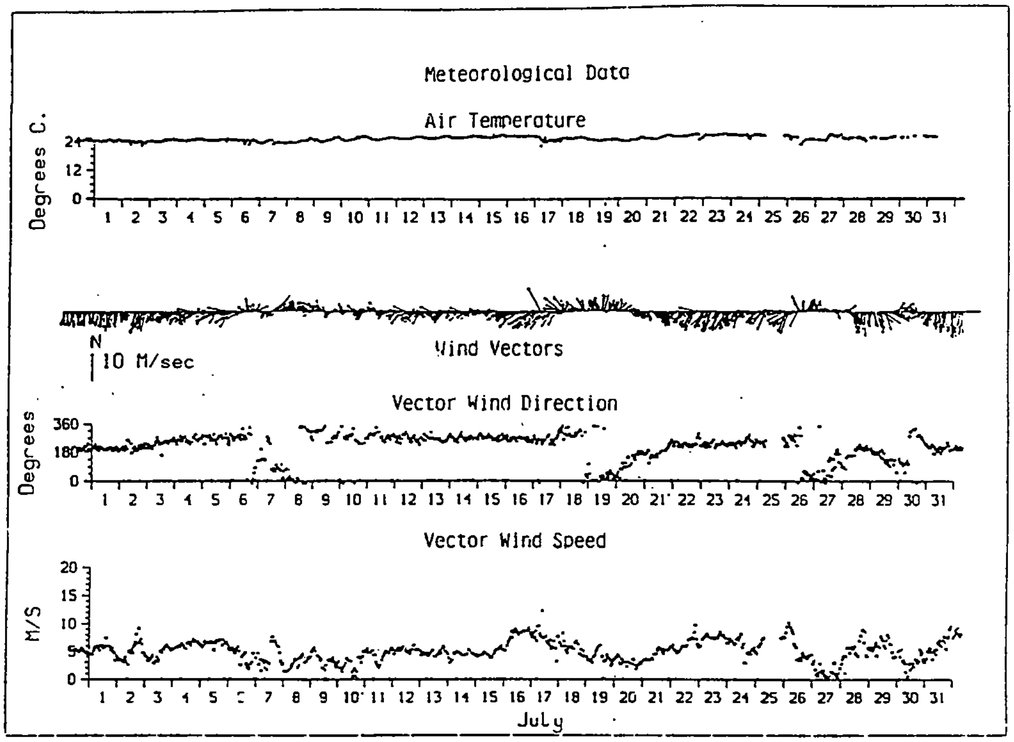


Figure 3-4a: ALTOMOOR I data from May 1993.
Current meter data shows hardwired and inductively-linked data for comparison



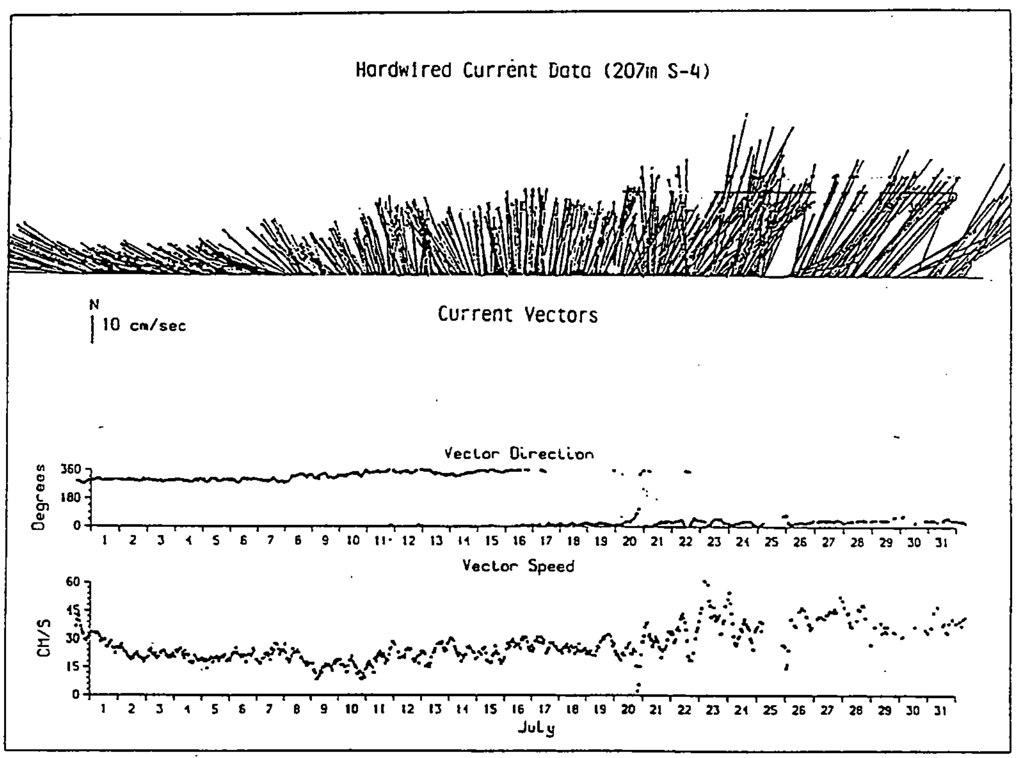
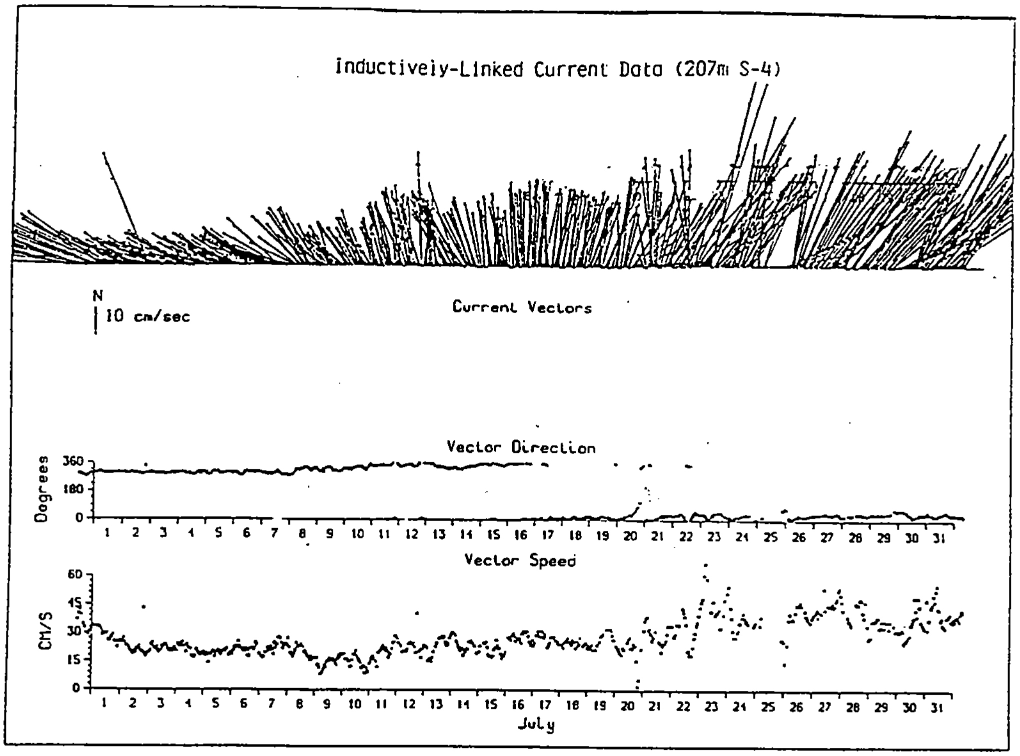


Figure 3-4b: ALTOMOOR I data from July 1993.
Current meter data shows hardwired and inductively-linked data for comparison



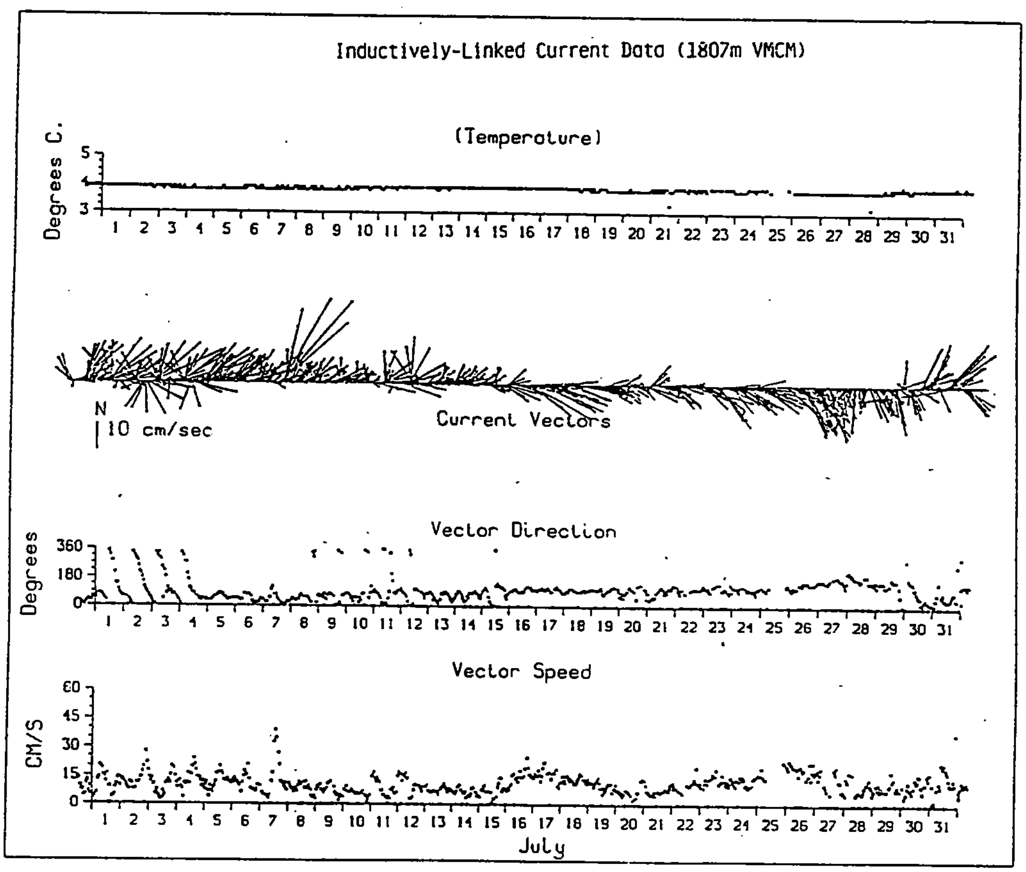


Figure 3-4b: ALTOMOOR I data from July 1993.
Current meter data shows hardwired and inductively-linked data for comparison

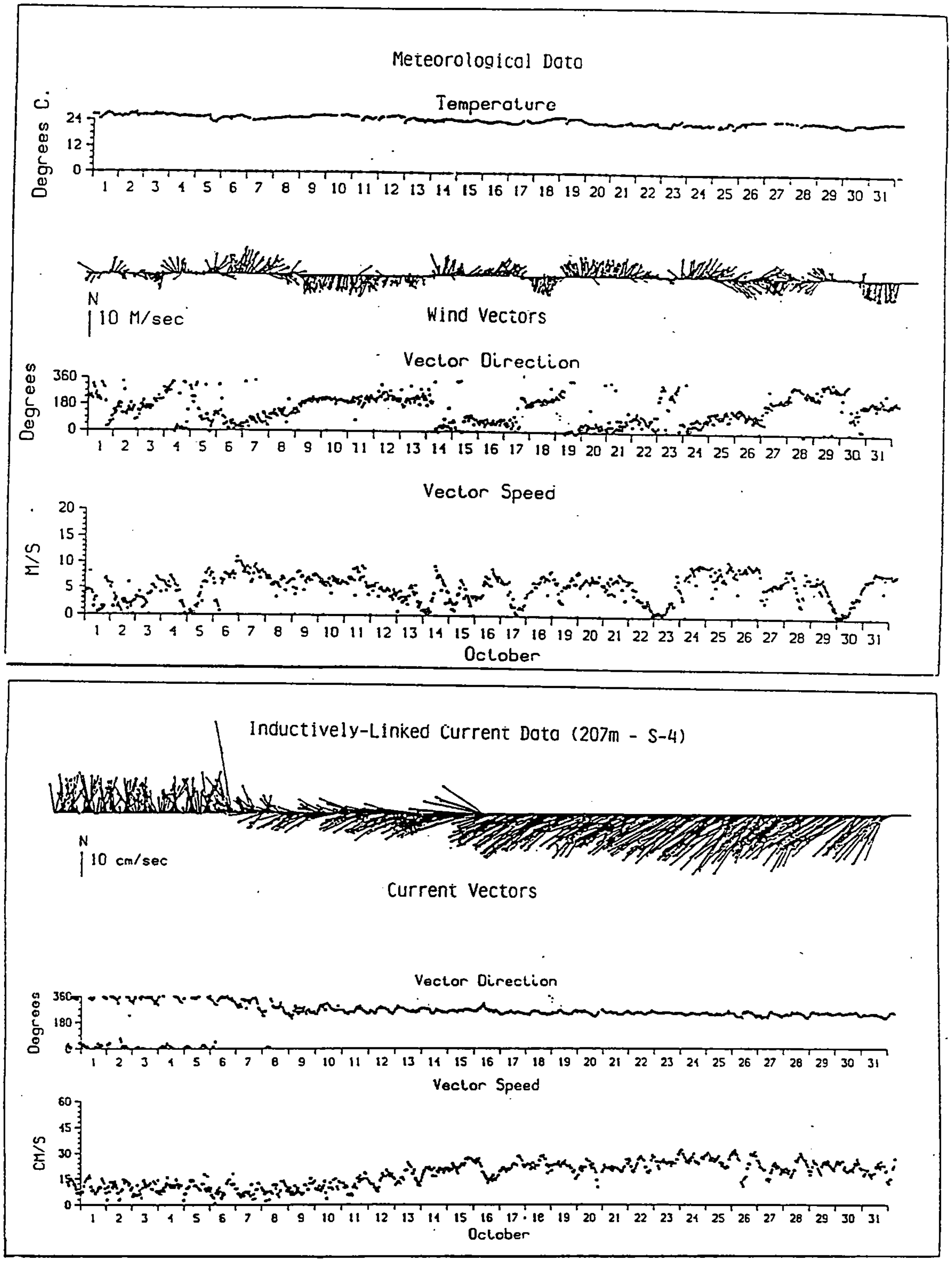


Figure 3-4c: ALTOMOOR I data from October 1993.

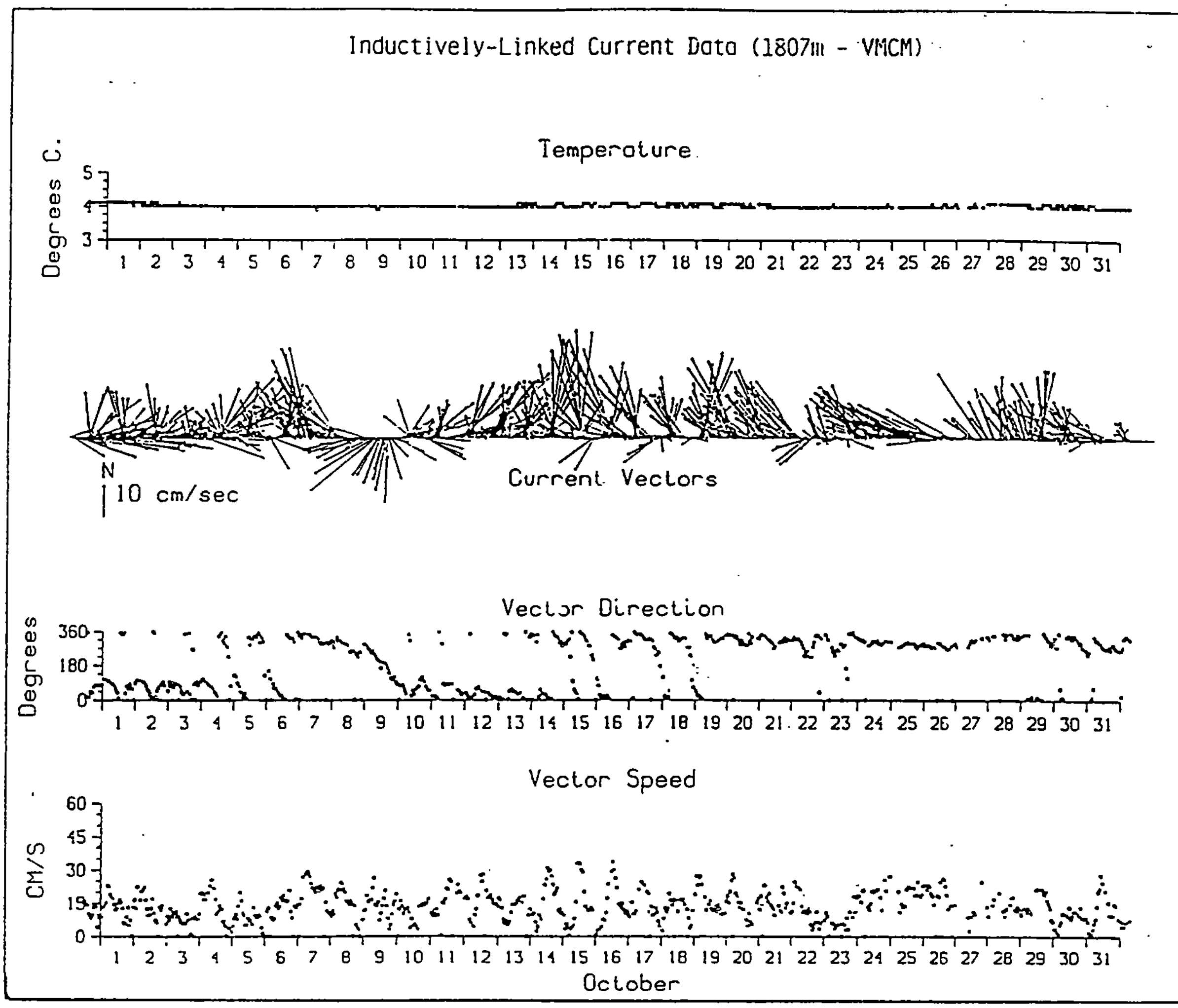


Figure 3-4c: ALTOMOOR I data from October 1993.

the lines with the stainless thread. No appreciable difference in fishbite resistance between the types of line was observed. The conclusion drawn was that protective wires of 3 and 6 mil diameter were not large enough to protect the Kevlar strands from fishbite damage. The manufacturing process used to make these lines, which was developed for making butchers' aprons and gloves, is limited to these small wire sizes. It is also limited to a relatively small number of wire strands which provide only about 10% coverage of the outer layer of line. For these reasons we have concluded that this method of protecting Kevlar from fishbite is not reliable for oceanographic moorings. Larger individual wires and higher percent coverage could overcome this problem, but special manufacturing techniques would have to be developed. This issue awaits further investigation.

E/M Cable Tests

Three conductor E/M cable was used to moor the S-4 current meters. The RS485 circuit was formed using these conductors while the inductive link used the cable's steel armor wires. The cables were terminated in cast epoxy fittings. The inductive link for this part of the mooring, as well as the wire rope sections used in the lower part of the mooring, used Mecca connectors wired to the termination body to provide electrical connection around the in line instruments. The E/M cable and wire rope termination techniques worked well on ALTOMOOR I. The cables were used for fourteen months without damage and appeared to be as good as new on retrieval.

4.0 ALTOMOOR II - 1994-1995

ALTOMOOR II was funded by ONR and NSF to both continue the work in real-time data telemetry and to use the deep-water mooring as a testbed for oceanographic instrumentation evaluation. The WHOI efforts in telemetry and mooring design were funded under the Moored Array Technology program by ONR and NSF funded Dr. Tom Dickey's Ocean Physics Group at the University of Southern California to deploy and analyze data from various oceanographic instruments. Under Dr. Dickey's direction, researchers at the Monterey Bay Aquarium Research Institution, the Massachusetts Institute of Technology, and Falmouth Scientific, Inc., have also supplied instruments for use on the mooring. Dr. Dickey also receives funds from NASA for certain of the instruments on ALTOMOOR II. This Technical Report is limited to a description of the WHOI efforts. Information on the other aspects of ALTOMOOR II can be found in [6].

4.1 Mooring Design

The mooring shown in Figure 4-1 was deployed on June 3, 1994 at 31° 44.95'N, 64° 10.17'W in 4567m of water about 90km SSE of St. Georges, Bermuda. The mooring was suspended from the same large surface buoy used on the ALTOMOOR I mooring but was re-configured with new electronics, new instruments, and new mooring components.

The mooring consisted of 3/8 torque-balanced wire rope from the surface to about 3000m. Below this depth were various nylon, polypropylene, and chain shots. Inductive telemetry from various instruments to the surface buoy was implemented using an improved modem design and an improved wire rope termination design. Figure 3-3 shows the termination swaged to the end of each wire rope shot. Each clevis had a special termination socket welded to it which was threaded to accept a standard pipe thread. An electrical pigtail with a pipe-thread nut and O-ring screws into the socket to provide a method to pass around in-line instruments. The clevises are coated to insulate them from seawater. The inductive link is terminated at the buoy and at the bottom of the instrumented section to silicon-bronze grounding plates isolated from the wire rope with large capacitors.

Table 4-1 shows the ALTOMOOR II instrumentation load as a function of deployment period. The instruments in bold operated as part of the real-time telemetry link and the instruments with asterisks were equipped with inductive modems.

4.2 Telemetry System

ALTOMOOR II incorporated two new telemetry systems. An inductive link was implemented on ALTOMOOR II, but rather than use the prototype modem designs used on ALTOMOOR I, an improved modem was developed that operated at lower power and could be packaged inside the instrument from which it was transmitting data. The power drain was low enough that the instrument battery could be used with almost no impact on the instrument itself.

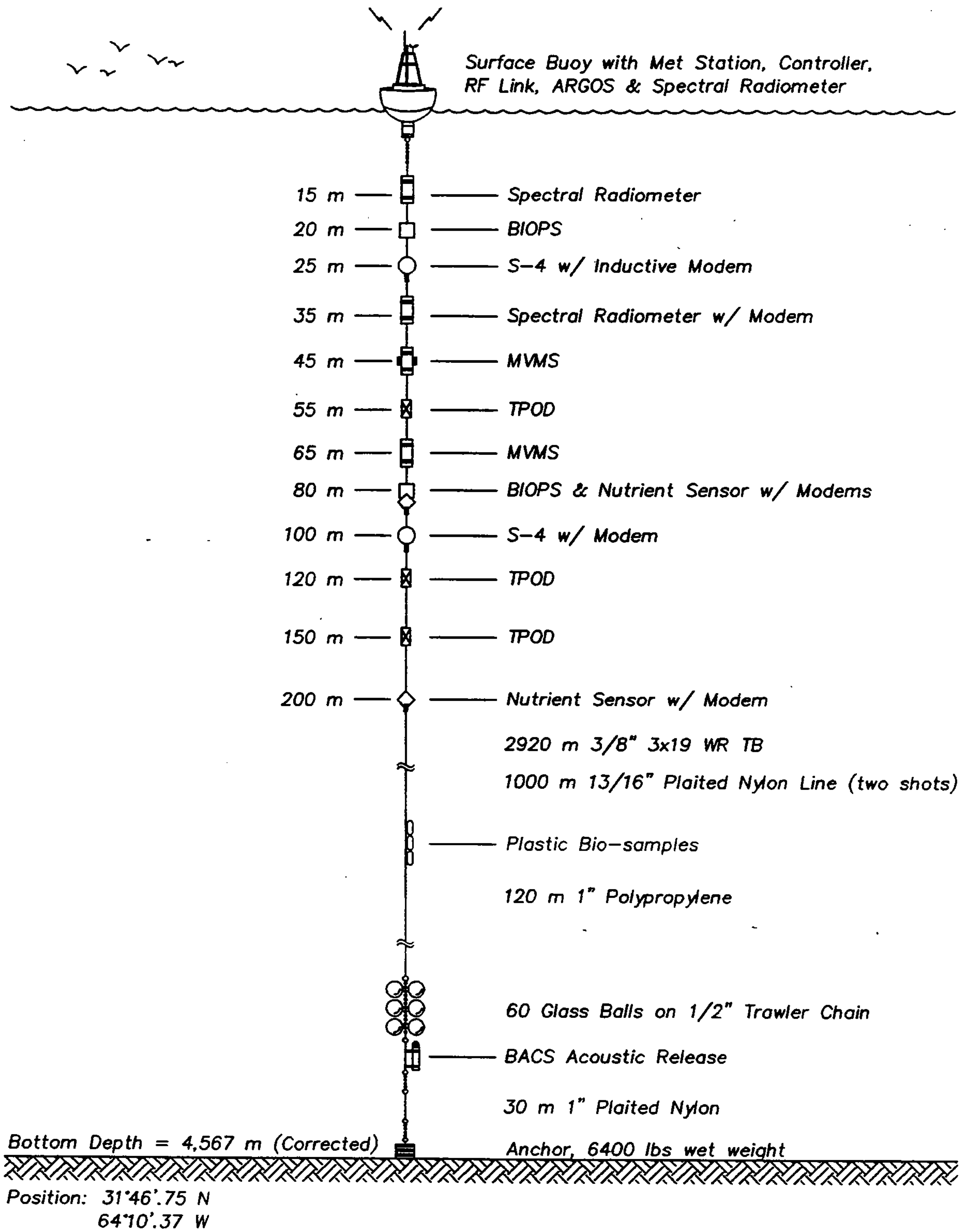


Figure 4-1: ALTOMOOR II instrumentation

Table 4-1: ALTOMOOR II Instrumentation

DEPLOYMENT 1 June - Sept. 1994 Depth ( )	DEPLOYMENT 2 Sept. 94 - Jan. 95	DEPLOYMENT 3 April 95 - Aug. 95	DEPTH Deployment 2 & 3
WeatherPak	**WeatherPak**	**WeatherPak**	On Buoy
Spectral Radiometer*	**Spectral Radiometer***	**Spectral Radiometer***	On Buoy
TPOD (10m)	Spectral Radiometer	Spectral Radiometer	15 meters
MVMS (20m)	BIOPS*	**BIOPS***	20 meters
TPOD (30m)	**S-4***	**S-4***	25 meters
S-4* (45m)	**Spectral Radiometer***	Spectral Radiometer*	35 meters
MVMS (60m)	MVMS	MVMS	45 meters
-------------	------------	Trace Metal Sampler	51 meters
TPOD (70m)	TPOD	TPOD (60 meter)	55 meters
-------------	MVMS	MVMS (71 meter)	65 meters
BIOPS* (80m)	BIOPS*	**BIOPS* (86 meter)**	80 meters
NUTS* (80m)	NUTS*	**NUTS***	80 meters
S-4* (100m)	S-4*	**S-4* (106 meter)**	100 meters
-------------	TPOD	TPOD	120 meters
------------	TPOD	TPOD	150 meters
NUTS* (200m)	NUTS*	**NUTS***	200 meters

NOTE: (1) Bold lettering indicates an instrument was part of the operational telemetry during this time frame.
(2) * indicates instrument with inductive modem

Table 4-2: Inductive Modem Specifications

Parameter	Specifications
Frequency	1300/2600 Hz Data
Baud Rate	1200 b/s uplink and downlink
Power	0.1 mW standby 50 mW active
Size	4 x 8 x 2 cm
Estimated Range	3 km
Power/Bit (transmit)	4×10^{-5} J/b

This design allowed the modems to be much cheaper (no pressure case, no battery), made them easier to install, and required only a two-pin connector installed on the instrument end cap for connection to the toroid. The improved modem was developed in cooperation with Falmouth Scientific, Inc., who are licensed to produce it commercially. A simplified schematic of the modem is shown in Figure 4-2a. A photograph of the modem is shown in Figure 4-2b. Table 4-2 lists the modem specifications. Figure 4-3 shows the toroid used with the redesigned modem. To solve the modem-to-instrument interface problem, a small buffer board was developed to act as a data storage device. It collects and stores instrument data and when addressed, downloads data to the modem.

The ALTOMOOR II inductive system operated as follows. Each instrument equipped with a modem downloaded data to the buffer board on its particular schedule coincident with writing the data to internal memory. The buffer stored the data in a low power state. The controller then addressed each instrument on an hourly schedule to offload any accumulated data. Each instrument (modem) had a unique ID so that only one instrument responded to a query. A very low power receiver in the modems allowed them to remain in a low power state while they waited for an address. A carrier tone woke all of the modems prior to each query, but only the addressed modem responded. The others waited a few seconds then returned to their low power receive mode.

A second new telemetry system was incorporated into ALTOMOOR II to overcome the data throughput limitations inherent with the Argos Data Collection System. Even when using multiple IDs, the daily throughput achievable with the Argos link is only about 500 Bytes/day/ID. With up to ten inductively-linked instruments, this was a serious handicap. To meet the demand for larger quantities of data, a short range radio link, whose specifications are shown in Table 4-3, was implemented on the buoy. A similar approach has been used by Von der Heydt [16] and [17].

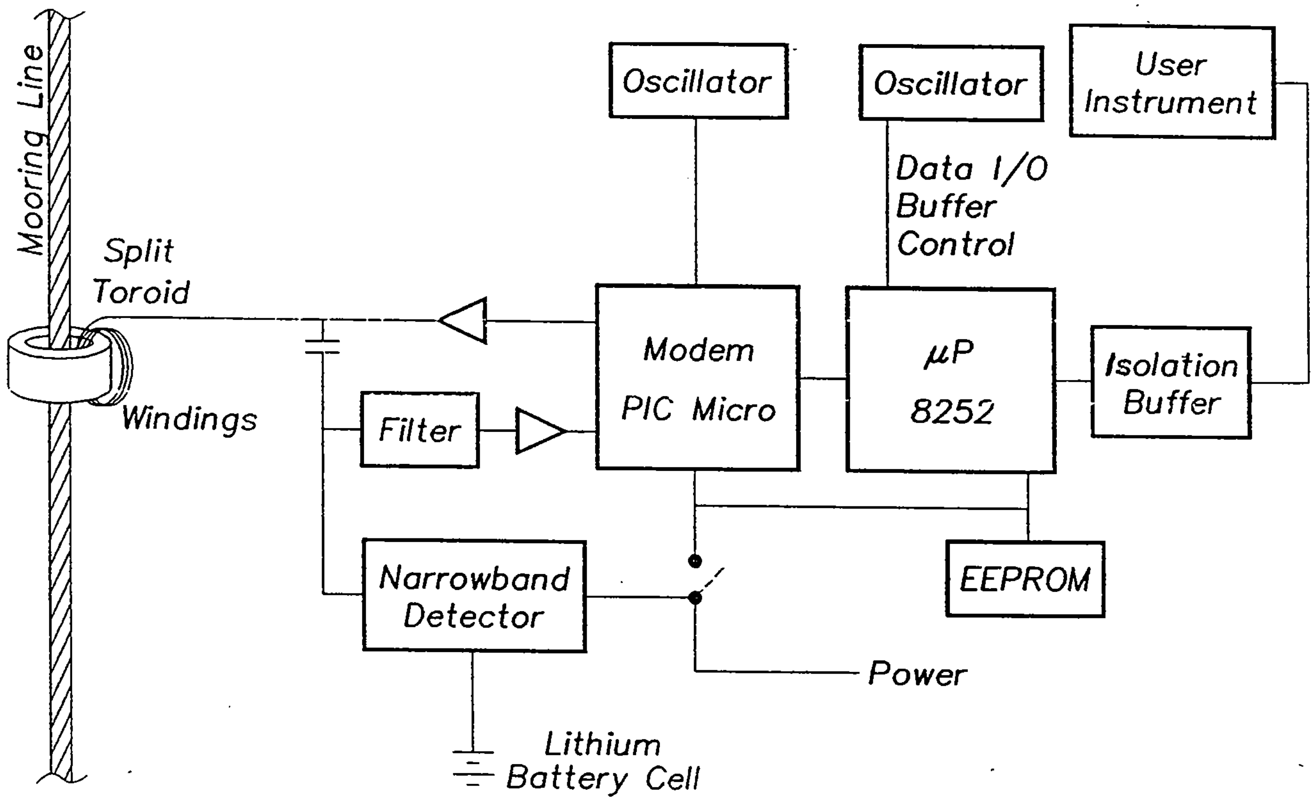


Figure 4-2: Inductive modem simplified schematic.

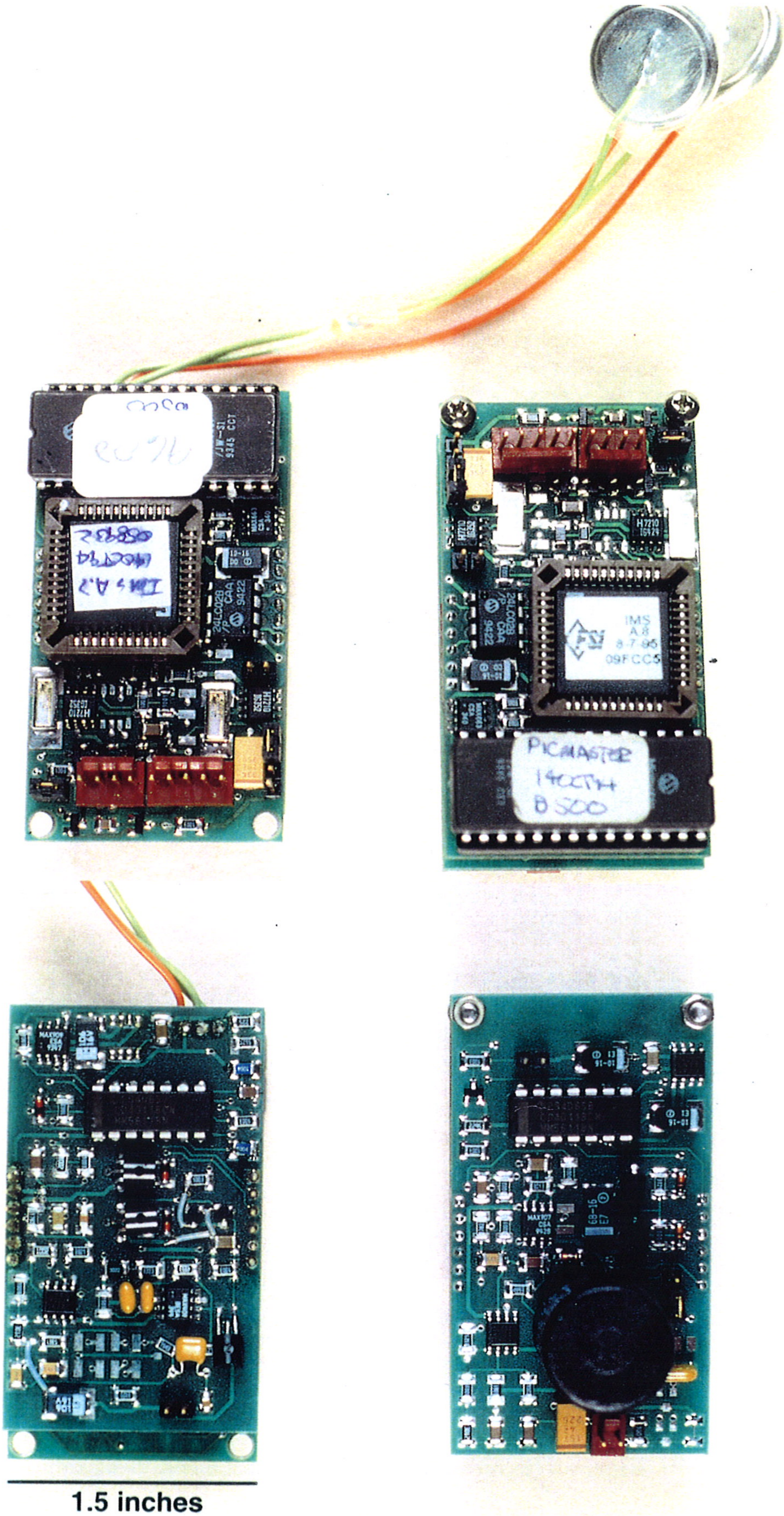


Figure 4-2b: Inductive modem two-board set showing remote (left) and master (right).

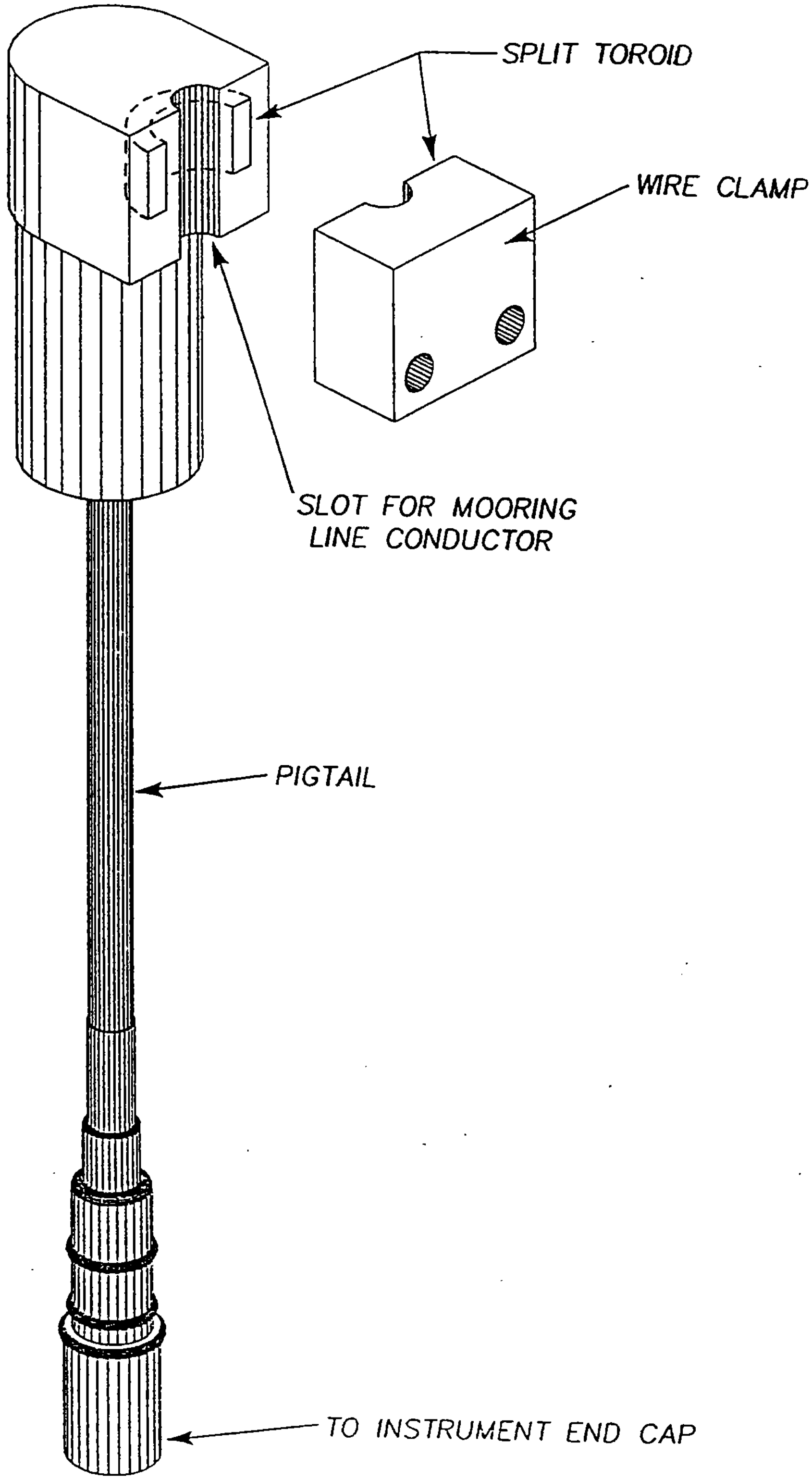


Figure 4-3: Inductive modem toroid used on ALTOMOOR II.

Table 4-3: RF Link Specifications (ARLAN Model 610)

LAN Interface:	Ethernet
Radio Data Rates:	27 - 169 Kbytes/sec
Frequency:	902-928 MHz
Modulation:	Direct sequence spread spectrum
Power Output:	One Watt
Size:	9.6 x 9.6 x 1.9"
Power Supply:	15 - 28 VDC, 18W
Operating Environment:	0 - 40° C
Range:	up to 6 miles with directional antennas

In the ALTOMOOR II application, because the buoy was out of range of land, the R/V WEATHERBIRD was used as a temporary store-and-forward site between the buoy and an Internet accessible station on shore, at the Bermuda Biostation. The system operated in conjunction with the ALTOMOOR II controller. Data collected by the controller was stored on hard disk each hour. The radio link was activated by the controller every half hour and it tried to make a connection with the WEATHERBIRD. If the ship was nearby, a link was established and contents of the disk were transferred at an average rate of 10kB/s. If no link was established, the radio shut down to save power and waited for the next half hour. To avoid transferring the contents of the disk over and over, which wastes power, the controller only allowed offloads to occur once per week and only data not previously transferred was telemetered. The ship had the same radio link as the buoy interfaced to a PC on the bridge and the data from the buoy disk were transferred to the PC disk. A similar operation occurred when the ship docked at the Biostation with a PC in the laboratory that was equipped with an RF link. The entire data set was stored on a large disk that was accessible via the Internet. Thus, data from the buoy could be accessed from WHOI with a few weeks delay. Figure 4-4 illustrates the RF link operation.

To facilitate use of the radio link (and hard disk) and the new inductive modem design, a new controller was used for ALTOMOOR II. This controller, based around a commercially available PC104 compatible device, was first used on the Surface Suspended Acoustic Receiver [18], an instrument designed to monitor acoustic signals for detecting changes in ocean temperature. The controller is a DOS device, programmable in C which is easily interfaced to PC-based peripherals such as hard disks and wireless ethernet links. The controller is shown in Figure 4-5 (block diagram).

Operation of the controller is based on a scheduler and is illustrated in the flowchart shown in Figure 4-6. The controller remained in a low-power state except when performing data collection, storage, or telemetry tasks. The system operated on a 30-minute cycle for all RF link tasks. It operated on an hourly cycle for data collection, Argos telemetry and storage of data to disk. Each polled instrument had a specific conditioning (filtering) program used to sort, calibrate, and format data so that the controller could then treat the data in a uniform manner. The Argos PTT (Seimac SmartCat III) operated independently once it was loaded with data on an hourly basis.

The power supply for the controller, Argos PTT, and radio was a 12V alkaline battery made up of four parallel stacks of D cells providing 360 AH of capacity. This was enough power for one year's operation. Separate alkaline batteries were installed in the buoy for the navigation light and for a secondary PTT which was used during the initial deployment period.

4.3 ALTOMOOR II Instrumentation Testbed Results

The initial ALTOMOOR II deployment was conducted on June 3, 1994. Problems with the inductive modem hardware prevented successful operation of the inductive link and as a consequence, the controller was removed from the buoy after deployment and returned to WHOI to aid in the debugging process. This eliminated both the inductive and RF telemetry links for the initial deployment period. All instruments on the mooring continued to operate in the internal recording mode so no data were lost as a consequence.

Inductive modems were modified at Falmouth Scientific, Inc. between the June deployment and the September turnaround and installed in the instruments and on the buoy during the turnaround. ALTOMOOR II was re-deployed on 24 September 1994. Inductive modems were installed on seven instruments (see Table 4-1) and the WeatherPak and Argos PTT were linked via an RS232 loop. Following deployment, however, it was discovered that telemetry from beneath the 35m Spectral Radiometer was not received at the buoy. This problem was subsequently traced to the Multi-Variable Measurement System (MVMS) at 45m whose stainless steel cage was inadvertently in electrical contact with the wire rope termination at its upper end. This effectively made the inductive link grounding plate the MVMS cage and no current flowed beyond this point. The wire rope clevises were subsequently shortened by grinding them down for the April deployment. The RF link was successfully demonstrated in December (1994)

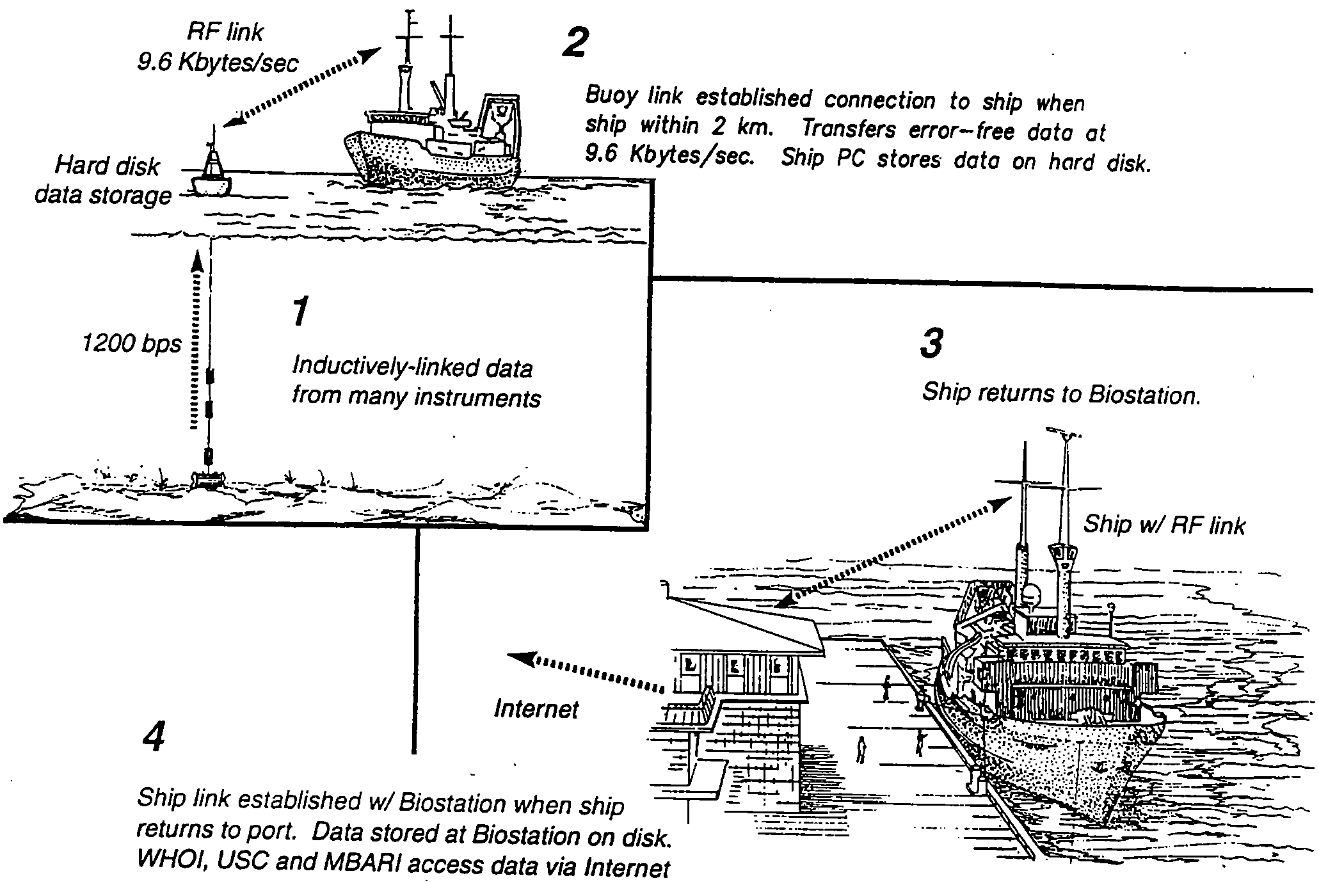


Figure 4-4: High speed RF link from ALTOMOOR II buoy to WHOI

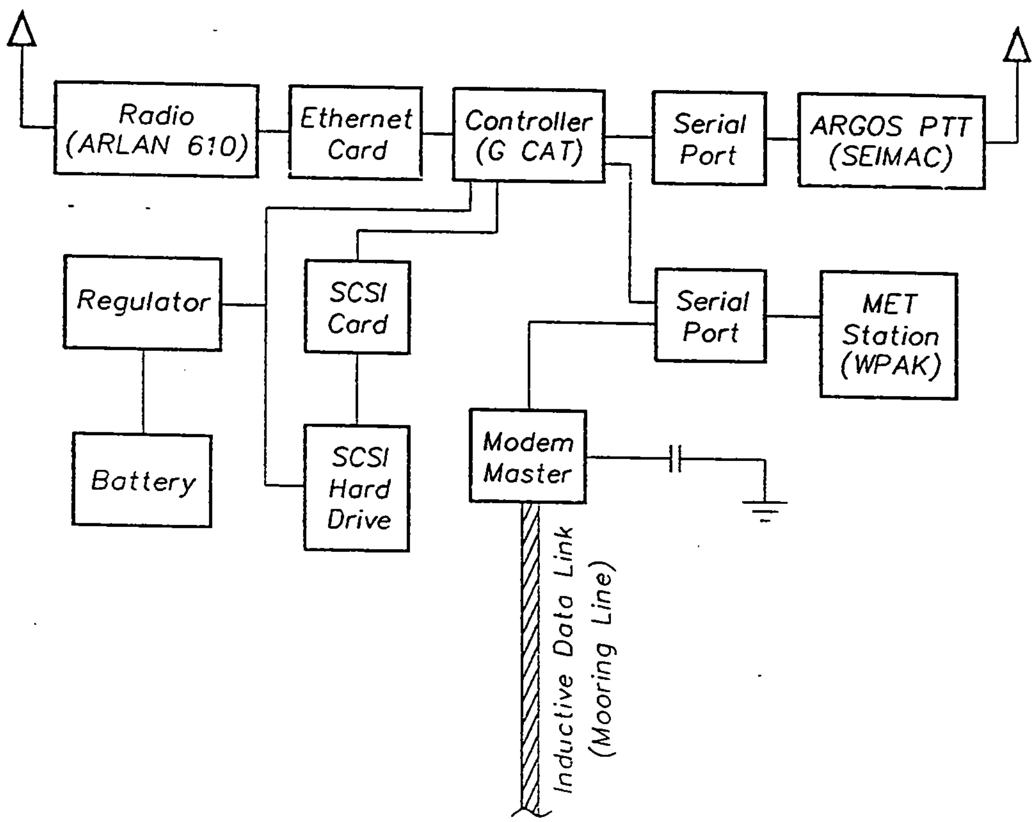


Figure 4-5: ALTOMOOR controller block diagram

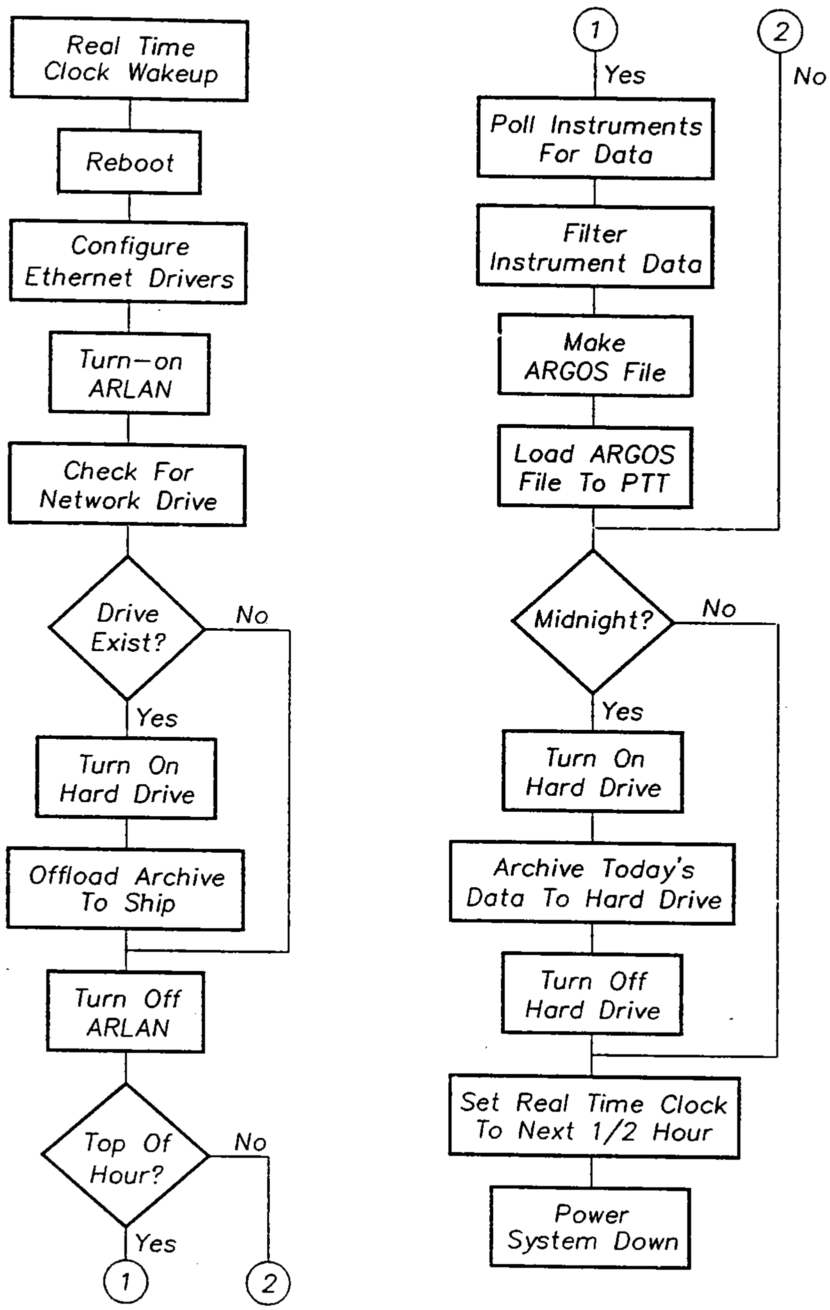


Figure 4-6: ALTOMOOR II controller flow chart

when a total of 6MBytes of data from the buoy hard disk were offloaded to the WEATHERBIRD at an average rate of 10 kB/s. These data were subsequently transferred via Internet.

ALTOMOOR II was recovered on January 28, 1995. It was turned around on shore in Bermuda and an attempt was made to deploy it between February 8-10, but the weather was uncooperative. The deployment cruise was re-scheduled and ALTOMOOR II was re-deployed on April 5. Eight instruments were equipped with inductive modems, but one, the Spectral Radiometer at 35m, was inoperative during bench tests. It was not repaired prior to the cruise.

Following deployment, the inductive link operated as designed with data collected hourly from seven inductively linked instruments and one hardwired instrument (WeatherPak). The RF link operated successfully, off-loading tens of Mbytes of data. Figure 4-7 shows an example of wind and current data collected during the initial deployment period (June-September 1994). Figure 4-8 shows inductively linked current meter data for the April-June 1995 period. Figure 4-9 shows winds and currents from August 1995 prior to the passage of Hurricane Felix which passed directly over the mooring site on August 15. At the height of the storm the inductive link failed due to a break in the conductor connecting the wire rope section at the top of the mooring to the controller. Data did continue to be recorded internally in all of the instruments and will be reported separately [19]. The mooring was recovered on August 23.

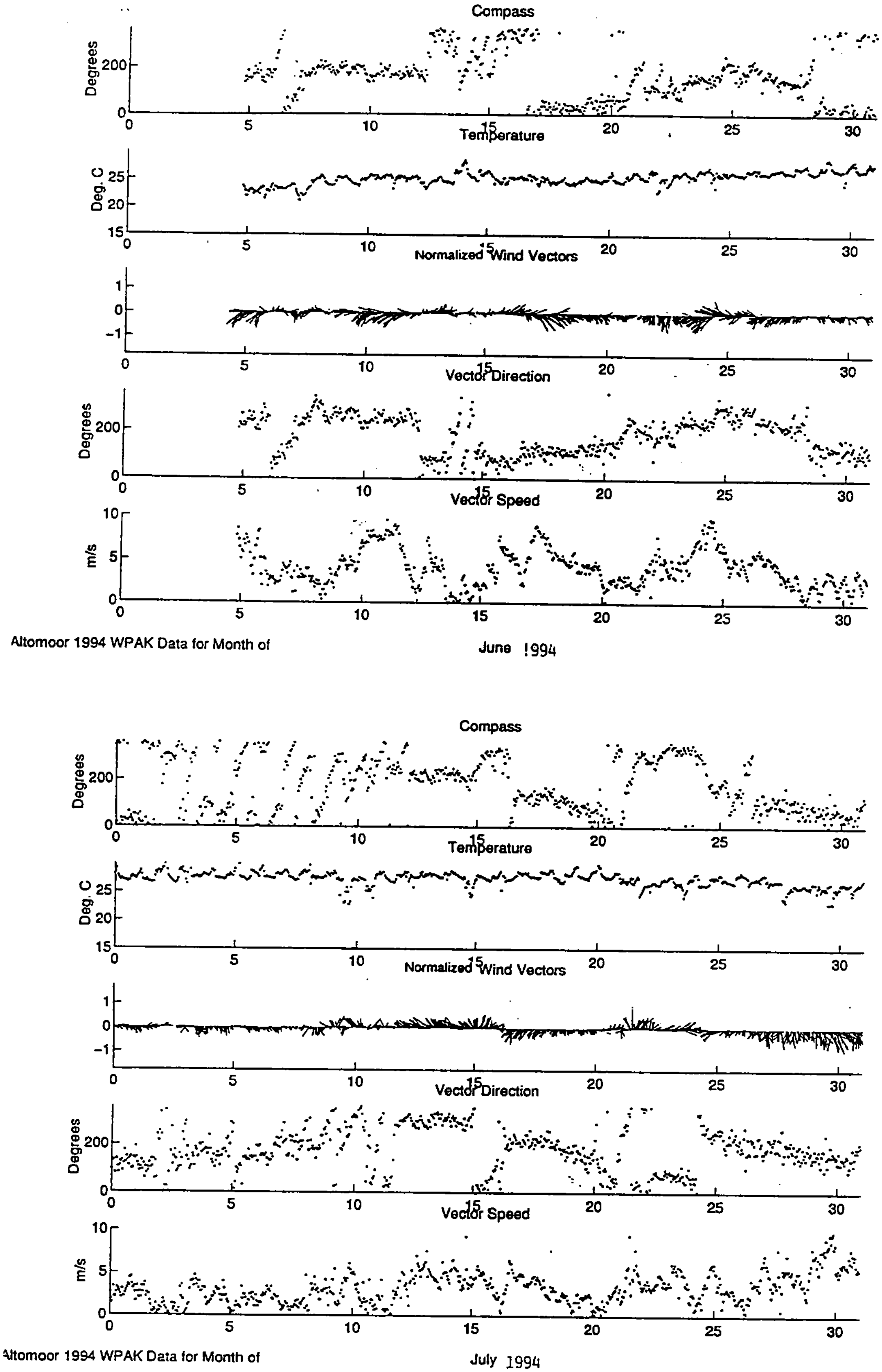
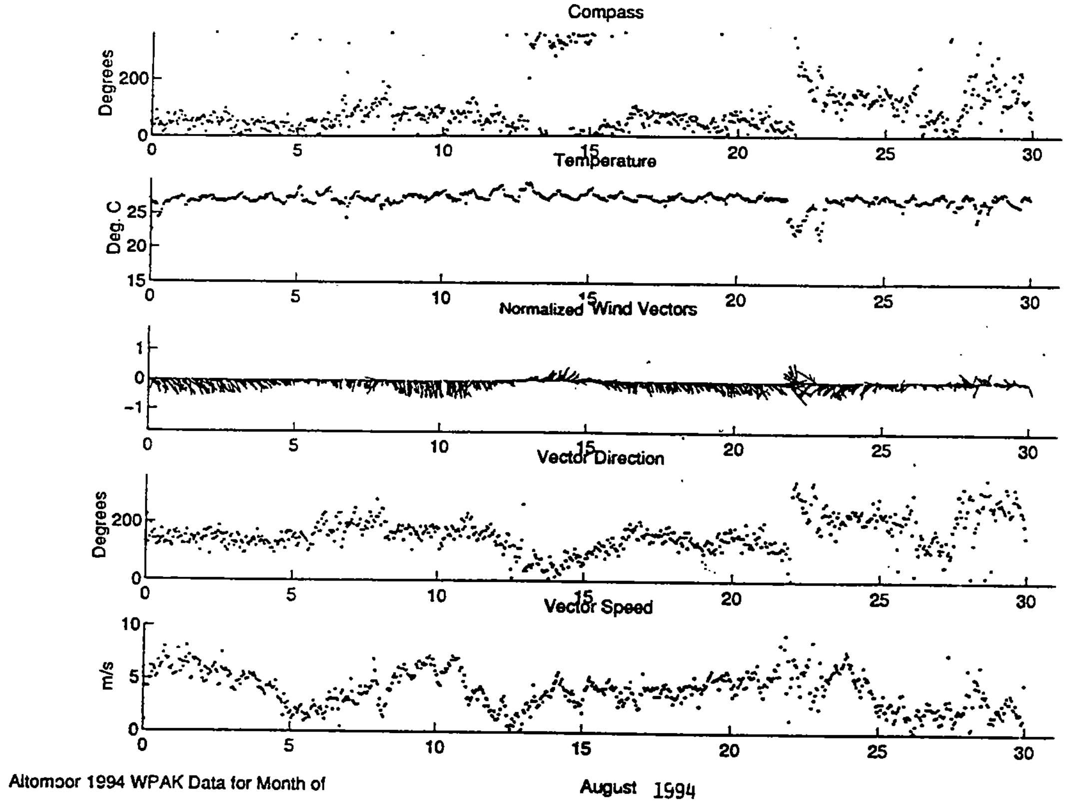


Figure 4-7a: Meteorological data from ALTOMOOR II from June-September 1994.



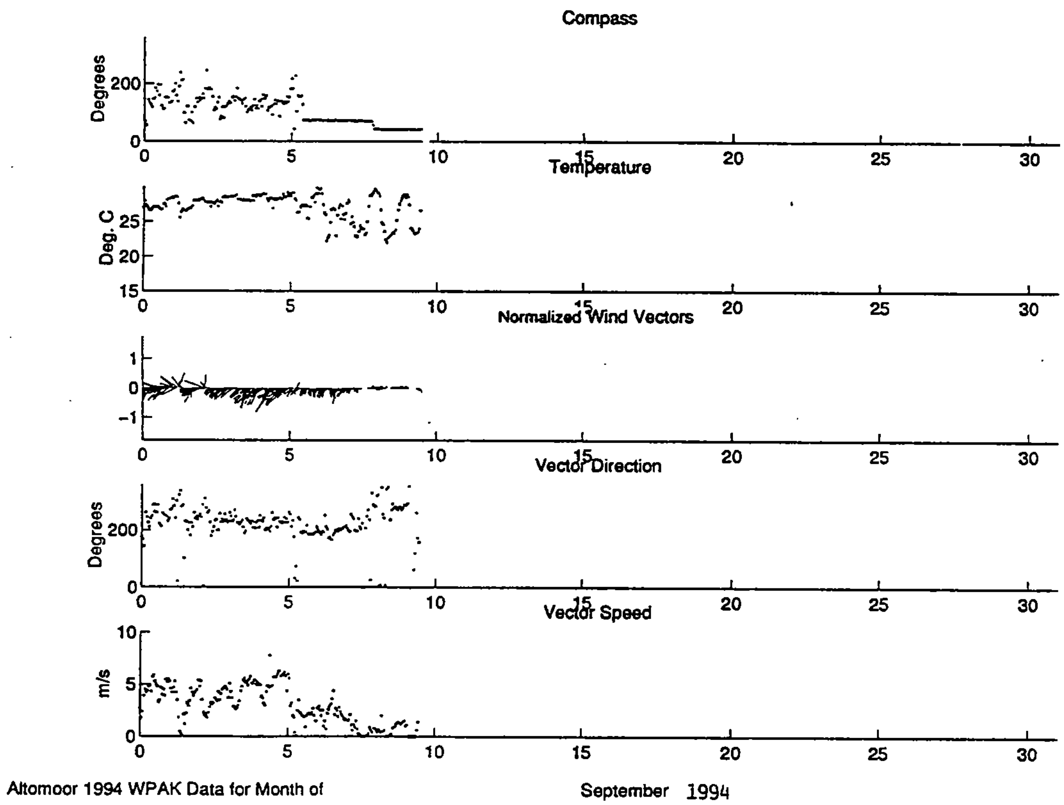
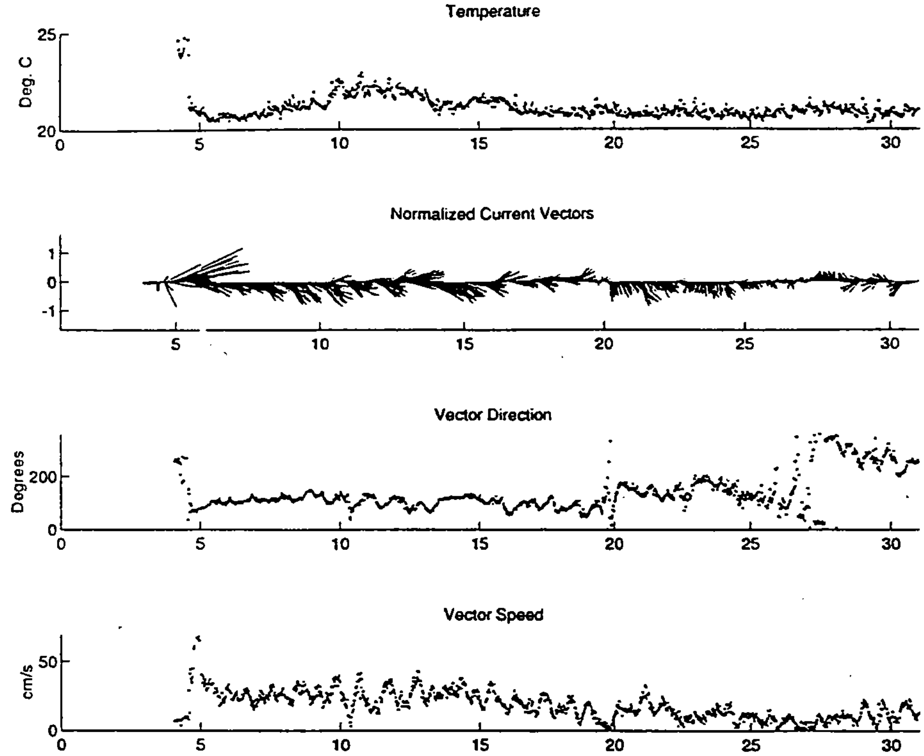
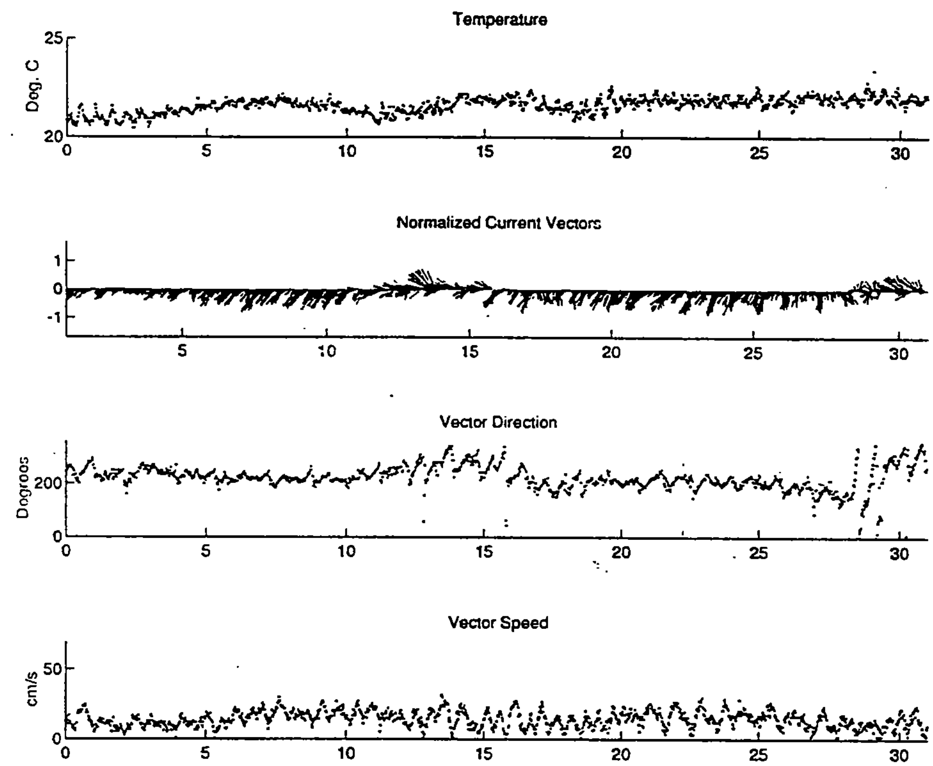


Figure 4-7a: Meteorological data from ALTOMOOR II from June-September 1994.



Altomoor 1994 25 m S4 Data for Month of June 1994



Altomoor 1994 25 m S4 Data for Month of July 1994

Figure 4-7b: Currents and temperature from 25m below the surface from June-September 1994. (Courtesy, T. Dickey, USC)

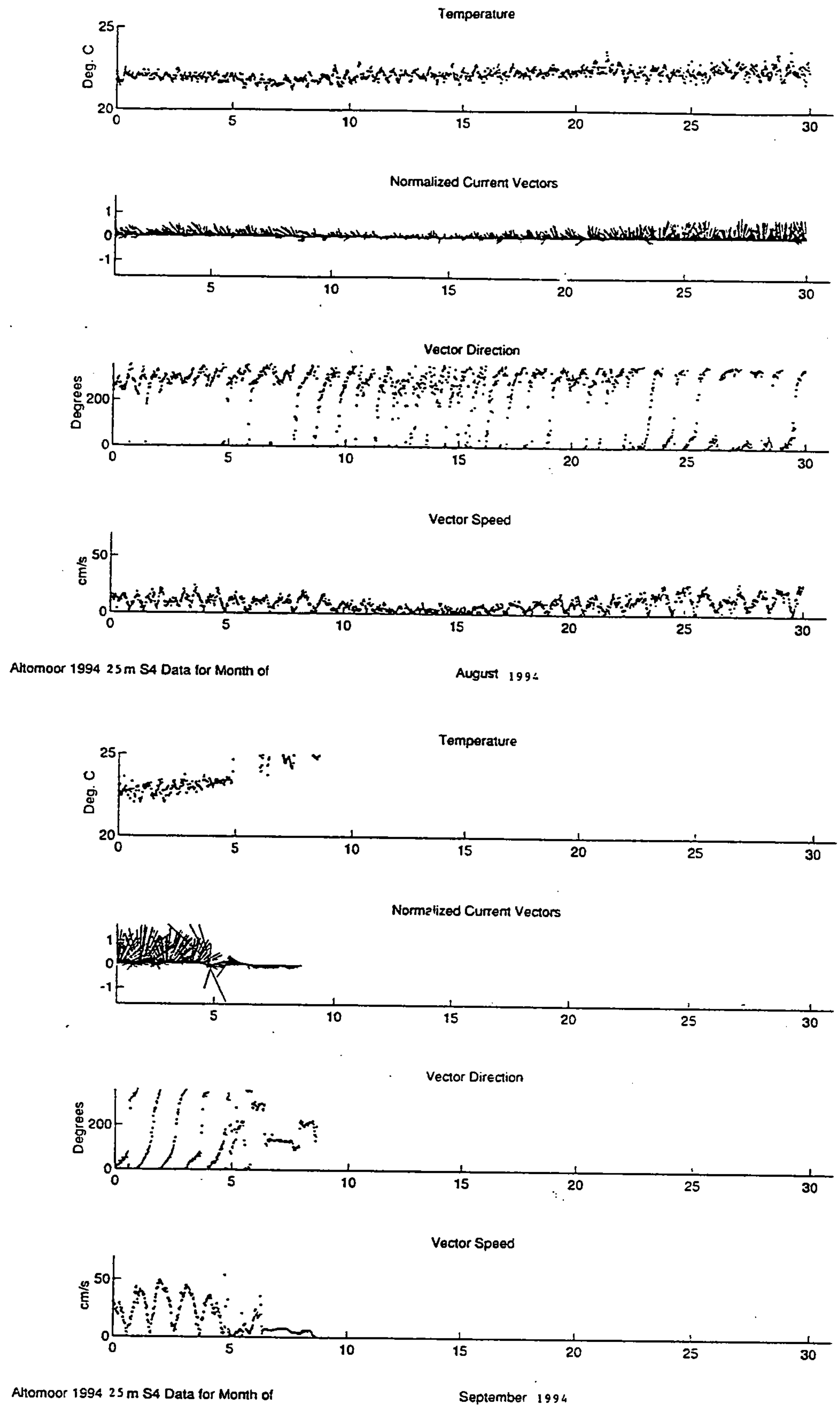


Figure 4-7b: Currents and temperature from 25m below the surface from June-September 1994. (Courtesy, T. Dickey, USC)

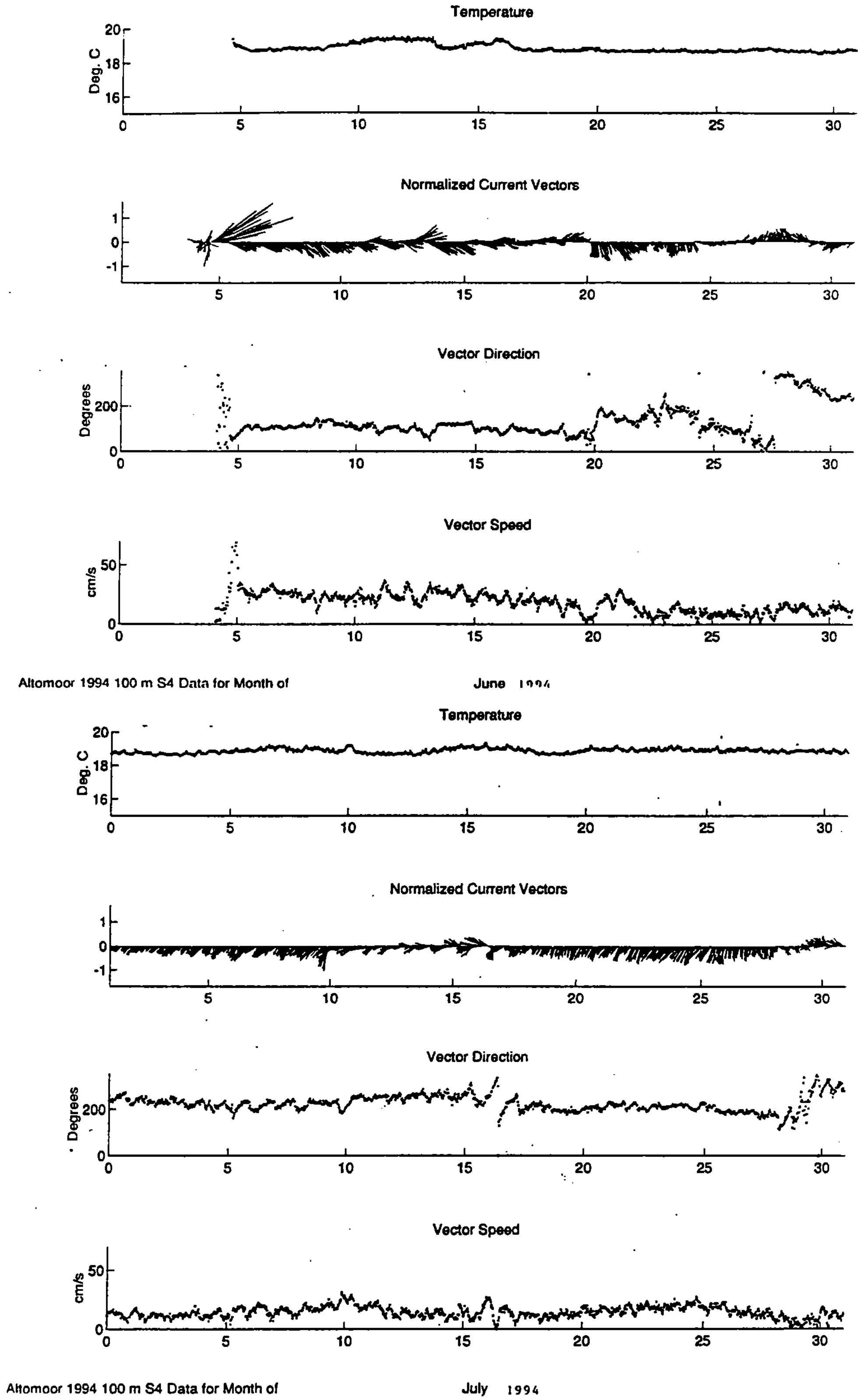
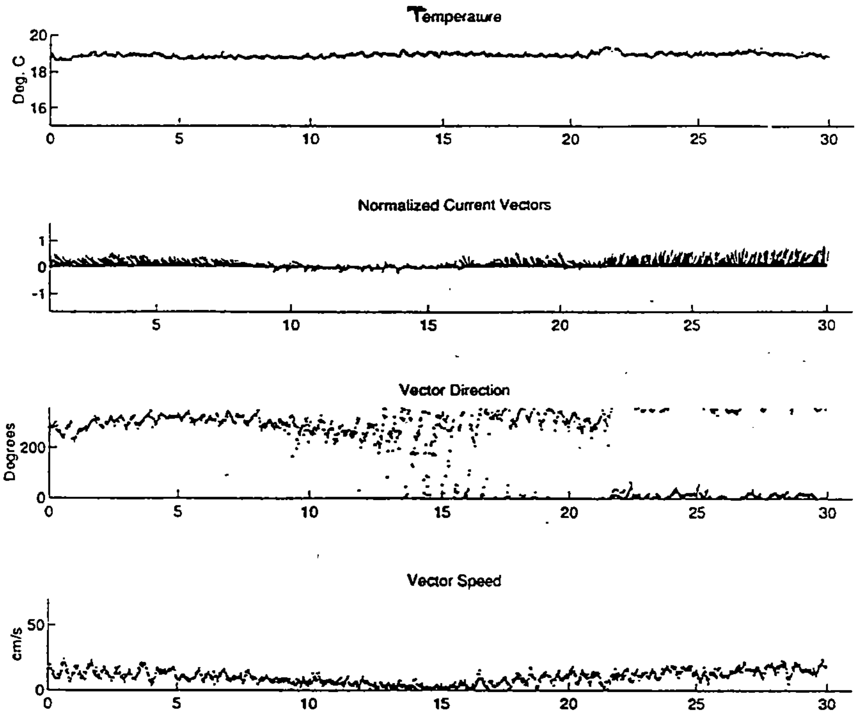
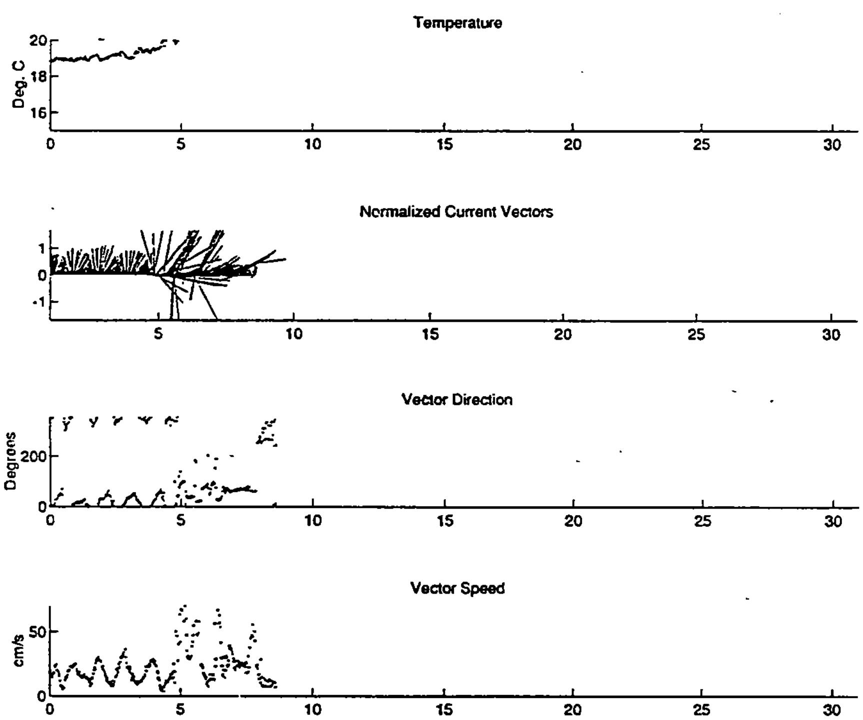


Figure 4-7c: Current and temperature from 100m below the surface from June-September 1994.



Altomoor 1994 100 m S4 Data for Month of August 1994



Altomoor 1994 100 m S4 Data for Month of September 1994

Figure 4-7c: Current and temperature from 100m below the surface from June-September 1994.

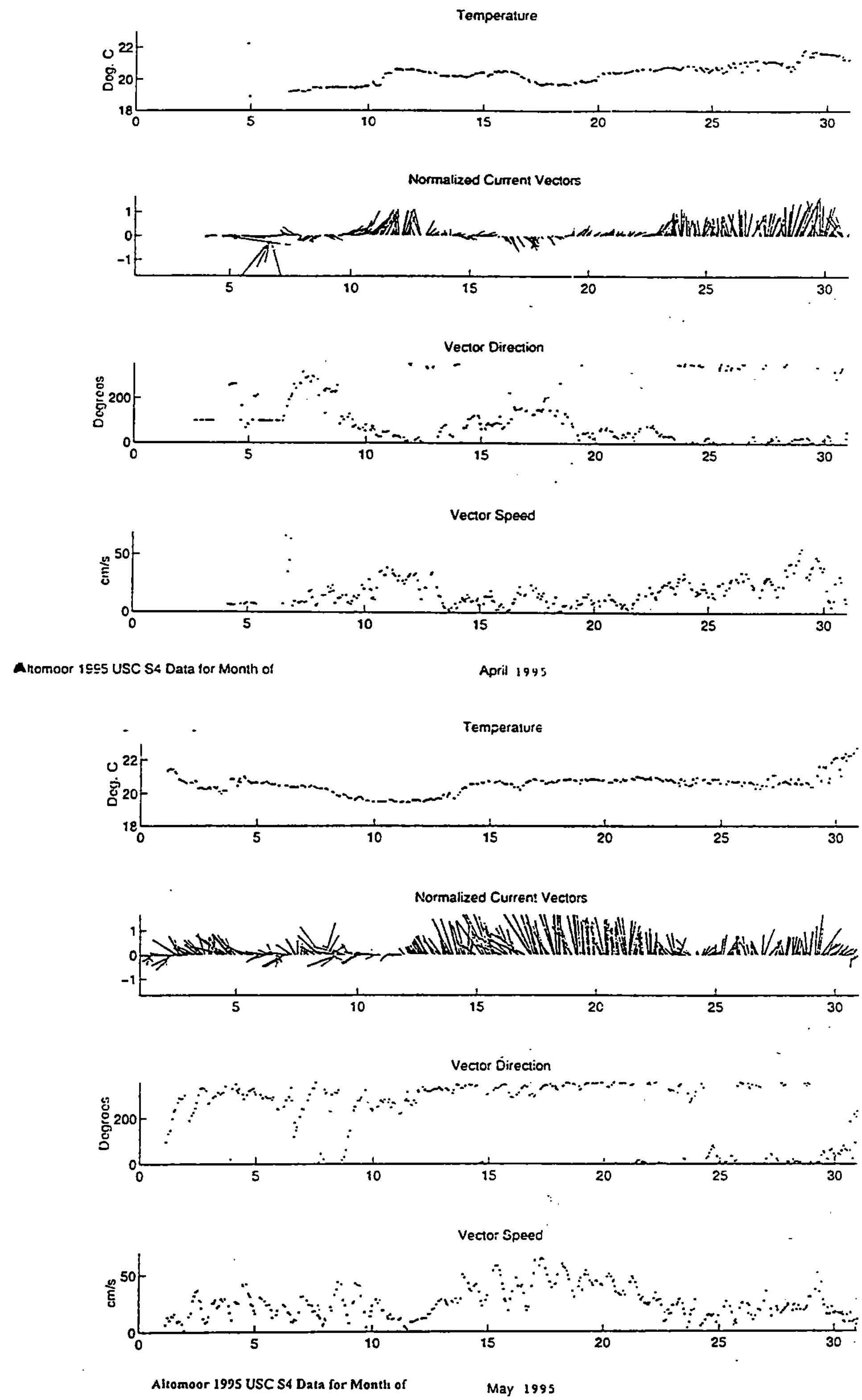


Figure 4-8a: Inductively-linked current data from the April-June 1995 period - 25m depth (Courtesy, Tom Dickey, USC)

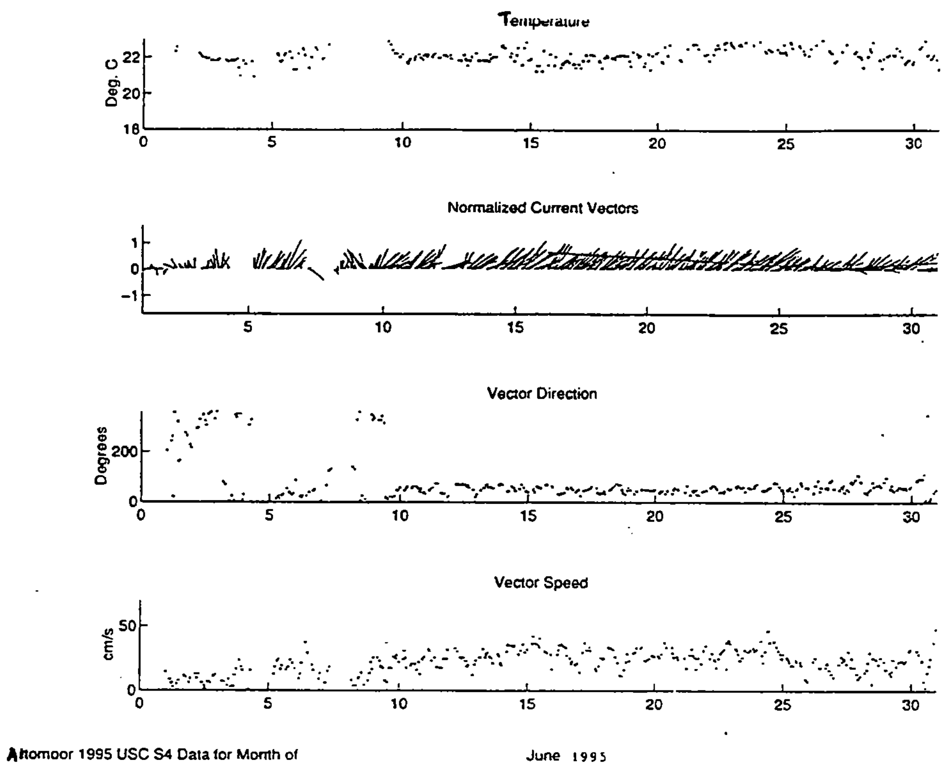


Figure 4-8a: Inductively-linked current data from the April-June 1995 period - 25m depth (Courtesy, Tom Dickey, USC)

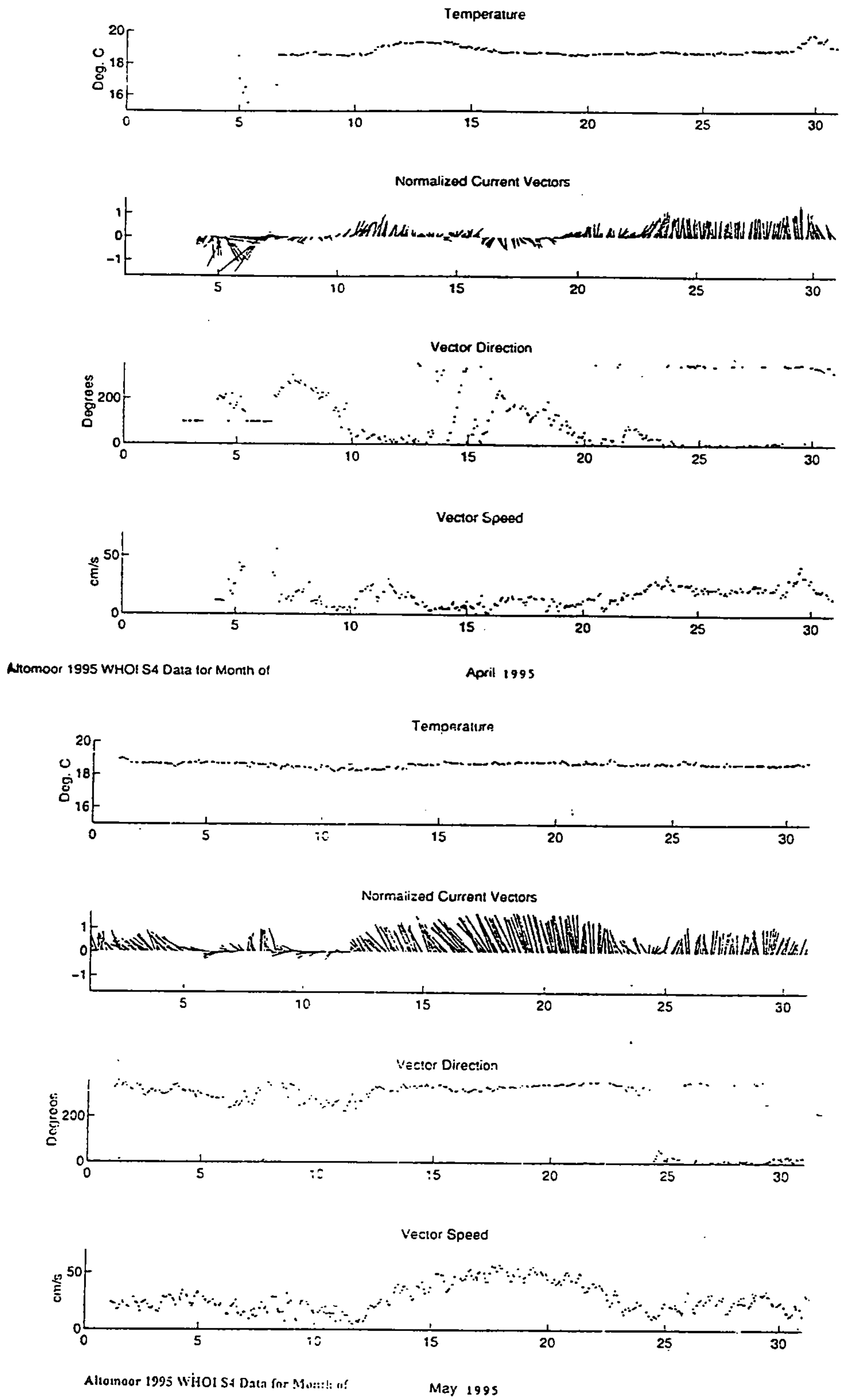


Figure 4-8b: Inductively-linked current data from April-June 1995 deployment 106m depth

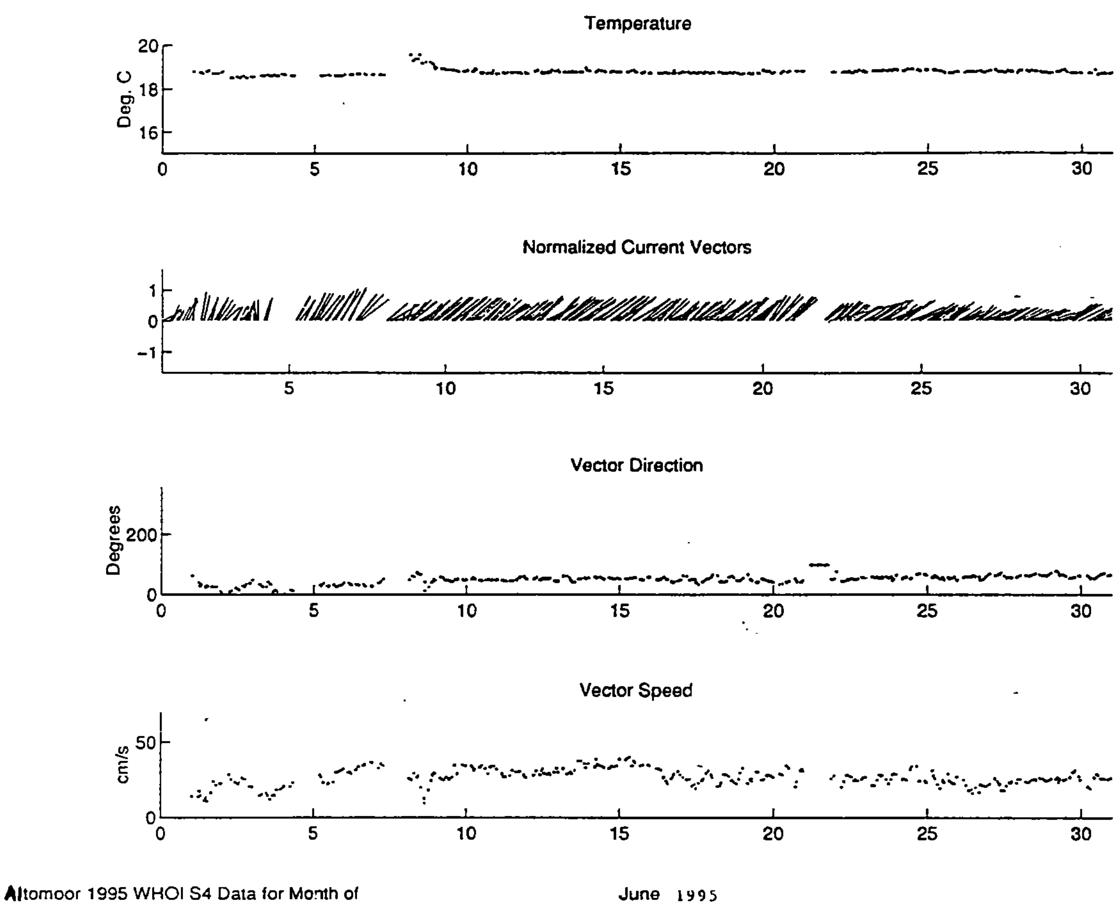


Figure 4-8b: Inductively-linked current data from April-June 1995 deployment 106m depth

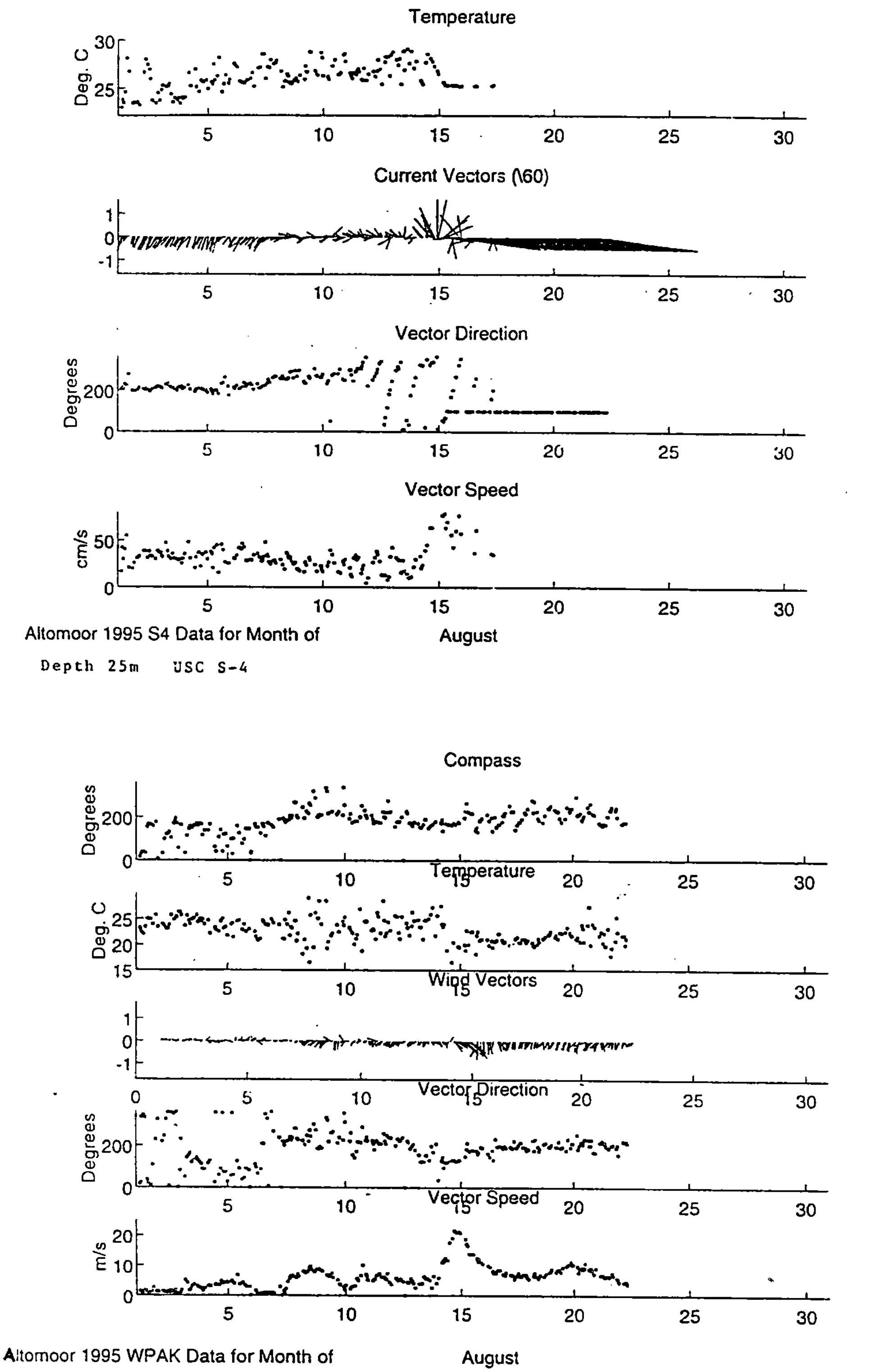


Figure 4-9: Currents and winds associated with Hurricane Felix on 8/15/95.

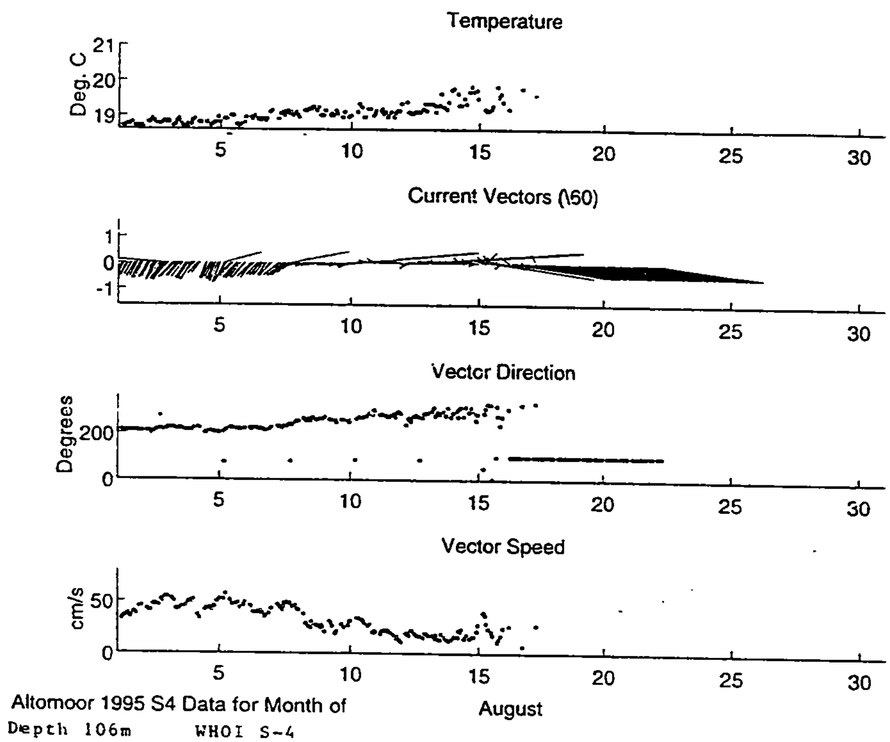


Figure 4-9: Currents and winds associated with Hurricane Felix on 8/15/95.

5. DISCUSSION

5.1 Inductive Telemetry

Inductive modems designed with off-the-shelf telephone modem chips were employed on ALTOMOOR I. After some initial firmware problems, these modems proved reliable and capable of operating over full ocean depth moorings. Because of the power required to run the modem chips, they were packaged in 5cm diameter titanium housings with three lithium D cells for power, making them about 45cm long.

To make the modems easier to use and applicable to a wider range of applications, they were re-designed on ALTOMOOR II with discrete components (rather than an off-the-shelf modem chip). This change reduced the standby power from 5mW to less than 1mW and the operating power from 270mW to 50mW and the size to 4 cm x 8 cm x 2 cm. More importantly, it allowed the modems to be installed inside the instrument pressure case and to be powered by the instrument's battery. This in turn reduced the cost of the modems by about 50% and eliminated the need to fabricate complicated underwater cable assemblies. The new modems require only a two-pin bulkhead connector to be installed on the instrument case end cap. The toroid pigtail then plugs into this connector. The toroid clamps onto the mooring wire, or onto a single conductor pigtail mounted on an in-line instrument cage that connects to the mooring line above and below the cage.

Again, after some initial problems, the second generation inductive modems worked very well and proved to be quite versatile in terms of their interface requirements. To date they have been used with a number of different instruments. They are available commercially through Falmouth Scientific, Inc., and FSI has supplied a number to international customers. The only real difficulty with the concept is that typical oceanographic instrumentation is still quite large and as a consequence is typically designed for use in line in the mooring. This complicates the inductive approach and removes many of its advantages over hardwired systems. For clamp-on instruments, the inductive modem is the ideal telemetry link.

5.2 RF Telemetry Link

The high speed, short range telemetry link using off-the-shelf wireless LAN technology offers a very low cost, highly capable system for moving large quantities of data from offshore buoys to nearby ships or shore stations. In the absence of high bandwidth satellite links, it is a useful and easy-to-implement solution. For the ALTOMOOR site, it was particularly attractive because the R/V WEATHERBIRD II was scheduled to be in the nearby vicinity at least once per month.

Difficulties with implementing the link were primarily a function of the special purpose software developed to handle the unique aspects of the buoy-to-ship-to-shore link. Once the link was operating, it transferred data flawlessly. Small problems like a broken antenna or a shipboard computer that was turned off made the long distance debugging process somewhat mystifying. Still to be determined is the reliable range of the link under various weather conditions and the long-term reliability of the hardware at sea. Several hardware failures occurred during ALTOMOOR II, but whether or not they represent fundamental problems with the equipment is unclear. Obviously, we were pushing equipment meant to be used in the office to perform in a difficult environment.

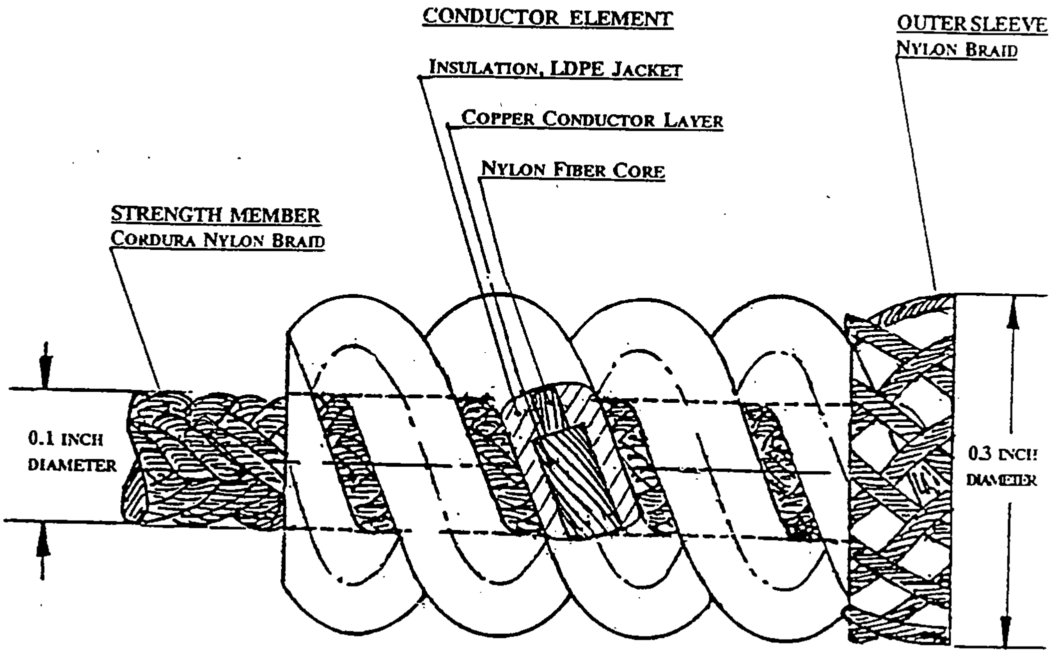
5.3 Mooring Design

The ALTOMOOR surface mooring has proved to be reliable mechanically. The mooring has been on station for several years, including the passage of four hurricanes. During August 1995, Hurricane Felix made a direct hit on the ALTOMOOR site with maximum winds over 40 m/sec. The mooring and buoy survived with only minor damage. Two other hurricanes also passed near the site in September 1995 without incident. The electromechanical cables used on ALTOMOOR I stood up well to fourteen months' usage as did the epoxy potted terminations. The new designs for the wire rope terminations for use with the inductive link on ALTOMOOR II worked very well, though the electrostatic coating that was applied on the clevises broke down and they had to be repainted for the April 1995 deployment.

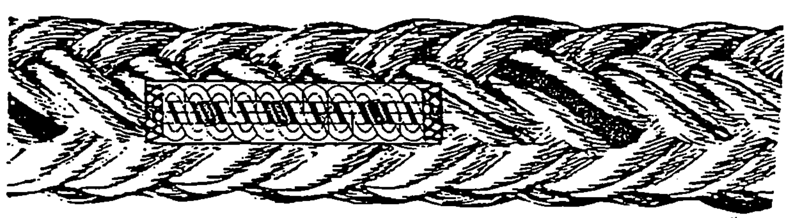
The fishbite resistant Kevlar experiment, however, concluded with a negative result. The types of cut resistant Kevlar used for butchers' aprons/gloves did not prove to be resistant to fishbite. In the few cases of serious fishbite that were seen on the Kevlar cables, the stainless steel reinforcing wires were also cut. DuPont was unable to make these lines with larger steel wires, at least with the available machinery; thus steel wire rope is still required for the upper 2000m and for any depth from which telemetry is needed unless a Kevlar (or other synthetic) line with a center conductor is used.

Initial design work has been done to develop a stretchable conducting line for use with nylon ropes [20]. This will allow telemetry from the lower portion of semi-taut surface moorings like ALTOMOOR. Figure 5-1 illustrates the design, which has been fabricated and tested for static stretch capability. This design can accommodate stretch up to 20% without putting strain on the copper wires which are helixed around a small nylon core. When placed inside a braided nylon line, the stretchable conductor is rigid so that it is not compressed when the outer braid is tensioned. Tension cycling tests are yet to be performed. If the cycling tests are successful, a sea test will be performed on the ALTOMOOR continuation project.

ALTOMOOR I and ALTOMOOR II both used a three-meter chain as the last link between the mooring and the buoy. This chain was encapsulated in urethane inside a heavy wall rubber hose. The electrical conductors, either from the three-conductor E/M cable used in ALTOMOOR I or the continuation of the inductive link used in both moorings, were threaded up the center of this hose, next to the chain, and encapsulated. This technique proved to be quite reliable and has applicability to most surface moorings or drifting buoys that use real-time



COMPLIANT CONDUCTOR ASSEMBLY, SIDE VIEW



NYLON ROPE WITH ENCLOSED COMPLIANT CONDUCTOR ASSEMBLY

Figure 5-1: Preliminary design of a stretchable conductor to be used as the core of a nylon mooring line.

telemetry. It is inexpensive and easy to fabricate and appears robust. This method was used successfully on the STEM mooring [21] which operated successfully at site D (40° N, 70° W) over the winter of 1988/89. The conductors in the molded chain were, however, broken on the January recovery of ALTOMOOR II. Sea conditions were very rough, and the hose was severely twisted and bent in the process of recovery. This hose was repaired in the field by spiraling a new conductor around the outside of the hose and taping it in place with self-curing neoprene tape.

5.4 Future of the ALTOMOOR Testbed

A deep-water testbed for evaluating new ocean instrumentation is an ongoing need in oceanography. Recognizing that, the ALTOMOOR Principal Investigators have worked with the funding agencies and the Bermuda Biological Station for Research and have come up with a plan to continue to maintain the testbed for a minimum of three years. NSF will continue to fund the instrumentation work while a combination of ONR, Biostation, NSF, and user funds will provide resources to maintain the mooring and replace the hardware on a yearly basis. Because of the limited funds available, real-time telemetry will not be implemented.

In addition to the present users, USC, WHOI, MBARI, FSI and MIT, access to the mooring will be open to all academic, government, and commercial instrumentation developers [22]. A users' fee will be charged based on the number of instruments installed and the length of time they are deployed.

As this report was in preparation, a failure of the ALTOMOOR mechanical system occurred on Thanksgiving Day, November 23, 1995. The mooring parted during storm conditions and drifted southwest until it was recovered on December 10, 1995 about 200 miles southwest of Bermuda.. On recovery it was found that the titanium instrument cage for the 25m S-4 had failed due to fatigue. These cages were fabricated specifically for this mooring and tested to 10,000 pounds load, but had been in service for 2 ½ years. Further investigation into this particular failure mode will be initiated. The lower portion of the mooring was recovered on March 17, 1996 and the refurbished system was re-installed on March 25, 1996.

6.0 REFERENCES

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7.0 APPENDICES

7.1 Appendix A: ALTOMOOR I Controller

The ALTOMOOR I controller is a 68HC11 based device employing a modified King Fish card and an inductive modem master. The King Fish card modifications include the addition of a Motorola R.T.C. (Real Time Clock) P/N MC146818AP, a dual one-shot P/N CD4538BE, a local 5 volt regulator P/N ICL7663BCTV and an RS485 receiver P/N LTC485.

The controller's CPU is programmed to spend most of its time in the STOP mode waking only to service interrupts. The normal processing duty cycle is 200 μs/s; however, the CPU's oscillator has a duty cycle of 5ms/s. At 15 volts the King Fish card draws 0.3mA while in STOP mode and 12mA while running. The inductive modem master draws a constant 25mA. For a one-year deployment, assuming the PTT will be powered from the same source, a 275 Ah battery is required. Using the 90 Ah/stack battery designed for a similar experiment, a minimum of three stacks are required. A second PTT designated the APIRB is powered with a separate stack.

The controller program is simply a loop which reacts to flags that are set or cleared by the various interrupts. Within the MIN loop are instructions which toggle PA5 thus holding one of the added one-shots retriggered. The output of this one-shot is OR'd with the 2Hz interrupt generated by the R.T.C. and used to trigger a second one-shot which resets the CPU should its program stop. The R.T.C. has a separate reset pin so time is not lost in case of a "deadman" reset. Memory location 23A3 is the reset counter and is cleared automatically after the !T command used to set the R.T.C. Any reset will increment this location and the number of resets since a !T command may be determined by executing a ?R command.

Activity is detected on the main SAIL loop via TIC3. This interrupt inhibits the STOP function for 15 seconds and enables the operator to complete an address string. The SCI portion of the program is based on the EVB COMPACT SAIL.A model to which has been added CRC, RAM TEST and the 82C52 UART handling routines. The attention character was also redefined for this module since a Coastal Climate Company WeatherPak and a Synergetics ARGOS PTT were connected to the top level SAIL and are each addressed with a "#string". Since this string must be generated by the controller, a logical conflict would result if the controller's attention character was also a "#". The new attention character is "&" and was chosen because it is recognized by neither the WeatherPak nor the ARGOS PTT. The controller's address is **&AM**. The program expects 300 baud, 8 data bits, 1 stop bit and no parity.

The XIRQ interrupt is triggered by DA true on the 82C52. Its response is to input to RAM, at OCCHR, the character received via the RS485 converter. If at least two seconds have elapsed since the previous XIRQ interrupt, the program assumes that this character is the first character of a 16-character packet. If the first two characters are recognized as the ID, the packet is transferred to the appropriate ARGOS buffer. All other data are transferred to this buffer in the order received. Character strings in excess of 16 characters are truncated and character strings containing less than 16 characters are ignored. All non-**HEX ASCII** characters within these two limitations received are transferred as "C's" to the ARGOS buffer.

The R.T.C. is initialized to generate interrupts at a 2Hz rate. This is the IRQ interrupt and functions as the principal wake-up call from STOP. A ½ second counter is incremented in this interrupt and if it reaches a count of 4 indicating 2 seconds have elapsed, MSGFLG bit 8 will be set. This is the second filter flag used by the XIRQ interrupt described in the previous paragraph. The IRQ interrupt also reads the R.T.C. and at the appropriate time requests data from the WeatherPak (if present), parses previously received data into the ARGOS buffers, causes MAIN to calculate and insert the checksums, and finally sets up the PTT and passes it the completed buffers for transmission.

<u>OPERATION</u>

Once the controller is installed in the buoy, operation consists simply of setting the R.T.C.'s time and insuring the battery switch is in the run position. Connect an open collector-to-RS232 converter box to the banana jacks on the front panel. An external 33 ohm pull-up resistor to an external 5 volts is required. The open collector connection is polarized; green is high. Set the terminal emulator for 8 data bits, no parity, and 1 stop bit.

To address the module type a few spaces and then the address string **&AM** followed by either a space, a carriage return or any valid command. (See the help file). The module will answer with the prompt string which contains a line feed, a carriage return, the ":" and the non-printing character ETX.

Addressing the controller:

&AM
:

The R.T.C. is set using the **!T** command. Time and date are entered free field; i.e., non-HEX characters are ignored. The time set operating may be terminated at any point by typing either an @, or the address string. In either case the system will reply with the prompt string. If this is not the case, more than 20 seconds elapsed since the last character entry and the system has de-addressed and entered the **STOP** mode. Time and date are expected in the following order: hhmmssmmddyy. The clock starts upon reception of the @ at the end of this string. Setting the clock also zeros the reset counter. Time is displayed by executing the **?T** command.

Setting the clock/calendar and displaying the time/date:

&&AM
:!T130730122992@
:&T 13:07:33 12/29/92

Setting the clock/calendar (using optional punctuation) and displaying the time/date):

&&AM
:!T15:35:59 01/04/92@
:?T 15:36:01 01/04/92
:

An 8-bit counter is used to keep track of the number of resets since system initialization. The contents of this counter are displayed in response to the **?R** command.

Displaying the reset count:

:

:?R Resets since power on = 00

The WeatherPak's clock must also be set. Since this is not a SAIL device a separate communications cable is employed. Connect this cable to a terminal and follow the instructions furnished with the WeatherPak.

The module contains a brief help file which may be accessed via the **H** command.

Displaying the Help file:

:**H**elp file for the ALTOMOOR Mon, Dec 21, 1992, 11:50 AM

<u>Monitor Commands</u>

?Maaaa_llllcr
!Maaaa_dd...cr...with all RCA UT4 conventions
R ... Initiates a 6116 RAM test, * = good pass.
?C ... Returns a CRC over the specified memory.
?A ... Dumps the two ARGOS buffers.
?R ... Returns number of rests since power on.

<u>Deployment commands</u>

!T hhmmss mmddyy @ ... Enters time and date, clock starts with the @

!C ... Clears the ARGOS data buffers.

The contents of memory may be viewed using the ?M command. The command may be terminated with either a space or a carriage return. All values are HEX and the first 4 characters of each line displayed indicate the starting address of that line.

Displaying memory:

:M2000 30
2000 AC12 EEFF FFFF FFDF 8400 0000 FEFF FFFF;
2010 3456 ACDE FFFF FFDF 0128 0854 FFFF FFFF;
2020 321D 0000 FFFF 7FDF 0000 0800 FFFF BFFF
:

Memory may be loaded using the !M command. External RAM begins at 2000 hex and runs to 27FF. Much of this memory is used by the module's SAIL routines and should be overwritten with caution. Spaces after the memory address are ignored and the command is terminated with a carriage return.

Loading memory:

:M2000 AABBCCDDEEFF11223344556677889900
:M2000 10
2000 AABB CCDD EEFF 1122 3344 5566 7788 9900;

Note that any command may be entered immediately after the address string.

Issuing a command concurrently with the address string:

&AM?MO 20
0000 8004 0203 0405 0607 0300 8100 0000 4609;
0010 FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF
:

External RAM may be tested using the **?R** command. This command is not locked but operator verification is required. This is an immediate command and is executed upon reception; i.e., a terminating carriage return is not required. A "Y" after the OK? will initiate the test while any other character will return the prompt. After each successful pass a * is printed. The test may be terminated either with a hardware reset or an address string starting with multiple **&**s.

Testing RAM:

:Ram Test... From 2000 Over 800 ...OK? Y

:****************************&&AM

:

A CRC may be obtained over any number of memory locations up to FFFF. This test is most useful in verifying EPROM validity. PROM starts at C000 and runs to FFFF.

Calculating the EEPROM's CRC:

:?Crc from **C000** over **4000 ...** = B7DC

Attmpting to test memory over 0 locations will generate an error message:

:?Crc from **0000** over **0000**
Must be greater than 0!

The buffered ARGOS data may be displayed using the **?A** command. This is an immediate command.

Displaying buffered ARGOS data:

:?A
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB

The ARGOS buffer may be cleared by using the **!C** command. This is also an immediate command.

Clearing and displaying the buffered ARGOS data:

:!C
:?A
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF

CONTROLLER SHIPPING LIST

Quantity	Description	Value
1	System controller aluminum mounting plate (WHOI)	$ 50.00

The following items are to be mounted on plate listed above:

Quantity	Description	Value
1	System controller electronics (WHOI)	$1500.00
1	Synergetics Argos PTT model 2120A S/N 2488A00413	750.00
1	Synergetics Argos PTT model 2120A S/N 3188A00441	750.00
1	Sea Cable junction box (WHOI)	25.00

The following items boxed separately from the controller electronics:

Quantity	Description	Value
1	RS232 to SAIL converter WET model SB1000wW/OC S/N 488	800.00
1	Coastal Climate WeatherPak model WP-100 S/N 419	2000.00
1	Telonics satellite uplink receiver model TSUR-B (WHOI 890358)	500.00
1	Toshiba computer model T1000 S/N 01814410AA	1000.00
1	Spares kit for controller CPU card (WHOI)	150.00
1	Misc. cables and connectors (WHOI)	500.00
2	Tool boxes containing misc. tools & supplies	250.00

7.2 Appendix B: PIC Buffer Board

This information is used to confirm communications to/from the PIC Buffer board with information available to date.

UPPER S-4:

S-4 to PIC Buffer:

Scan Rate: 1 data frame per hour.
Communication Rate to PIC Buffer: 4800 baud, No parity.
Communications Mode: CMOS level RS232
Data Format to PIC Buffer: 17 ASCII Hex characters.

```
NNNEEE_TTTT_DDDD_
NNN  - North {3 characters}
EEE  - East {3 characters}
_    - Space (20 Hex)
TTTT - Temperature {4 characters}
_    - Space (20 Hex)
DDDD - Depth {4 characters}
_    - Space (20 Hex)
```

PIC Buffer to E/M Cable:

Scan Rate: Immediate transmission after receipt from S-4
Communications Rate: 9600 baud, No parity.
Communications Mode: RS485
Data Format: 18 ASCII Hex characters.

```
INNNEEE_TTTT_DDDD_
I                 - Single Character ID, (55 Hex)
NNNEEE_TTTT_DDDD_ - Same as above
```

PIC Buffer to Inductive Modem:

Scan Rate: 10 second delay after receipt from S-4
Communications Rate: 9600 baud.
Communications Mode: CMOS RS232
Data Format: Same as E/M cable except ID is 5A Hex.

LOWER S-4

S-4 to PIC Buffer:

Scan Rate: 1 data frame per hour.
Communication Rate to PIC Buffer: 4800 baud, No parity.
Communications Mode: CMOS level RS232
Data Format to PIC Buffer: Same as Upper S-4.

NNNEEE_TTTT_DDDD_

PIC Buffer to E/M Cable:

Scan Rate: Immediate transmission after receipt from S-4
Communications Rate: 9600 baud, No parity.
Communications Mode: RS485
Data Format: Same as Upper S-4 except ID is AA Hex.

INNNEEE_TTTT_DDDD_
I_________________________ Single Character ID, (AA Hex)

PIC Buffer to Inductive Mode:

Scan Rate: 20 second delay after receipt from S-4
Communications Rate: 9600 baud.
Communications Mode: CMOS RS232
Data Format: Same as E/M cable except ID is A5 Hex.

VMCM

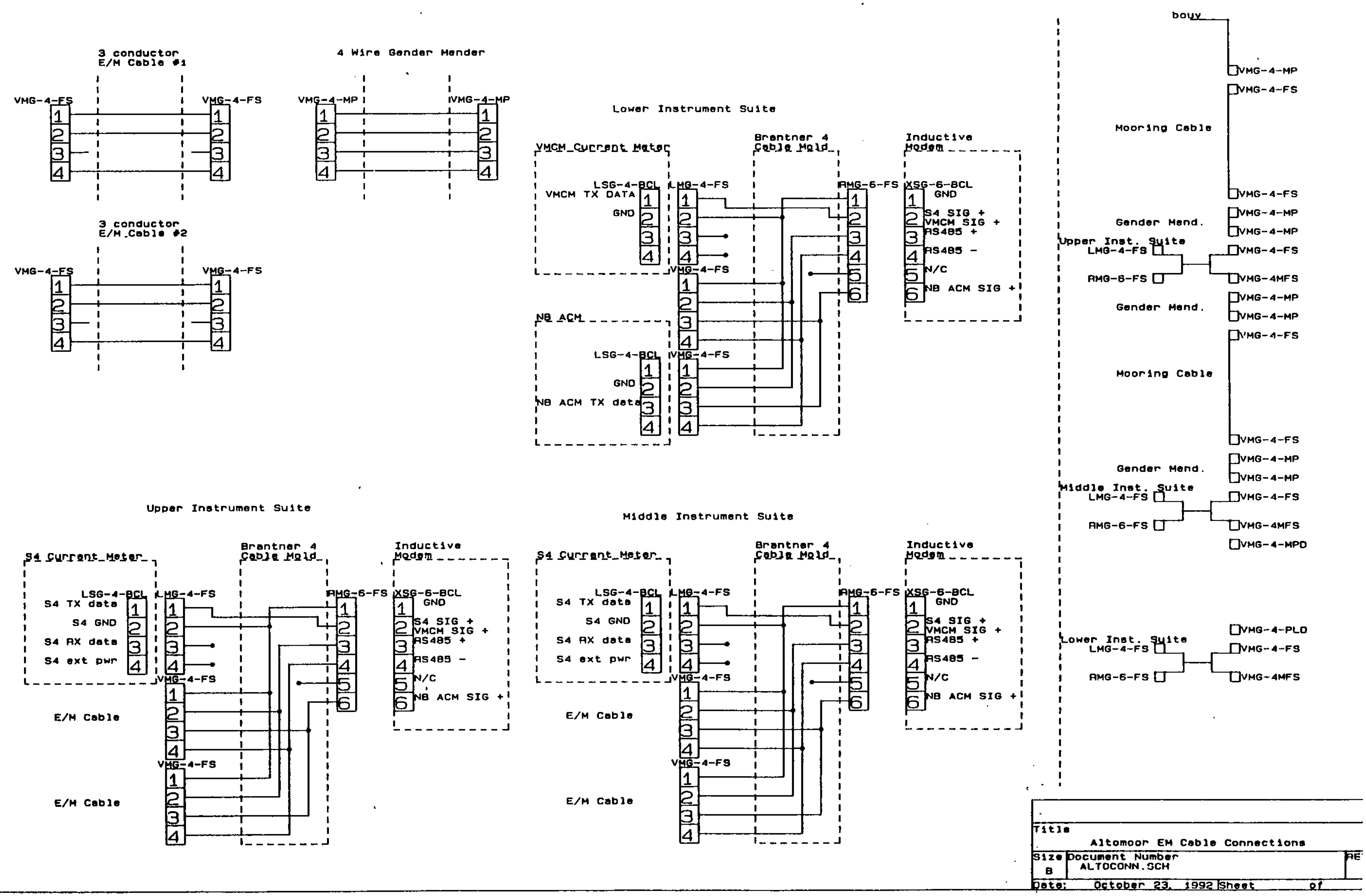
VMCM to PIC Buffer:

Scan Rate: 4 data frames per hour.
Communications Rate: 300 baud with parity.
Communications Mode: CMOS RS232 assumed possible.
Data Format: 30 characters, exact format coming from Dave Hosom.

PIC Buffer to Inductive Modem:

Scan Rate: 1 data frames per hour representing the last data received from both NLB & VMCM.
Communications Rate: 9600 baud, parity is the same as supplied from instruments.
Communications Mode: CMOS RS232.
Data Format: 48 characters.

```
INNNNNNNNNNNNNNNNNVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
||_______________||____________________________|
|                               |__ 30 VMCM characters
|
|______ 1 ID character (69 Hex)
```



3 conductor E/M Cable #1
VMG-4-FS
VMG-4-FS
3 conductor E/M Cable #2
VMG-4-FS
VMG-4-FS
4 Wire Gender Mender
VMG-4-MP
VMG-4-MP
Lower Instrument Suite
VMCM Current Meter
LSG-4-BCL
VMCM TX DATA
GND
LMG-4-FS
VMG-4-FS
NB ACM
LSG-4-BCL
GND
NB ACM TX data
VMG-4-FS
Brantner 4 Cable Mold
RMG-6-FS
Inductive Modem
XSG-6-BCL
GND
S4 SIG +
VMCM SIG +
RS485 +
RS485 -
N/C
NB ACM SIG +
Upper Instrument Suite
S4 Current Meter
LSG-4-BCL
S4 TX data
S4 GND
S4 RX data
S4 ext pwr
LMG-4-FS
VMG-4-FS
E/M Cable
VMG-4-FS
E/M Cable
Brantner 4 Cable Mold
RMG-6-FS
Inductive Modem
XSG-6-BCL
GND
S4 SIG +
VMCM SIG +
RS485 +
RS485 -
N/C
NB ACM SIG +
Middle Instrument Suite
S4 Current Meter
LSG-4-BCL
S4 TX data
S4 GND
S4 RX data
S4 ext pwr
LMG-4-FS
VMG-4-FS
E/M Cable
VMG-4-FS
E/M Cable
Brantner 4 Cable Mold
RMG-6-FS
Inductive Modem
XSG-6-BCL
GND
S4 SIG +
VMCM SIG +
RS485 +
RS485 -
N/C
NB ACM SIG +
bouy
VMG-4-MP
VMG-4-FS
Mooring Cable
VMG-4-FS
Gender Mend.
VMG-4-MP
VMG-4-MP
Upper Inst. Suite
LMG-4-FS
VMG-4-FS
RMG-6-FS
VMG-4MFS
Gender Mend.
VMG-4-MP
VMG-4-MP
VMG-4-FS
Mooring Cable
VMG-4-FS
Gender Mend.
VMG-4-MP
VMG-4-MP
Middle Inst. Suite
LMG-4-FS
VMG-4-FS
RMG-6-FS
VMG-4MFS
VMG-4-MPD
VMG-4-PLO
Lower Inst. Suite
LMG-4-FS
VMG-4-FS
RMG-6-FS
VMG-4MFS
Title
Altomoor EM Cable Connections
Size
B
Document Number
ALTOCONN.SCH
RE
Date: October 23, 1992
Sheet
of

7.3 Appendix C: Automated Data Retrieval and Delivery System (ADRADS)

Abstract

One of the problems encountered in many areas of scientific research and experimentation is data retrieval and delivery. Instrumentation is deployed in remote or difficult to reach locales and the task of recovery for the purpose of data retrieval can be a significant portion of the research budget. A mechanism whereby data retrieval occurs without recovery and redeployment of the instrument would result in reduced operations costs. The Automated Data Retrieval and Delivery System (ADRADS) is just such a mechanism. ADRADS provides the researcher access to his instrumentation and data without costly recovery and redeployment and utilizes low-cost technology and off-the-shelf components.

Overview

ADRADS is more a conceptual design than a rigid application. The actual implementation of ADRADS within an application can be quite diverse. ADRADS is comprised of three major components; the remote system, the mobile system and the base system, and although the implementation, configuration and application of the system can vary there are characteristics which are common to each component and to a few basic requirements; communications, operating system, and connectivity to which they adhere.

The Remote System

The remote system describes any system which by virtue of accessibility is too difficult and/or too expensive to visit regularly yet its data is desired frequently. Examples of these types of system are deep-sea buoys, subsea instrument packages, Arctic instrumentation, etc. Some of the general characteristics which distinguish a remote system are finite power resources, small capacity data storage and low duty cycle or low bandwidth data acquisition cycles. These characteristics suggest typical configurations utilizing low power, low capacity storage media such as RAM, SRAM and Flash RAM for frequent data acquisitions and utilizing larger forms of data storage, i.e., hard disks, tape cartridge or WORM drives, when capacities are reached.

The Mobile System

The mobile system describes any system which can be moved within access range of the remote system. It provides temporary storage of collected data and transport to the base system. Examples include a workstation on board a cargo ship which passes by a buoy once every two weeks, or a laptop carried by snowmobile within range of Arctic deployed instrumentation.

Basic Requirements

There are three basic requirements needed to implement ADRADS; communication or a data transport mechanism, operating systems, and connectivity.

The data transport mechanism enables data to be recovered from the remote site. Some common choices include ARGOS, cellular telephone, and line-of-sight RF links. There are advantages and disadvantages to each including cost, range and availability. RF technology's low cost, high bandwidth and hardware ethernet support are a good match for remote-to-mobile system interaction. Cellular telephone, which provides more range and higher bandwidth would be more appropriate for mobile-to-base system interaction.

The operating systems requirements, like communications, can be split by the system. The remote system only requires a rudimentary operating system, such as DOS, capable of data acquisition and offload. The mobile and base systems require a more sophisticated system capable of data archiving, computer networking and task scheduling. UNIX or UNIX-like operating systems are required.

The only connectivity needed is that of the base system to the rest of the world. A mechanism is required to allow external access to the base system for data retrieval and dissemination. This is provided via internet and networking services provided by the UNIX operating system. These services include rlogin, mount, ftp and mail.

Control and Data Flow

Each component has basic system control and data flow between systems.

The remote system acquires data at some periodic rate. When necessary, data is moved from temporary storage to fixed storage. If an upload is desired, a search for the mobile system is initiated. If detected, the remote system determines the data to be transferred, the fixed storage media is powered up, a connection is established, and the transfer is made. If the mobile system is not detected, the remote system goes to sleep or into its acquisition mode.

The mobile system detects a request for a connection made by the remote system. A dialog is established and the transfer begins. When the transfer is complete or terminated, the data is temporarily archived. The transfer status is mailed to the mobile systems ADRADS account. The mobile system requests data offload to the base system. When the base system is detected, its archive file system is mounted and the data is moved there for permanent storage.

The base system receives requests for data sets via email. Subject headers are parsed and the requests are serviced. Specific data sets can be requested and then mailed back directly. Or if desired, or when requests for large data sets dictate, the data can be extracted from the data base and stored and compressed into a single file suitable for ftp. The locations of the retrieved data will be mailed back to the requestor. If so desired, data could also be automatically ftp'd and put in the requestor's incoming ftp directory. Access is limited to email to provide a standard interface to the permanent data base. The requestor need not know anything about the configuration or location of the actual database in order to access the data.

Conclusion

ADRADS, while not a panacea for all the problems associated with data recovery and delivery, offers a stable and reliable, low cost method of accessing remote instrumentation while providing access to that data to the community at large in a standard and timely fashion. Figure 7-C-1 illustrates the ALTOMOOR ADRADS.

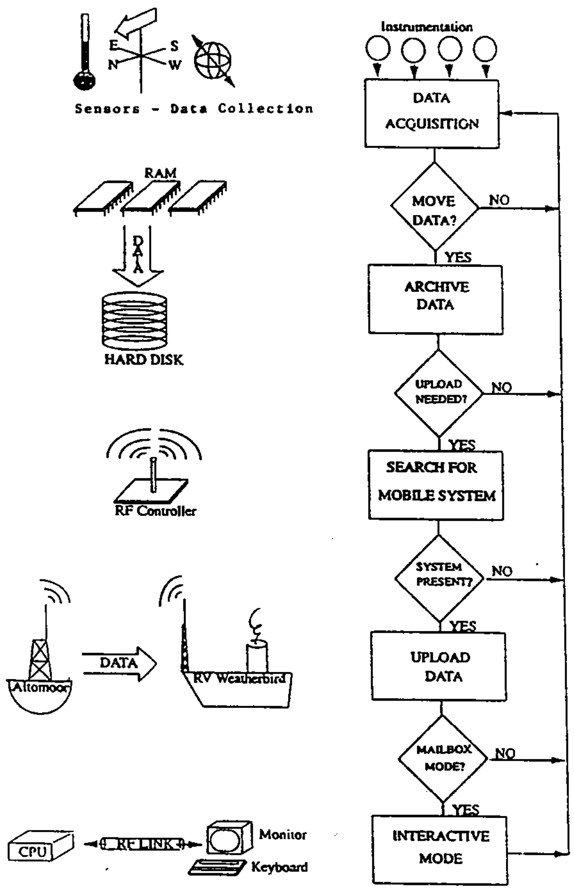


Figure 7-C-1a:Remote system control flow

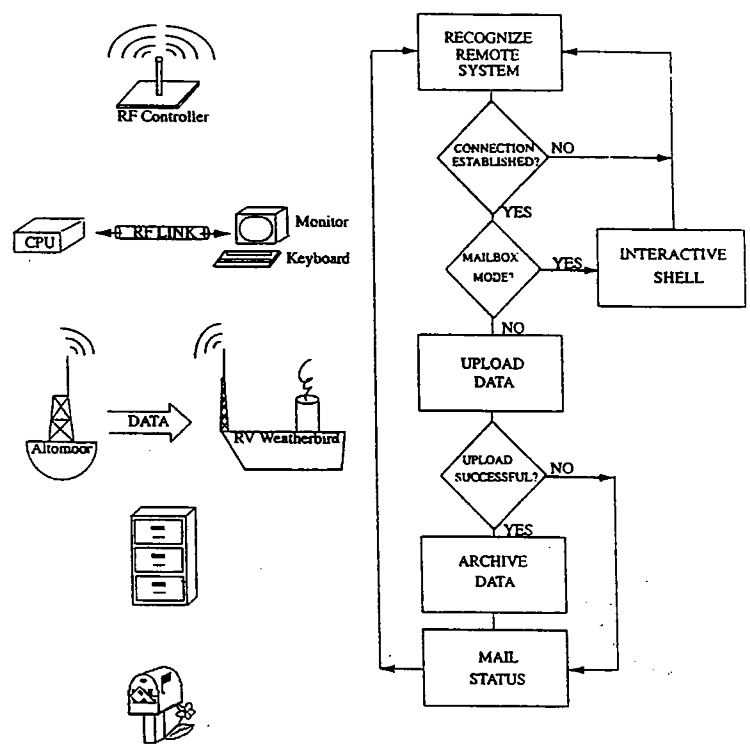
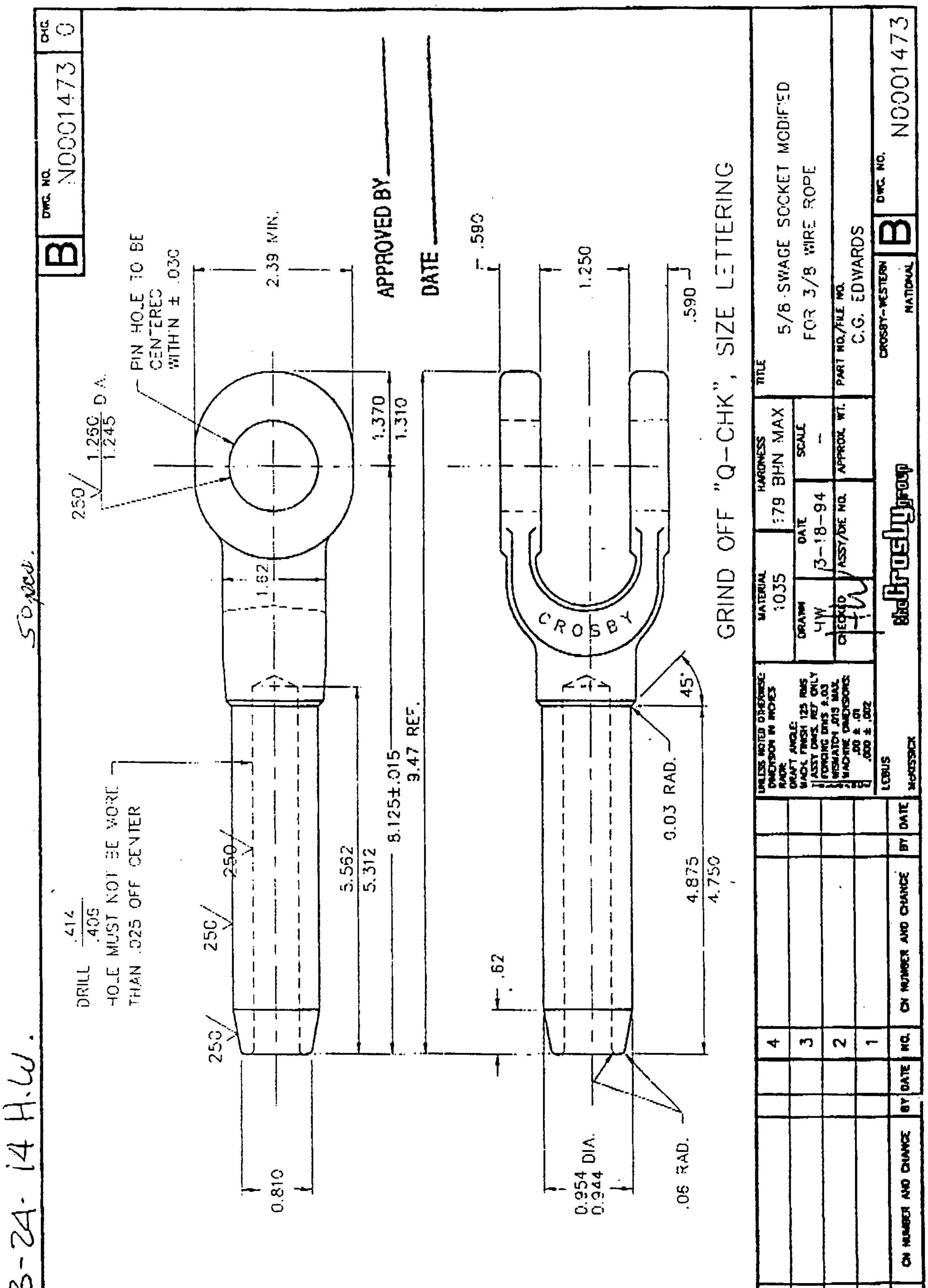
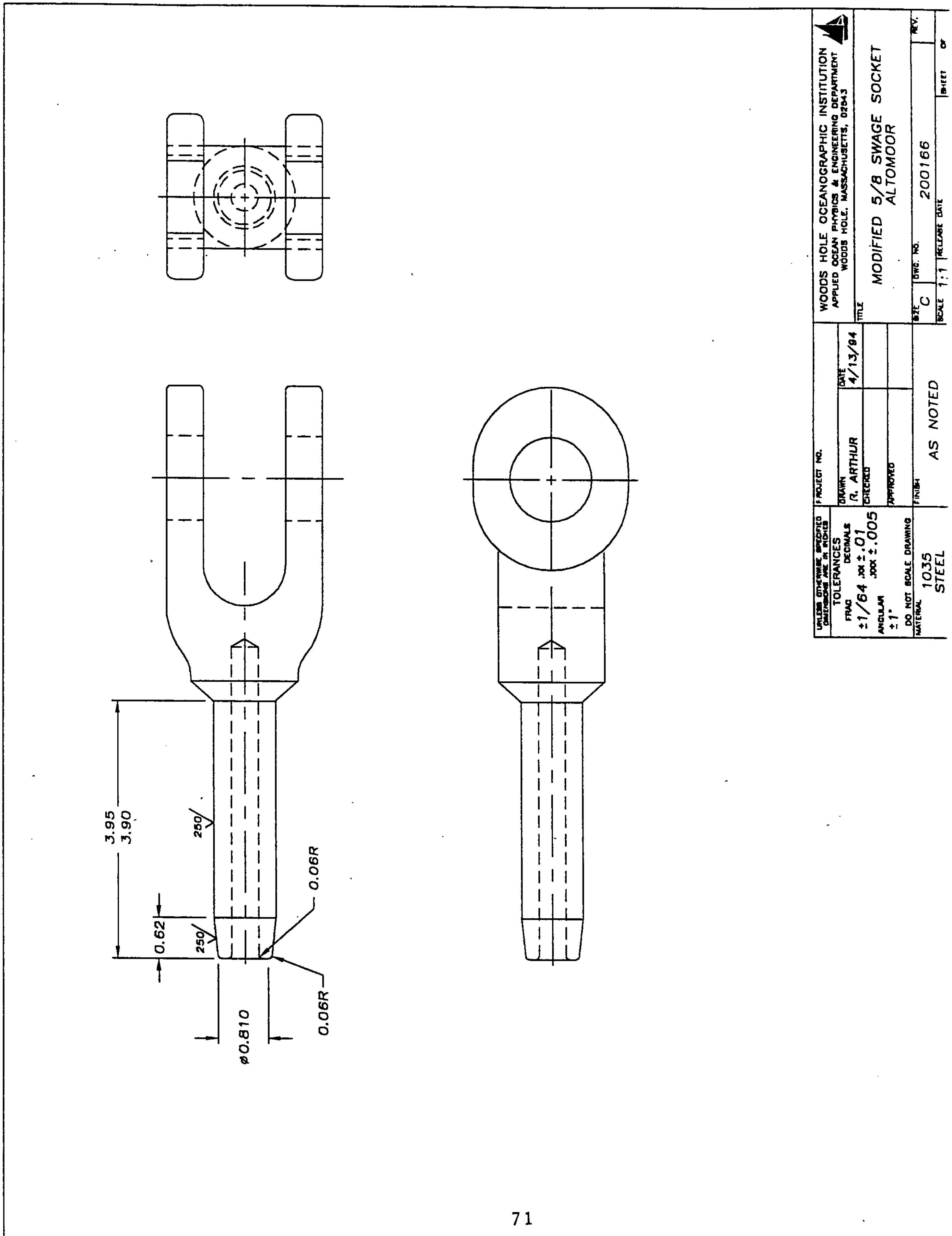


Figure 7-C-1b:Mobile system control flow

7.4 Appendix D:ALTOMOOR II Mechanical Drawings



DWG. NO. N0001473
CHG. 0
B
PIN HOLE TO BE CENTERED WITHIN ± .030
1.250 / 1.245 DIA.
2.39 MIN.
APPROVED BY
DATE
.590
1.250
.590
1.370
1.310
1.82
CROSBY
45°
0.03 RAD.
8.125±.015
9.47 REF.
5.562
5.312
4.875
4.750
DRILL .414 / .406
HOLE MUST NOT BE MORE THAN .025 OFF CENTER
.62
0.810
0.954 / 0.944 DIA.
.06 RAD.
GRIND OFF "Q-CHK", SIZE LETTERING
TITLE
5/8 SWAGE SOCKET MODIFIED FOR 3/8 WIRE ROPE
MATERIAL 1035
HARDNESS 179 BHN MAX
DRAWN HW
DATE 3-18-94
SCALE -
PART NO./FILE NO. C.G. EDWARDS
CROSBY-WESTERN
NATIONAL
DWG. NO. N0001473
CN NUMBER AND CHANGE
BY
DATE
NO.
3-24-14 H.W.


WOODS HOLE OCEANOGRAPHIC INSTITUTION
APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT
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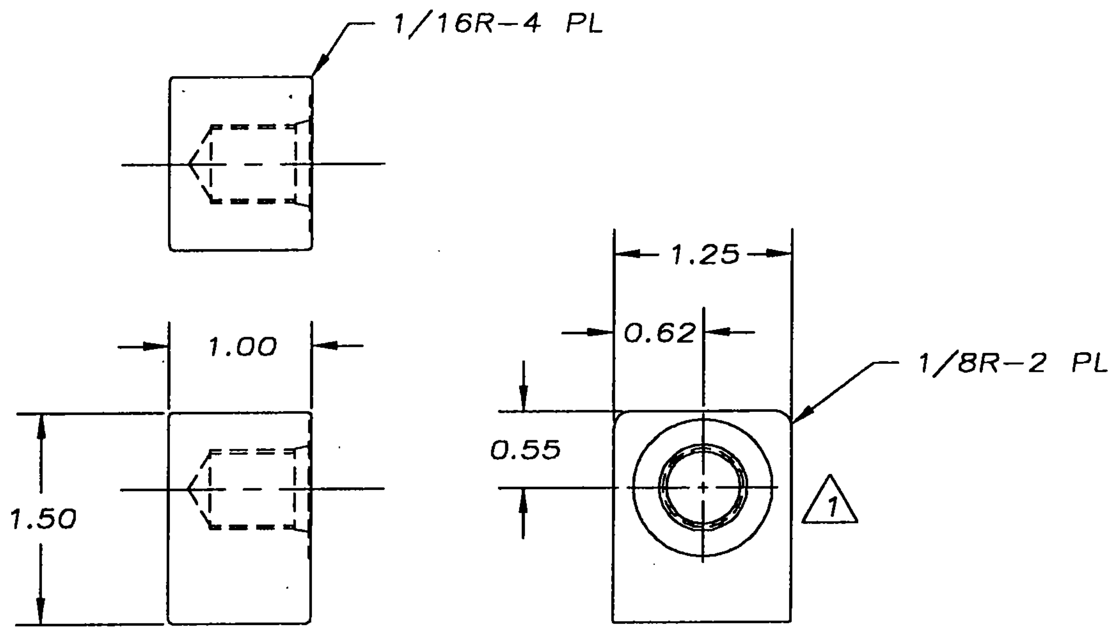
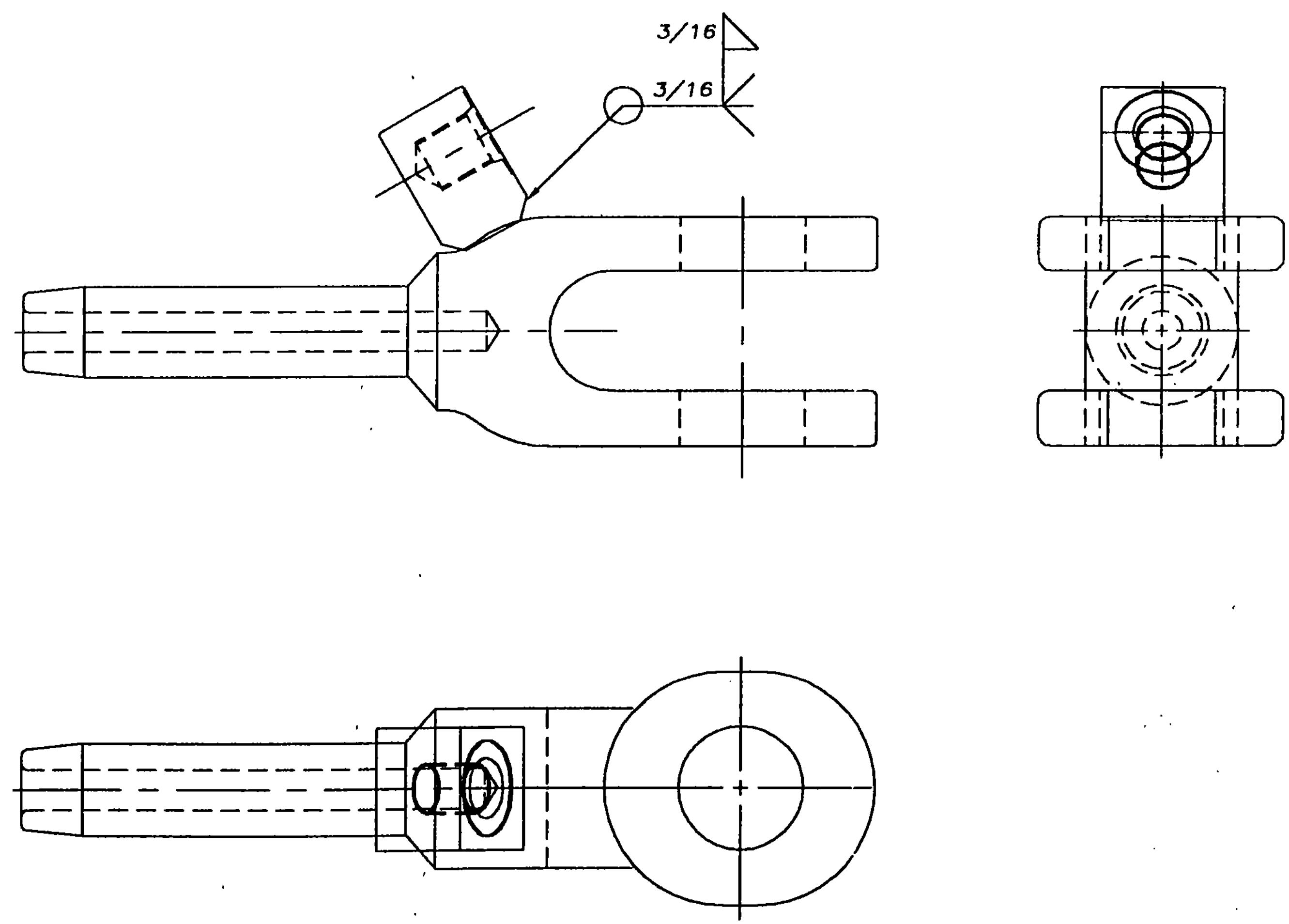
TITLE
MODIFIED 5/8 SWAGE SOCKET
ALTOMOOR
SIZE C
DWG. NO. 200166
SCALE 1:1
RELEASE DATE
SHEET OF
REV.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRAC ±1/64
DECIMALS .XX ±.01 .XXX ±.005
ANGULAR ±1°
DO NOT SCALE DRAWING
MATERIAL 1035 STEEL
PROJECT NO.
DRAWN R. ARTHUR
DATE 4/13/94
CHECKED
APPROVED
FINISH AS NOTED
3.95
3.90
250
0.62
250
0.06R
0.06R
ø0.810



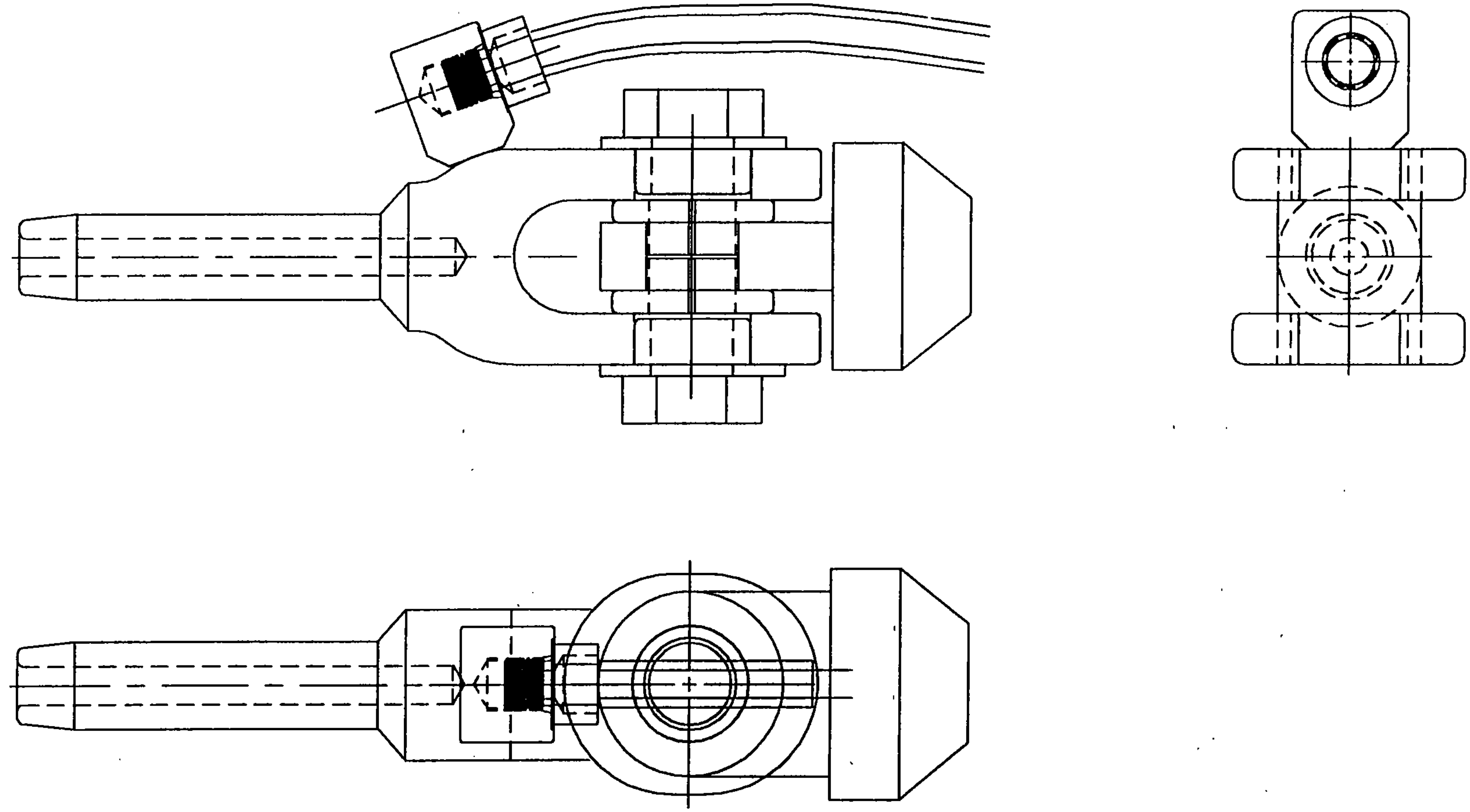
△1 DRILL AND BOTTOM TAP FOR SAE BOSS FITTING SIZE NO. 6. BOSS DIMENSIONS PER SAEJ514 TABLE 11 AND MS16142 (USE PARKER COUNTERBORING TOOL NO. Y34734). THREAD TO BE 9/16–18 UNF–2B. SPOT FACE ø0.975–0.985 X 0.20–0.30 DEEP.

NOTES:
BREAK ALL SHARP EDGES.

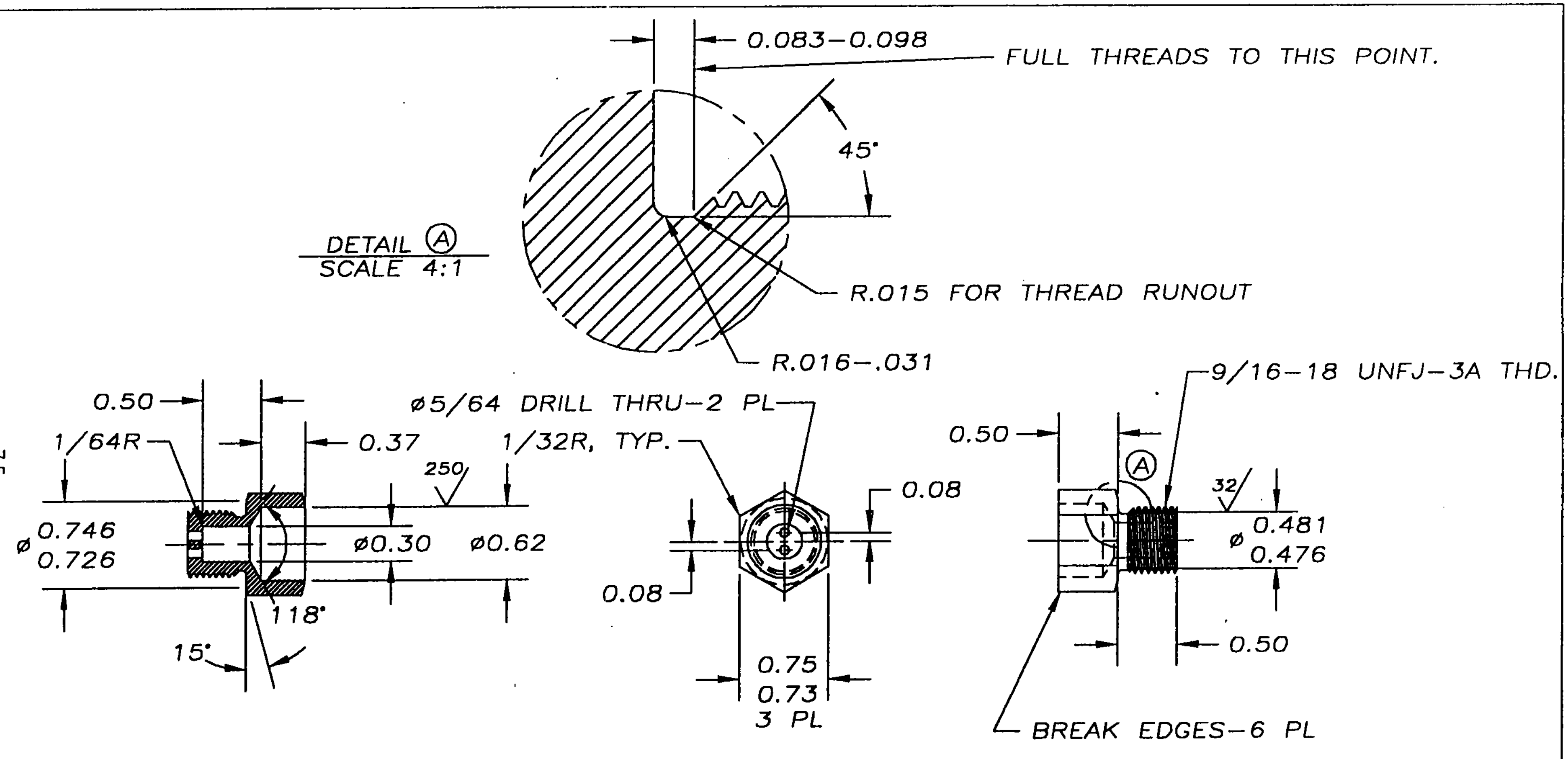
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/64 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO.		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543
	DRAWN R. ARTHUR	DATE 4/14/94	TITLE TAB, CONNECTOR ALTOMOOR
	CHECKED		
	APPROVED		
MATERIAL M1020 STEEL	FINISH		SIZE B · DWG. NO. 200180 · REV.
			SCALE 1:1 · RELEASE DATE · SHEET OF



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/64 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO. DRAWN R. ARTHUR CHECKED APPROVED	DATE 4/13/94	WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543 TITLE MODIFIED 5/8 SWAGE SOCKET ALTOMOOR
MATERIAL 1035 STEEL	FINISH AS NOTED		SIZE C · DWG. NO. 200166 · REV.

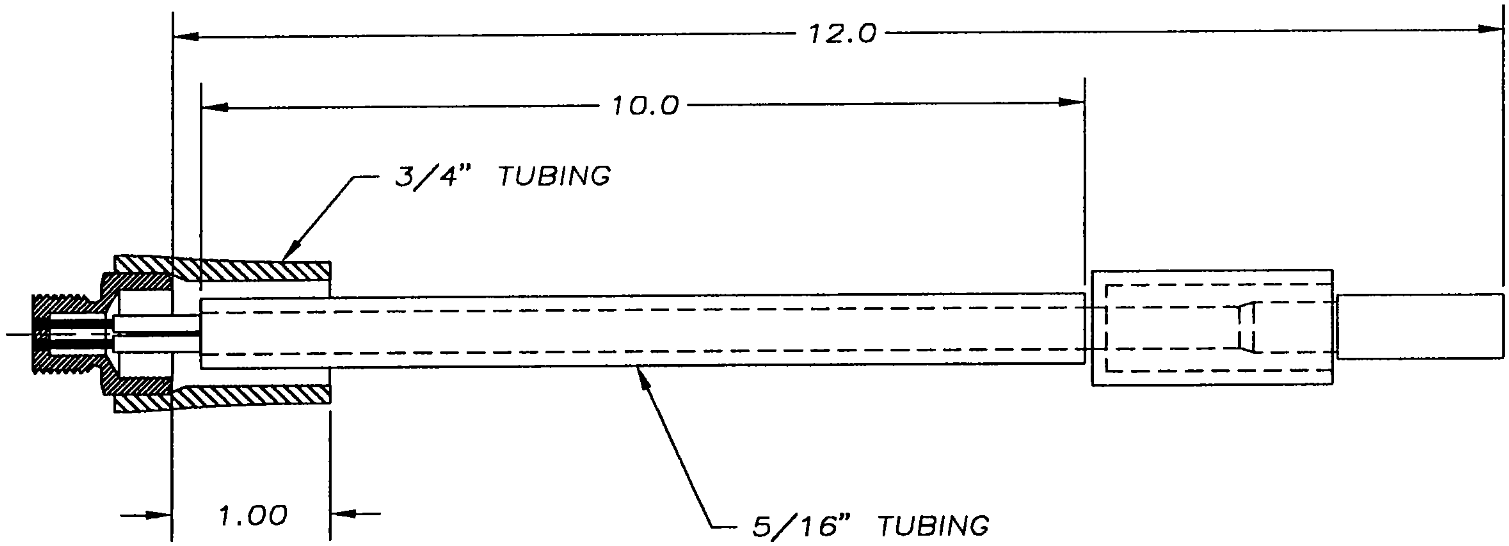


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/64 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO. DRAWN R. ARTHUR DATE 4/13/94 CHECKED APPROVED	WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543 TITLE MODIFIED 5/8 SWAGE SOCKET ALTOMOOR
MATERIAL 1035 STEEL	FINISH AS NOTED	SIZE C DWG. NO. 200166 REV. SCALE 1:1 RELEASE DATE SHEET OF

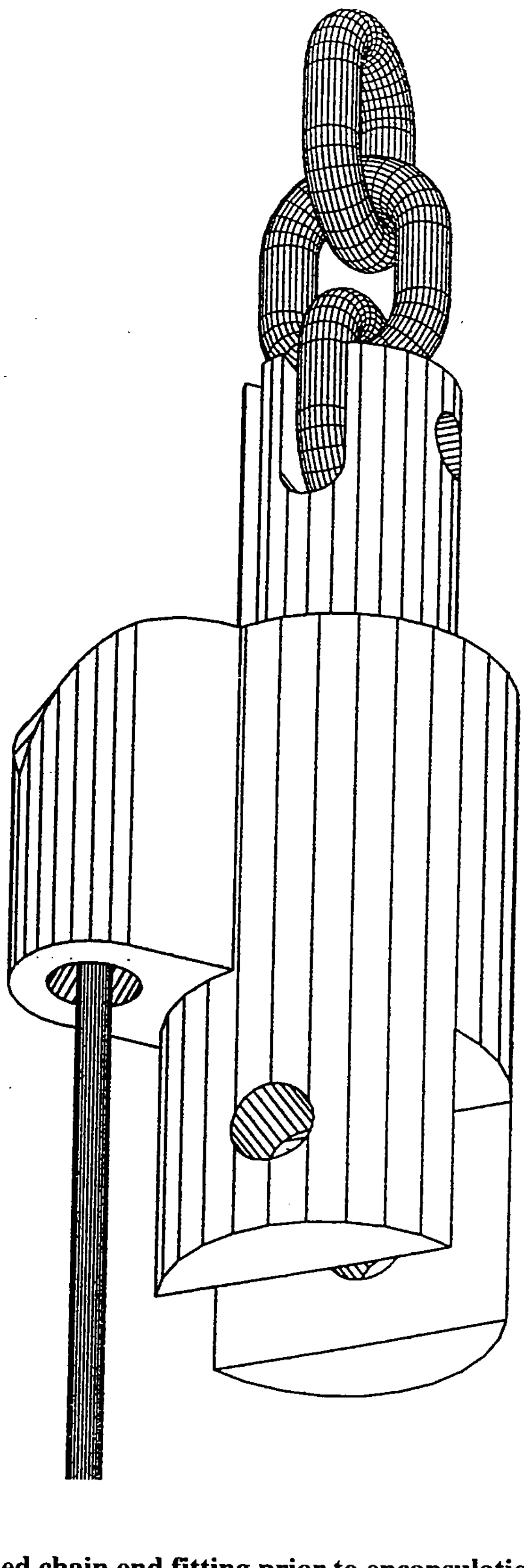


NOTES:

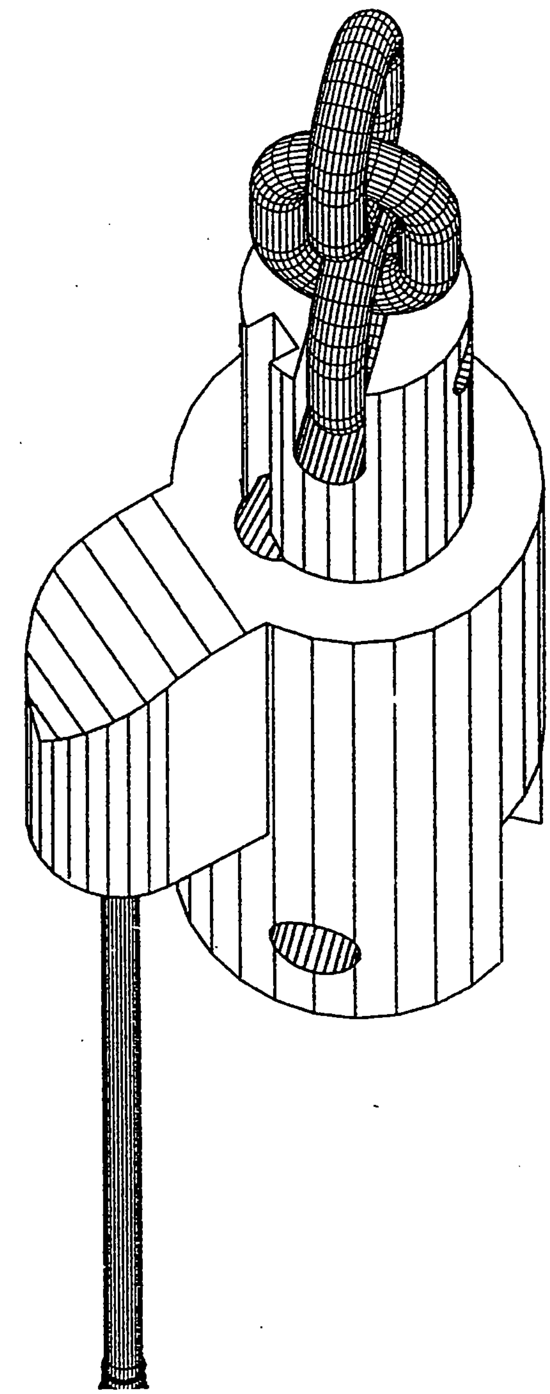
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/64 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO. 130346.00 DRAWN R. ARTHUR — DATE 3/25/94 CHECKED APPROVED	WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543 TITLE CONNECTOR, PIGTAIL ALTOMOOR
MATERIAL 1035 STEEL	FINISH	SIZE B — DWG. NO. 200167 — REV. SCALE 1:1 — RELEASE DATE — SHEET OF



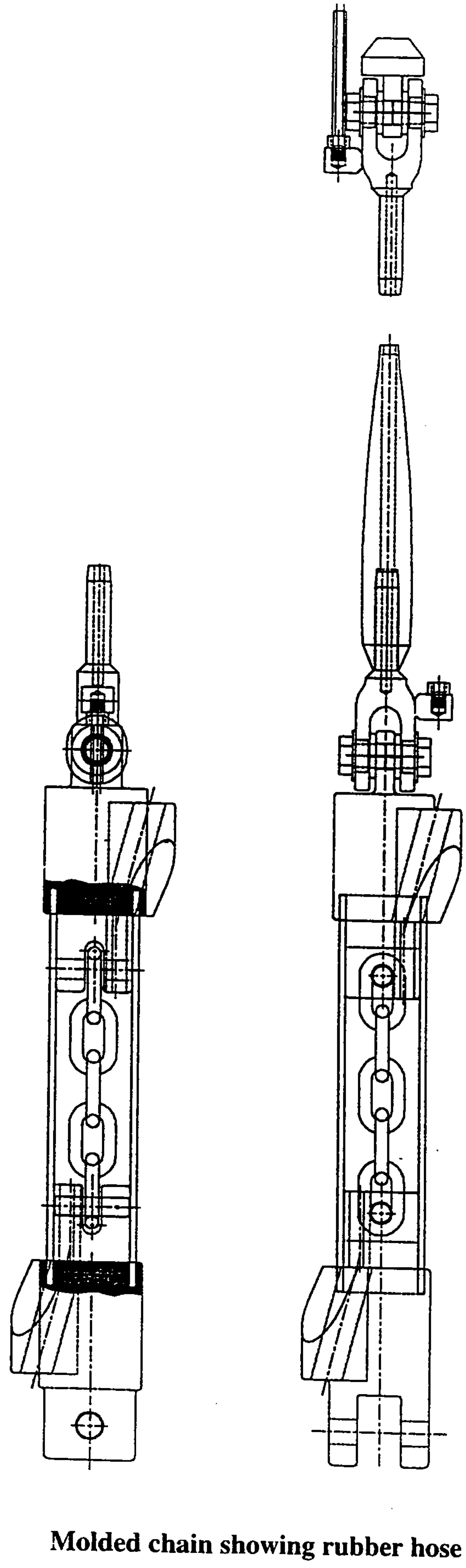
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/64 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO. 130346.00 DRAWN R. ARTHUR DATE 3/25/94 CHECKED APPROVED	WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543 TITLE CONNECTOR, PIGTAIL ALTOMOOR
MATERIAL 1035 STEEL	FINISH	SIZE B DWG. NO. 200167 REV. SCALE 1:1 RELEASE DATE SHEET OF



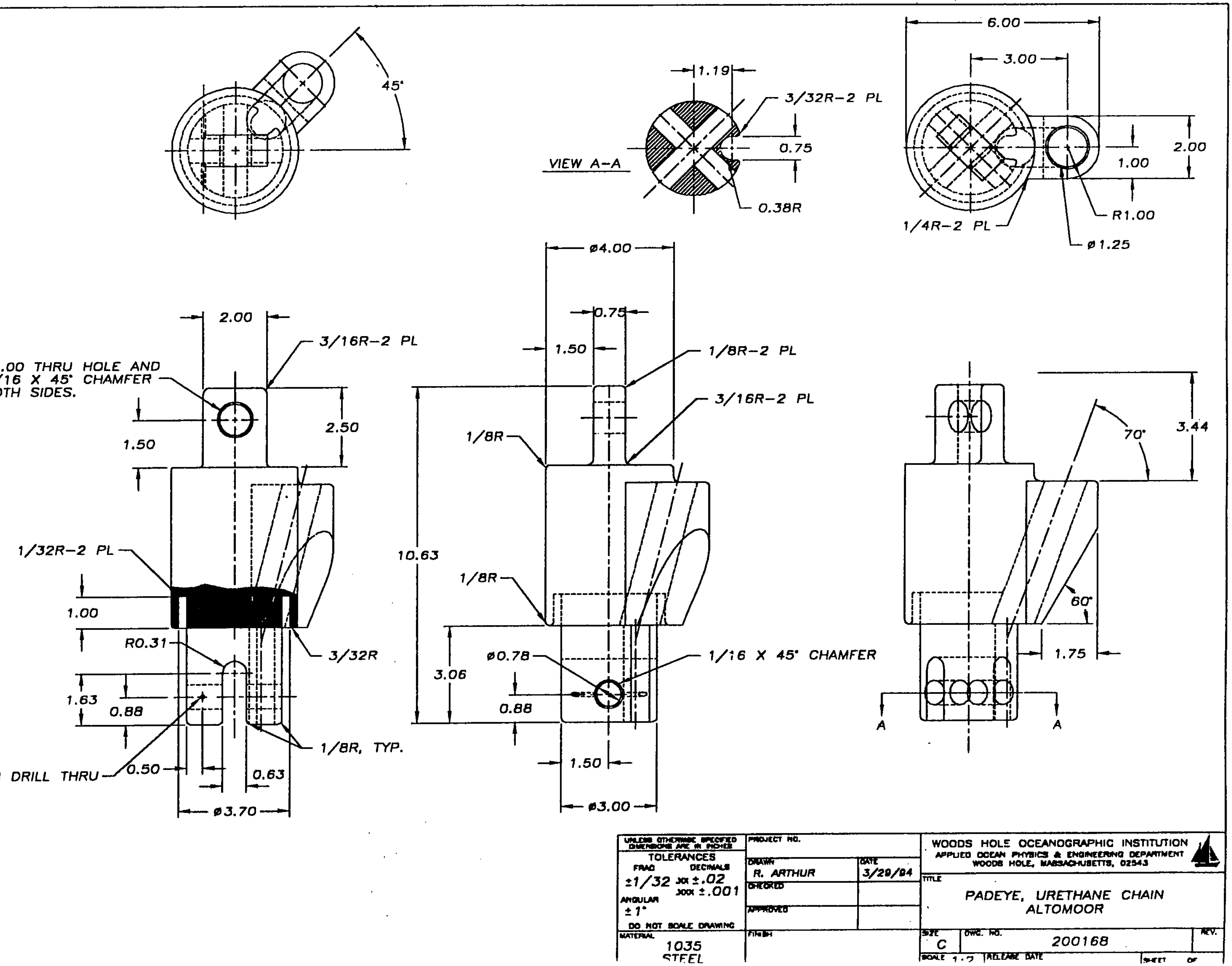
Molded chain end fitting prior to encapsulation

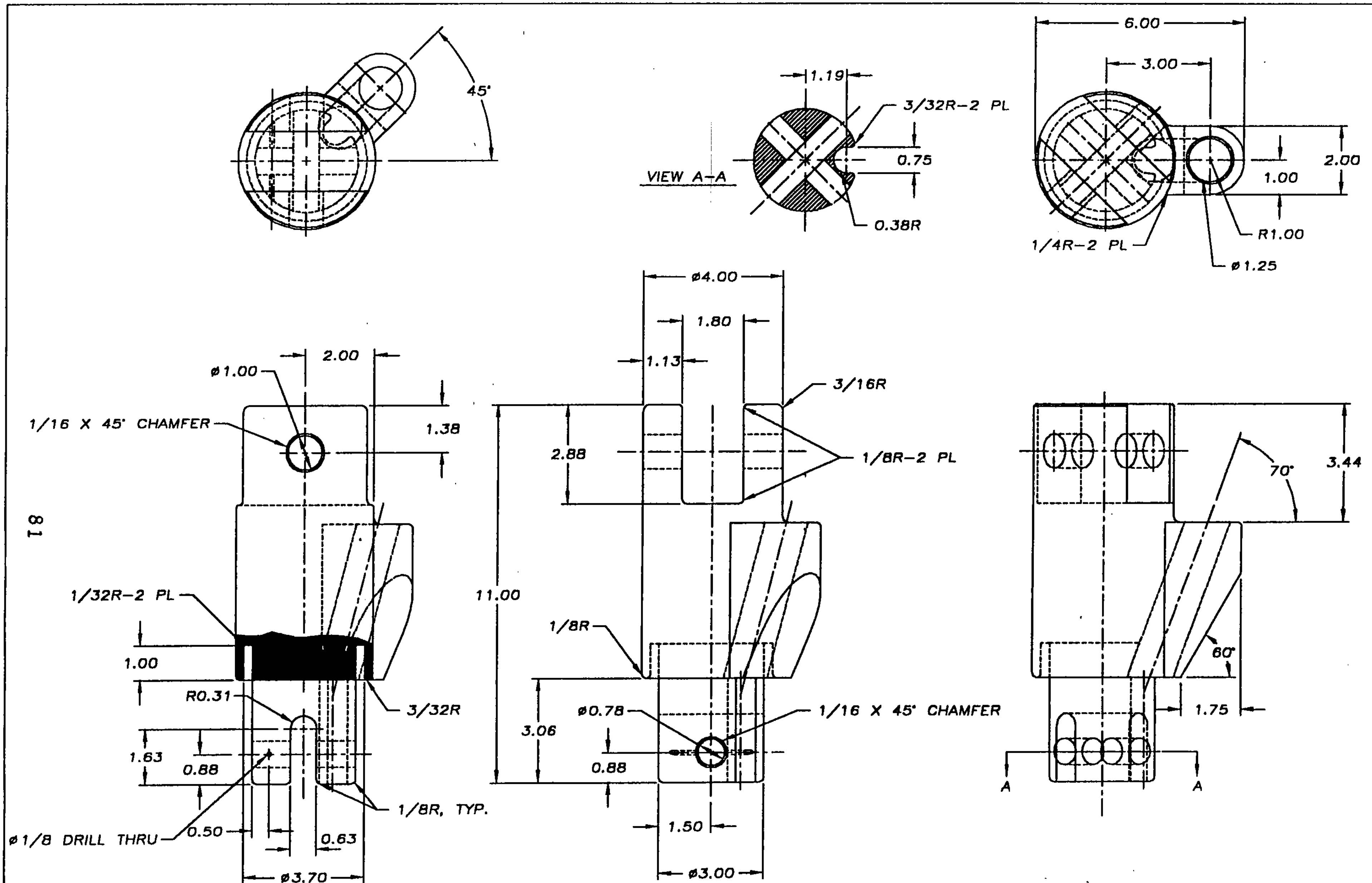


Molded chain end fitting



Molded chain showing rubber hose


45°
1.19
3/32R-2 PL
0.75
VIEW A-A
0.38R
6.00
3.00
2.00
1.00
R1.00
ø1.25
1/4R-2 PL
ø4.00
2.00
3/16R-2 PL
ø1.00 THRU HOLE AND 1/16 X 45° CHAMFER BOTH SIDES.
2.50
1.50
0.75
1.50
1/8R-2 PL
3/16R-2 PL
1/8R
10.63
1/8R
70°
3.44
60°
1.75
1/32R-2 PL
1.00
R0.31
3/32R
1.63
0.88
1/8R, TYP.
ø1/8 DRILL THRU
0.50
0.63
ø3.70
ø0.78
1/16 X 45° CHAMFER
3.06
0.88
1.50
ø3.00
A
A
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRAC ±1/32
DECIMALS .XX ±.02 .XXX ±.001
ANGULAR ±1°
DO NOT SCALE DRAWING
MATERIAL 1035 STEEL
PROJECT NO.
DRAWN R. ARTHUR
DATE 3/29/94
CHECKED
APPROVED
FINISH
WOODS HOLE OCEANOGRAPHIC INSTITUTION
APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT
WOODS HOLE, MASSACHUSETTS, 02543
TITLE
PADEYE, URETHANE CHAIN
ALTOMOOR
SIZE C
DWG. NO. 200168
REV.
SCALE 1:2
RELEASE DATE
SHEET OF



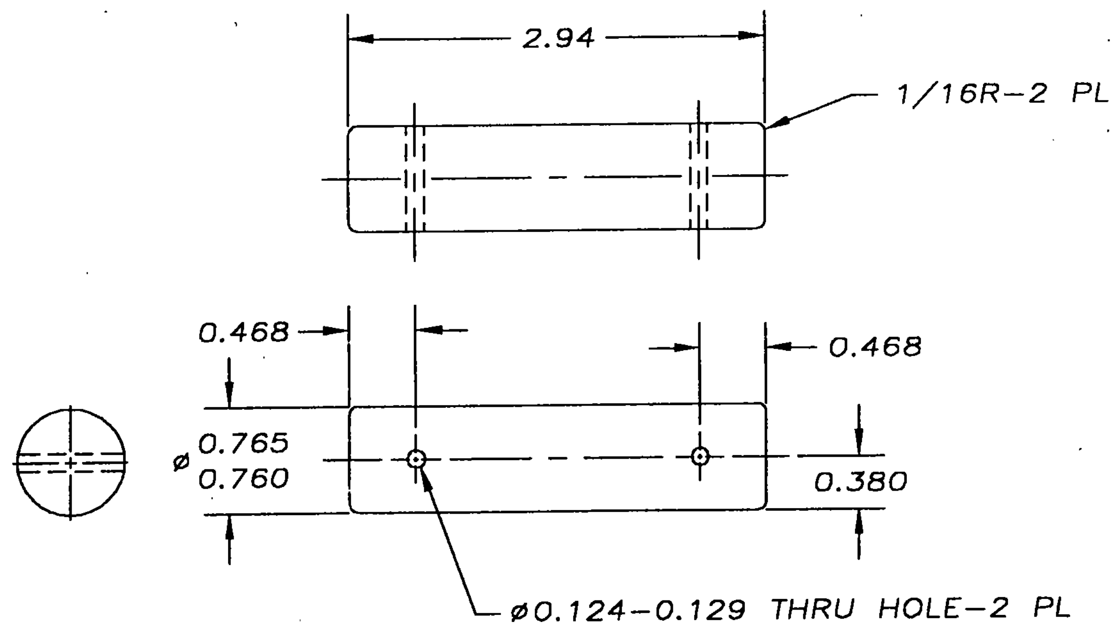
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRAC ±1/32 DECIMALS .XX ±.02 .XXX ±.001
ANGULAR ±1°
DO NOT SCALE DRAWING
MATERIAL 1035 STEEL

PROJECT NO.
DRAWN R. ARTHUR DATE 3/29/94
CHECKED
APPROVED
FINISH

WOODS HOLE OCEANOGRAPHIC INSTITUTION
APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT
WOODS HOLE, MASSACHUSETTS, 02543

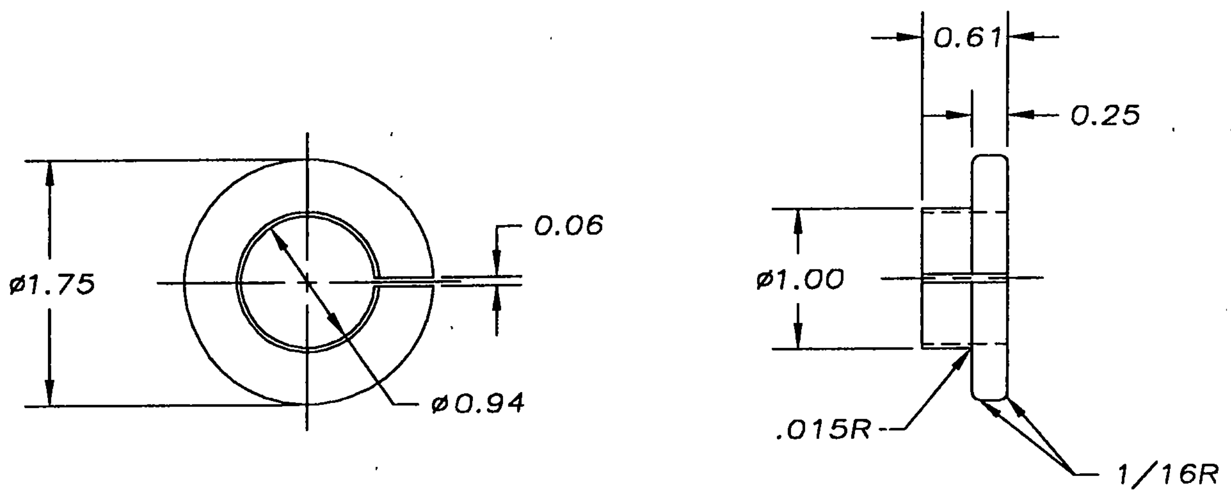
TITLE CLEVIS, URETHANE CHAIN ALTOMOOR

SIZE C DWG. NO. 200113 REV.
SCALE 1:2 RELEASE DATE SHEET OF



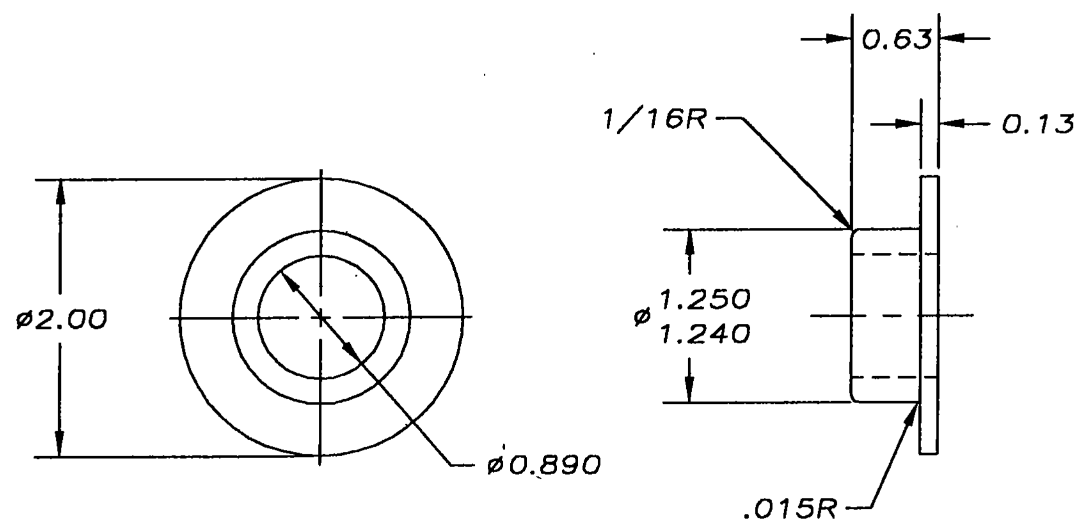
NOTES:
BREAK ALL SHARP EDGES.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/32 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO. DRAWN R. ARTHUR DATE 4/18/94 CHECKED APPROVED	WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543 TITLE PIN, URETHANE CHAIN ALTOMOOR
MATERIAL 11L17 STEEL	FINISH NONE	SIZE B DWG. NO. 200181 REV. SCALE 1:1 RELEASE DATE SHEET OF



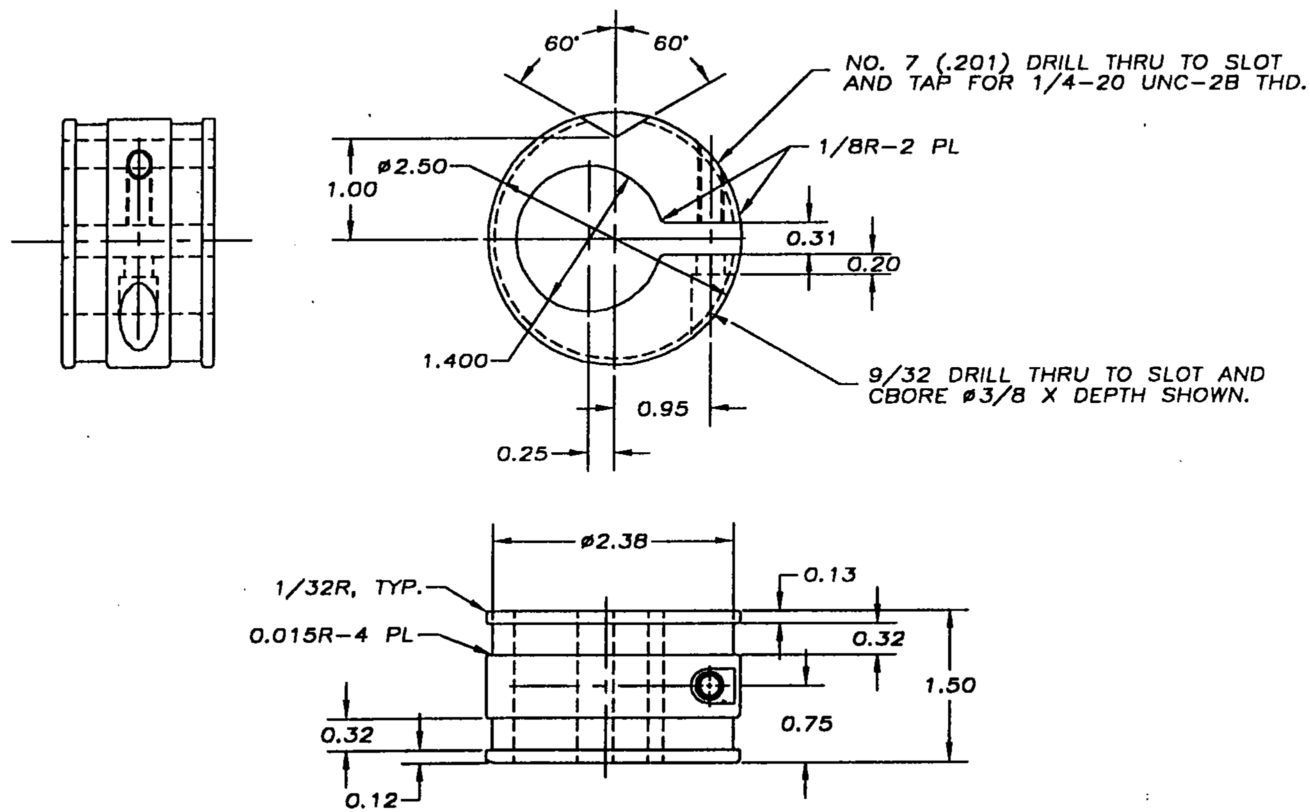
NOTES:
BREAK ALL SHARP EDGES.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	PROJECT NO.		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543
TOLERANCES FRAC ±1/32 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1°	DRAWN R. ARTHUR	DATE 4/18/94	TITLE MODIFIED VMCM BUSHING, 3/4 PIN ALTOMOOR
	CHECKED		
DO NOT SCALE DRAWING	APPROVED		SIZE B · DWG. NO. 200182 · REV.
MATERIAL BLACK DELRIN	FINISH		SCALE 1:1 · RELEASE DATE · SHEET OF



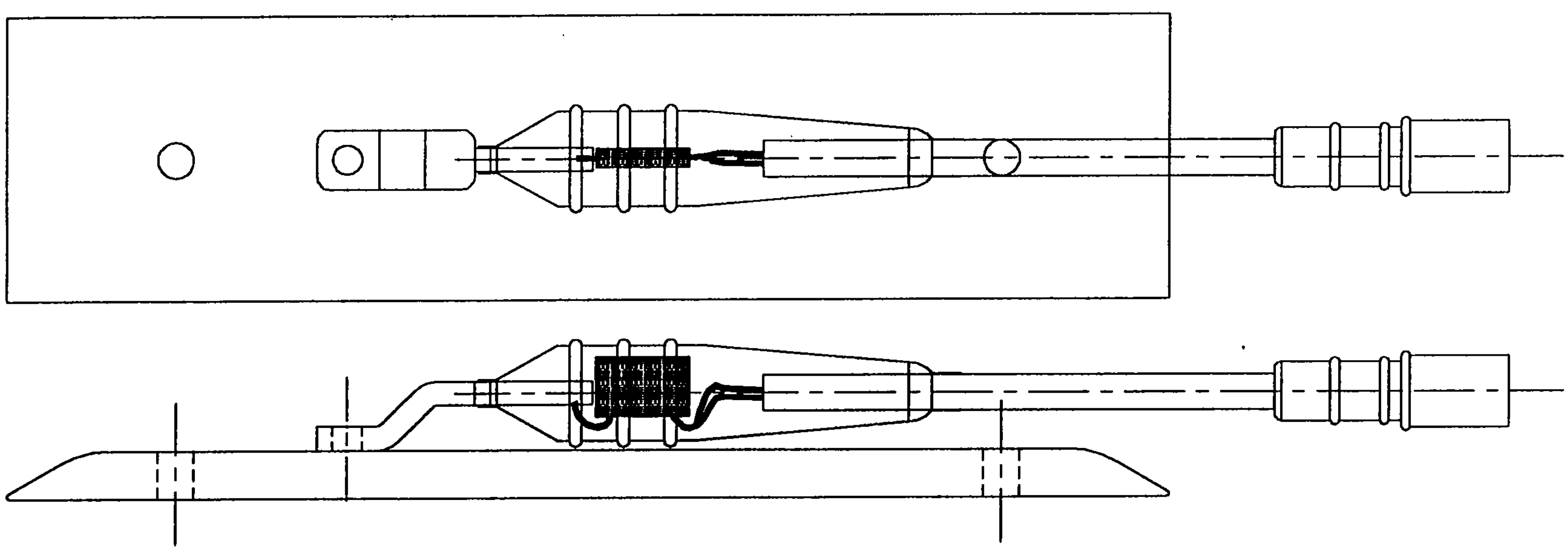
NOTES:
BREAK ALL SHARP EDGES.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/32 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO. DRAWN R. ARTHUR — DATE 4/14/94 CHECKED APPROVED	WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543
MATERIAL BLACK DELRIN	FINISH	TITLE BUSHING, 3/4 PIN ALTOMOOR SIZE B — DWG. NO. 200179 — REV. SCALE 1:1 — RELEASE DATE — SHEET OF



NOTES:
BREAK ALL SHARP EDGES.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/64 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ±1° DO NOT SCALE DRAWING	PROJECT NO.		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543
	DRAWN R. ARTHUR	DATE 4/26/94	TITLE MOUNTING BRACKET, TOROID ALTOMOOR
	CHECKED		
	APPROVED		
MATERIAL BLACK DELRIN	FINISH		SIZE C · DWG. NO. 200184 · REV.
			SCALE 1:1 · RELEASE DATE · SHEET OF



ITEM	PART OR DWG. NO.	DESCRIPTION	QTY

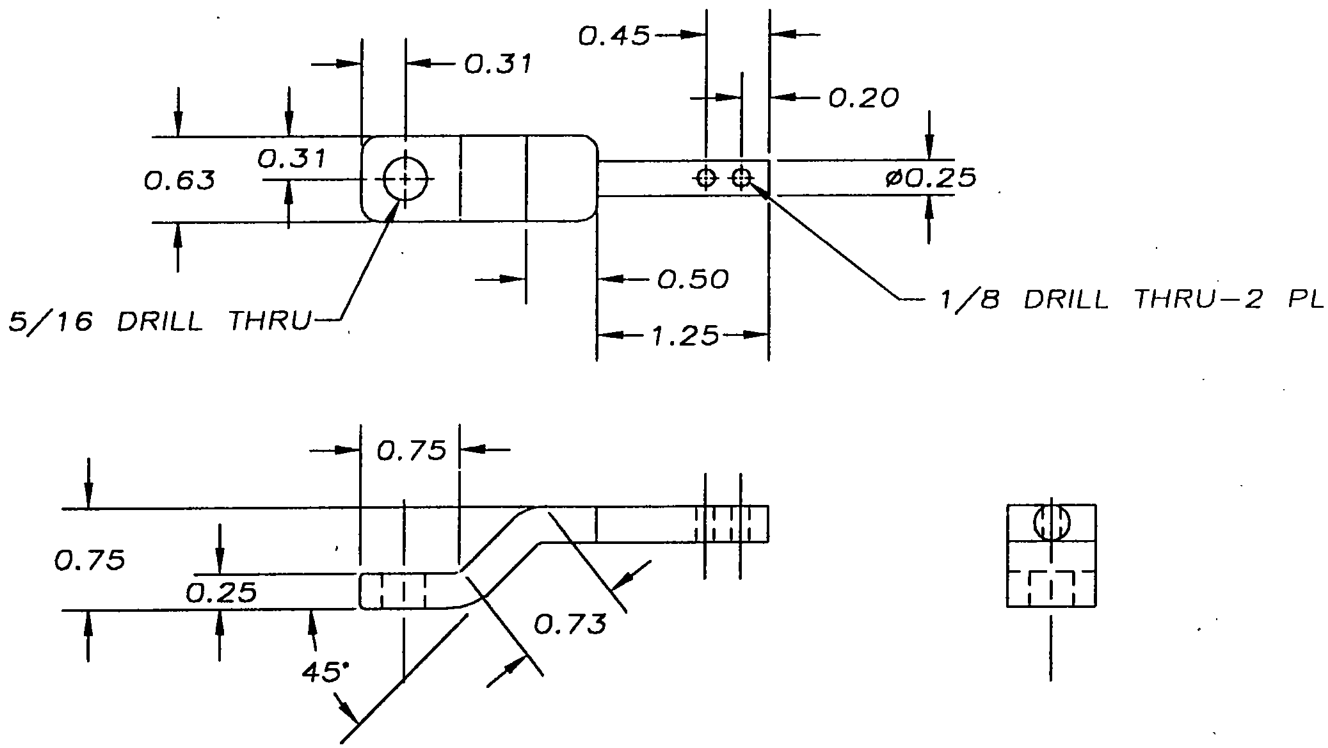
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRAC ± DECIMALS .XX ± .XXX ±
ANGULAR ±
DO NOT SCALE DRAWING
MATERIAL

PROJECT NO.
DRAWN R. ARTHUR DATE 4/21/94
CHECKED
APPROVED
FINISH

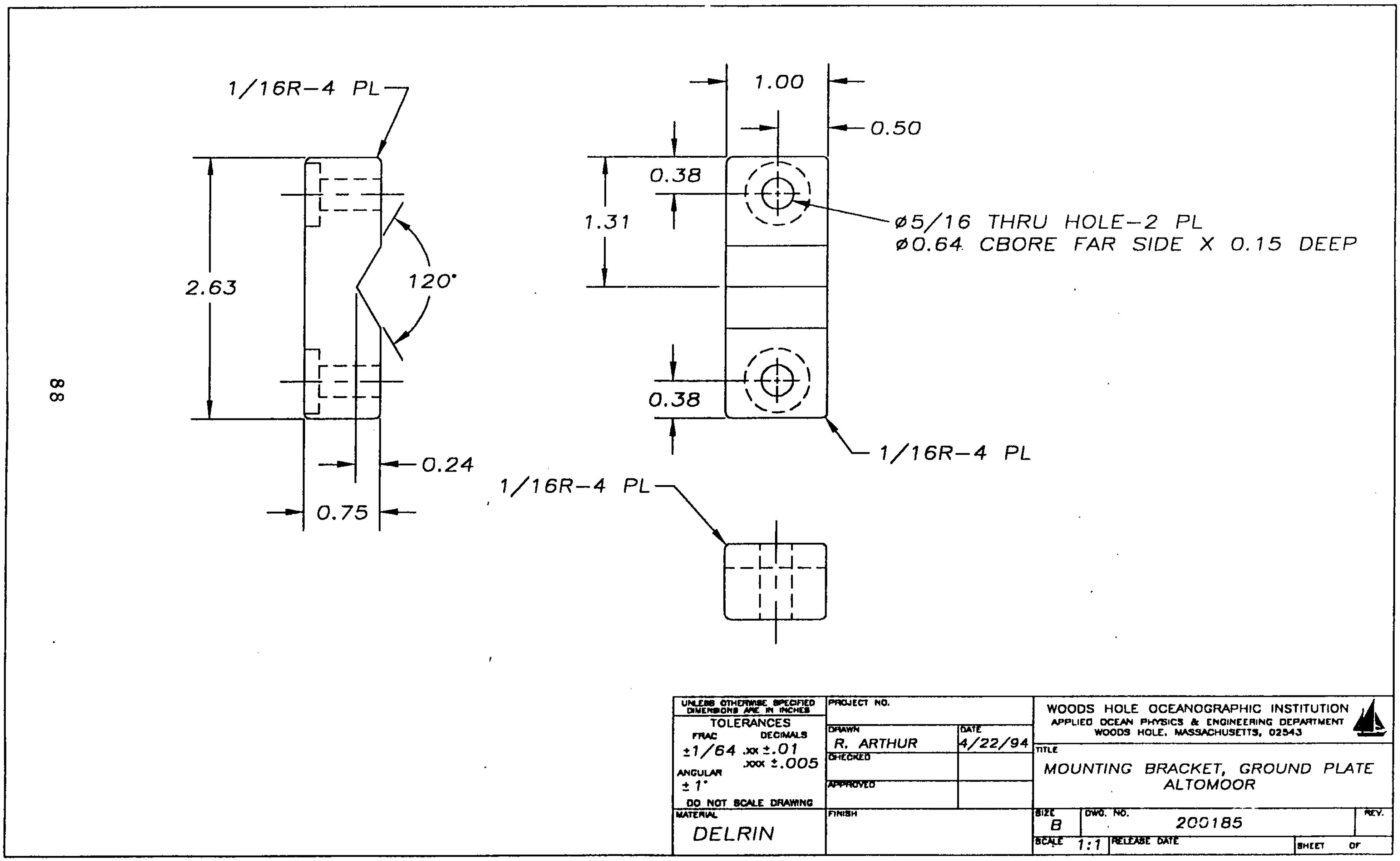
WOODS HOLE OCEANOGRAPHIC INSTITUTION
APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT
WOODS HOLE, MASSACHUSETTS, 02543

TITLE
GROUND STRAP ASSEMBLY
ALTOMOOR

SIZE C DWG. NO. 200185 REV.
SCALE 1:1 RELEASE DATE SHEET OF



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES FRAC ±1/64 DECIMALS .xx ±.01 .xxx ±.005 ANGULAR ± 1° DO NOT SCALE DRAWING	PROJECT NO.		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT WOODS HOLE, MASSACHUSETTS, 02543
	DRAWN R. ARTHUR	DATE 4/22/94	TITLE LUG, GROUND PLATE ALTOMOOR
	CHECKED		
	APPROVED		
MATERIAL COPPER	FINISH		SIZE B / DWG. NO. 200185 / REV. SCALE 1:1 / RELEASE DATE / SHEET OF


1/16R–4 PL
2.63
120°
0.24
0.75
1.00
0.50
0.38
1.31
0.38
ø5/16 THRU HOLE–2 PL
ø0.64 CBORE FAR SIDE X 0.15 DEEP
1/16R–4 PL
1/16R–4 PL
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRAC DECIMALS
±1/64 .xx ±.01
.xxx ±.005
ANGULAR
± 1°
DO NOT SCALE DRAWING
MATERIAL
DELRIN
PROJECT NO.
DRAWN
R. ARTHUR
DATE
4/22/94
CHECKED
APPROVED
FINISH
WOODS HOLE OCEANOGRAPHIC INSTITUTION
APPLIED OCEAN PHYSICS & ENGINEERING DEPARTMENT
WOODS HOLE, MASSACHUSETTS, 02543
TITLE
MOUNTING BRACKET, GROUND PLATE
ALTOMOOR
SIZE
B
DWG. NO.
200185
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SCALE
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5. Report Date
March 1996

6.

7. Author(s) Daniel Frye, Steve Merriam, Bob Eastwood, John Kemp, Neil McPhee, Steve Liberatore, Ed Hobart, Alex Bocconcelli, and Susan Tarbell

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Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

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16. Abstract (Limit: 200 words)

The Atlantic Long-Term Oceanographic Mooring (ALTOMOOR) has been maintained offshore Bermuda since 1993 as a testbed for the evaluation of new data telemetry technologies and new oceanographic instrumentation. It is currently a joint project between the Woods Hole Oceanographic Institution and the University of Southern California. This report documents the WHOI contributions which have focused on the development of new data telemetry methods and new mooring technology. Details of the instrumentation evaluations will be published separately.

A new inductively-coupled telemetry technology for ocean moorings has been developed and tested on ALTOMOOR. The inductive link uses standard, plastic-jacketed mooring wire as the transmission path for data generated at the individual instruments installed on the mooring. The signals are inductively linked to the mooring wire via toroids clamped around the wire, thus avoiding the need for multiconductor electromechanical cables terminated at each instrument. Seawater provides the electrical return path. The inductive modems send and receive data at 1200b/s. A controller in the surface buoy collects data from each of the subsurface instruments and forwards the data to shore by traditional satellite telemetry (Argos) and by short range radio using a nearby ship as a store and forward node. The buoy-to-ship link operates over about 2 km at 10kBytes/sec. When the ship docks, data are offloaded automatically to a computer on shore which can be accessed via the Internet.

17. Document Analysis a. Descriptors
mooring technology
data telemetry
inductive modem

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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